JPPS (Jurnal Penelitian Pendidikan Sains)
Homepage : https://journal.unesa.ac.id/index.php/jpps
Email : jpps@unesa.ac.id

p-ISSN : 2089-1776 ; e-ISSN : 2549-1597
JPPS, Vol. 14, No. 1, November 2024 : 23-38

EFA Analysis of Digital Technology Teaching Materials in Improving Students' Critical Thinking in Physics Learning

Rahmatta Thoriq Lintangesukmanjaya[1*], Agusti Mahendra[1], Sherlynggar Anugrah[1], Binar Kurnia Prahani[1], Dwikoranto[1], Muhammad Satriawan[1], Iqbal Ainur Rizki[2]

[1] Universitas Negeri Surabaya, Surabaya, Indonesia
[2] Victoria University of Wellington, Wellington, New Zealand

DOI : https://doi.org/10.26740/jpps.v14n1.p23-38

Sections Info

Article history:
Submitted: January 31, 2025
Final Revised: February 28, 2025
Accepted: March 03, 2025
Published: March 18, 2025

Keywords:
Critical Thinking Skills
Digital Technology
Instructional Media
Physics Learning
Physics

ABSTRACT

Objective: *The research aims to analyze the effectiveness of physics learning by applying technology or digital teaching materials significantly to improve students' critical thinking abilities. Knowledge regarding the need to use digital technology in educational institutions today can be used to implement innovative learning plans in the future.* ***Method:*** *The research was carried out using quantitative descriptive methods based on the data that had been obtained. Statistical tests in research involve the analysis of student response questionnaire results and literature reviews. Analysis of case study questionnaire responses on using technology in learning and the media needs of 92 students were analyzed using Exploratory Factor Analysis (EFA).* ***Results:*** *Based on the case study analysis obtained using EFA analysis, the need for learning using digital technology is very high. The response of students' motivation and interest in future learning received the maximum response that students need interactive learning with the help of engaging digital media, one of which is virtual simulation, which is relevant in improving critical thinking skills.* ***Novelty:*** *Application of Exploratory Factor Analysis (EFA) to analyze students' needs for digital media to improve critical thinking skills in physics learning. With support, the literature review shows a relevant relationship between the needs and challenges of developing technology in current digital learning media in providing an impact on alternative aspects of cost, time, space, and security to improve critical thinking skills. This research can be used to plan innovative learning in the future.*

INTRODUCTION

In the development of the Industrial Revolution 5.0, society will always be involved in digital-based information related to information-based technology, technological activities, network logic, flexible technology, and integrated systems (Surahman, 2020). This development certainly has an impact on educational processes and institutions. The aims and objectives of national education are to improve the quality of Indonesian people who are faithful, devout, and have noble characters, personalities, independence, discipline, professionalism, responsibility, and productivity (Hasibuan, 2023). Good education is also influenced by optimal learning. Learning must be carried out, planned, and interconnected with the supporting factors of education (Irmayanti et al., 2023). With optimal learning, 21st-century skills can be improved (Kennedy & Sundberg, 2020; Le et al., 2022). One of the skills that students need to have is critical thinking skills. Critical thinking occurs when someone can reflect on their thoughts rationally based on the reasoning in determining the main idea or idea to solve a problem (Lintangesukmanjaya et al., 2024).

The challenge of realizing good learning is one of the problems faced by teaching staff. Cognitive development is related to increasing the ability to think, solve problems, and make decisions, as well as intelligence and talent (Anggraeni et al., 2022; Sumarni & Kadarwati, 2020). The decline in the quality of skills and numeracy in Indonesian education, which is below the average for OECD countries, is one of the problems (Almarashdi & Jararah, 2023; Sutrimo et al., 2024). This is due to the lack of maximum implementation of national learning models and media. Learning media is an instrument that can be used in communication activities between teachers and students to realize learning both virtual and in-person (Riyasni, 2023). Teaching media is a form of facility that students need in the KBM (Teaching and Learning Activities) process. The difference in the use of learning media influences students' comprehension of material, one of which is in physics learning.

Physics learning, in general, examines the phenomena of the relationship between living things and natural phenomena using scientific theoretical concepts (Rizaldi, 2020). Physics has a level of cognitive understanding above average than most other subjects. Physics learning feels boring because the learning process is generally less interactive, so innovation or changes in learning methods need to be made (Maysyaroh & Dwikoranto, 2021). Seeing these conditions, developments are certainly needed regarding using teaching materials given to students. One of the developments in learning media that is currently relevant is teaching materials using digital technology.

Teaching materials using digital technology in learning are implemented to significantly impact educators' ability to develop digital competence (Sahronih, 2023). Digital teaching materials are a form of learning media that contain multimedia compositions with reading text content, images, videos, and visual animations in the form of information or learning materials that are integrated into the use of technology (Amelia, 2023). The content in digital teaching materials varies. This variation is the trigger in attracting students' enthusiasm for learning. The quality of learning is always directly proportional to the learning media and active learning without ignoring the character of the student's way of learning (Nurmaya, 2023). The application of technology in digital teaching materials is generally developed in the form of hardware or software with or without applications (Hastuti, 2023). The combination of multimedia elements makes digital teaching materials more interactive to use.

Based on the above, it is necessary to analyze the current use of digital teaching materials through case studies and literature reviews. Effective learning instruments are teaching materials designed with an attractive design; the content is applicable and able to stimulate students' curiosity about the material provided in an informative manner so that it can improve students' cognitive abilities in certain subjects (Fitri, 2023). The effectiveness of teaching materials or instruments can be determined from their use results in terms of their effect on student learning outcomes and skills. This research aims to analyze the effectiveness of physics learning by applying technology or digital teaching materials, significantly improving students' critical thinking skills. Through Exploratory Factor Analysis (EFA) in physics learning to find out trends and factors that influence digital technology considerations used in learning. So, there is knowledge regarding the use of digital technology in educational institutions today and the effectiveness of digital teaching materials by several educational institutions. In that case, this can be used to learn how to implement innovative learning plans in the future.

RESEARCH METHOD

General Background

The research was carried out using quantitative descriptive methods based on the data that had been obtained. Quantitative research examines samples by statistically analyzing data using specific numerical samples (Pramudita et al., 2023). Primary data is obtained from observations in the context of case studies through student responses. Furthermore, secondary data was obtained from a literature review on the research's theoretical basis (Madyani et al., 2020; Rizalia & Wuriani, 2023). The following is a draft research design in Figure 1.

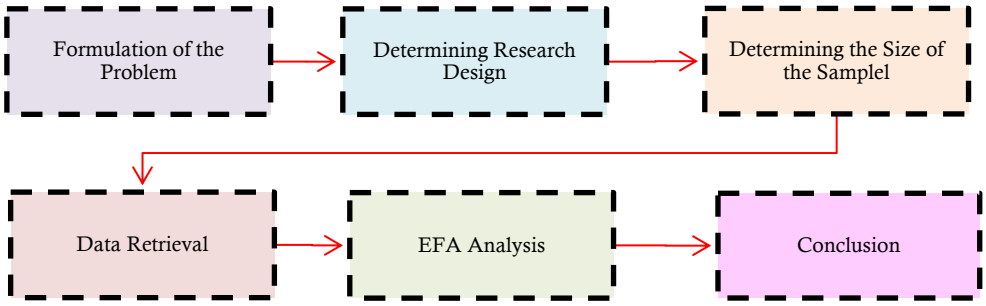

Figure 1. Research Design

Research Sample

The research was carried out at high schools in Surabaya, East Java. Samples from the study were taken randomly from the entire population involved (Sutrimo et al., 2024). The total number of research samples was 92 students from several schools. Apart from that, data collection was also used, obtained from the results of analysis of reviews of relevant articles, and data reduction was collected through the results of previous data summaries. From the results of the data presentation, generalizations can be made to decide and verify new findings (Suliyanah et al., 2021). From the results of data analysis, knowledge was obtained about the effects of using digital teaching materials in improving critical thinking in physics learning.

Instrument and Procedures

This research was carried out with findings from case study data in the field and literature studies of relevant articles. Primary data was obtained from observations in the form of student response questionnaires. Furthermore, secondary data was obtained from a literature review on the research's theoretical basis (Madyani et al., 2020; Rizalia & Wuriani, 2023). The response questionnaire instrument is applied to students by following the statement points in Table 1.

Table 1. List of Student Questionnaire Statements

No	Questionnaire
1	Learning physics is a lesson that is difficult to learn without the help of digital technology.
2	Students can receive the material presented by the teacher well.

No	Questionnaire
3	Physics learning currently carried out uses digital technology.
4	Teachers have taught using digital media and teaching materials.
5	Students are motivated if physics learning is carried out through active student activities such as practicums, discussions, and observations.
6	Students are interested in whether physics learning activities involving digital technology learning media are carried out at school.
7	Students need learning media that is easily accessible and interactive when learning physics.

Data Analysis

Research analysis was conducted using statistical tests from the research results (Hardani et al., 2020). Statistical tests in research involve student response questionnaire results and literature review analysis. Analysis of case study questionnaire responses on the use of technology in learning and students' media needs were analyzed using Exploratory Factor Analysis (EFA). Exploratory Factor Analysis (EFA) is used to identify structure and correlation in data sets consisting of many variables (Mohtar et al., 2024; Suprapto, 2019). The results obtained are concluded and strengthened using the results of relevant article study literature based on the findings in the research objectives.

RESULTS AND DISCUSSION

Results

Digital technology is necessary for the development of learning media. Interactive learning media can improve students' learning abilities (Idris et al., 2023).

EFA Analysis Results

EFA analysis (Exploratory Factor Analysis) was carried out to analyze the response to students' media needs. In reviewing the questionnaire, responses via KMO (Kaiser–Meyer–Olkin) were obtained to prove the reliability of the questionnaire and correlation (Suprapto, 2016, 2019). The following are the results of the KMO analysis in Table 2.

Table 2. KMO Test Results

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.557
Bartlett's Test of Sphericity	Approx. Chi-Square	56.388
	df	21
	Sig.	0.000

Based on Table 2, it shows that the Kaiser–Meyer–Olkin (KMO) Value Is 0.557. the Bartlett test results are significant ($df = 21$, $p < 0.001$), indicating that the data is reliable and suitable for further analytical study (Ince et al., 2020). Apart from that, the results of the Eigenvalue diagram distribution obtained three main factors in the response questionnaire given to students in Figure 2.

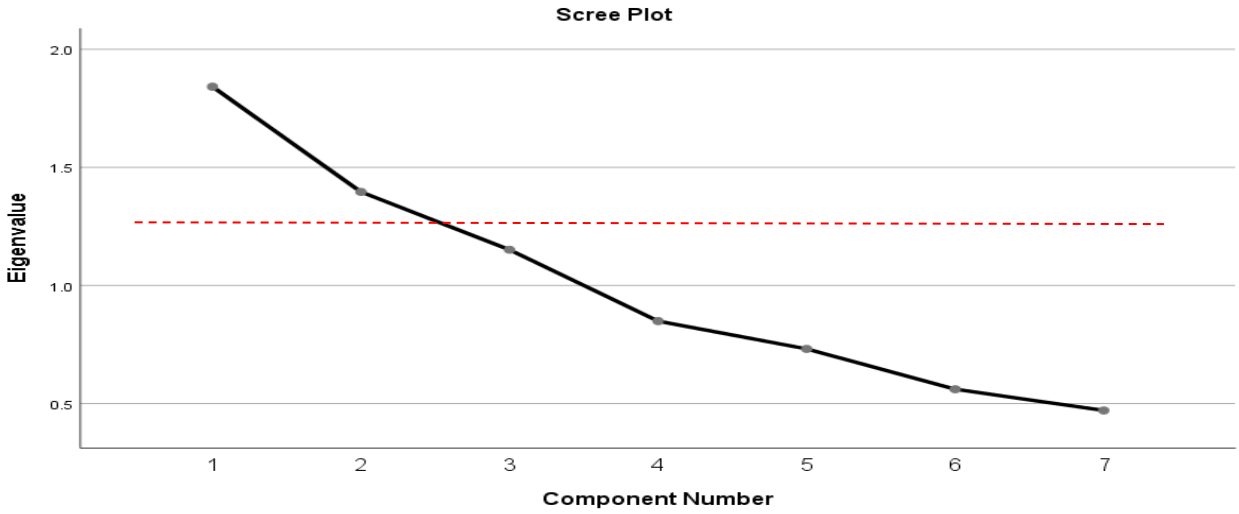

Figure 2. Eigenvalue diagram

Table 3. Eigenvalue Factors in the 3 Main Factors of Response Questionnaires

Component Factor	Initial Eigenvalues		
	Total	% (Variance)	% (Cumulative of Variance)
1	1.842	26.310	26.310
2	1.396	19.943	46.252
3	1.151	16.443	62.695

From the results in Table 3, the three eigenvalue factors account for 62.695% of the total variance. This factor contains a questionnaire response to an analysis of students' needs in learning physics. Meanwhile, loading factors with a value <0.400 were excluded from the analysis (Suprapto, 2019). Other values measured in the total variance are between 0.4706 and 0.8490. Overall, the Cronbach Alpha value is 0.633. In knowing the grouping of relationships between response questionnaire components it can be seen in the following data in Table 4.

Table 4. Pattern Metrix in Questionnaire Response Factors

Pattern Matrix			
	Component		
	1 (KB)	**2 (PB)**	**3 (EB)**
Students need learning media that is easily accessible and interactive in learning physics (7)	0.769		
Students are interested in physics learning activities involving digital technology learning media are carried out at school (6)	0.756		
Students are motivated if physics learning is carried out by involving active student activities such as practicums, discussions, and observations (5)	0.566		
Physics learning currently carried out uses digital technology (3)		0.885	

Pattern Matrix			
	Component		
	1 (KB)	2 (PB)	3 (EB)
The material presented by the teacher can be well received by students (2)		0.777	
Learning physics is a lesson that is difficult to learn without the help of digital technology (1)			0.853
Teachers have taught using digital media and teaching materials (4)			0.661

Based on data from Table 4, variables 7, 6 and 5 are in the same factor group KB (Learning Needs), variables 3 and 2 are in the PB (Learning Process) group and variables 1 and 4 are in the EB (Learning Evaluation) group. All variables have a factor loading value > 0.50, so they fulfill the existing component grouping where the variables are questionnaire statements. If analyzed from the average results of each response questionnaire, the following data is obtained in Figure 3.

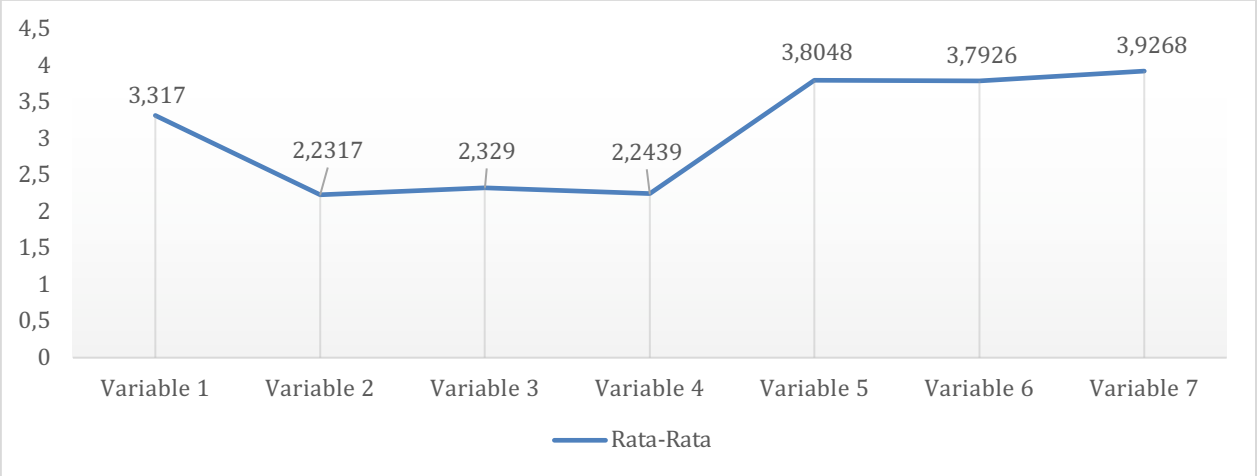

Figure 3. Average Student Response Results

The highest agreement value was in questionnaire response number 7, which stated that students need learning media that are easily accessible and interactive to learn physics (Muflikhun & Setyarsih, 2022). The response with the lowest agreement was number 2, which means the students did not well receive the material presented by the teacher. Knowing the media analysis studies and learning models that students need is very important.

Literature Study Results

In using interactive technology-based teaching materials, some skills need to be improved. One of these skills is the ability to think critically. According to Ennis (1996), critical thinking skills are part of rational thinking or deep thinking based on reason in solving problems that require high confidence and are implemented and even familiarized with other people (Black, 1988; Fatmawati et al., 2020; Lintangesukmanjaya

et al., 2024; Yusuf, 2022). In strengthening arguments related to the relationship between using digital media to improve critical thinking skills, the results of a review of accredited and relevant articles were obtained as follows in Table 5.

Table 5. Results of Literature Review of Relevant Articles

Source	Review
Rosyida, K. M. I., & Prahani, B. K. (2025).	**Findings:** The integrationof 3D digital modules, is crucial for improving students' critical thinking skills in topics likerotational dynamics.
Wardhani, S., Yusnita, D., & Astriani, M. (2025)	**Findings:** The results of the implementation analysis at each meeting in the experimental class show that the implementation of learning with electronic LKPD has reached excellent criteria.
Lintangesukmanjaya, R., Prahani, B., Marianus, M., Wibowo, F., Costu, B., & Arymbekov, B (2024)	**Findings:** Future inquiry learning will change the CTS of SMA Negeri 2 Tuban students to the kinetic theory of gases. Because students need more understanding.
Putri, S. J., & Prahani, B. K. (2024).	**Findings:** Students still needhelp solving physics problems involving heat material, particularly regarding the five critical thinking skill indicators with applying more varied learning models, such as combining PBL withother technologies, such as Augmented Reality (AR) or Virtual Reality (VR).
Riyasni, S., Purnama Yani, I., Kemala Sari, W., & Zulhendra, Z. (2023).	**Findings:** This research shows that learning still does not use digital teaching materials, so it is necessary to develop teaching materials based on the PJBL learning model that is integrated with STEM to help students with project assignments.
Kuswinardi, J. W. Rachman , A. ., Taswin, M. Z. ., Pitra, D. H. ., & Oktiawati , U. Y. (2023)	**Findings:** The use of AR greatly increases student engagement and creates a more engaging and interactive learning experience. Furthermore, AR has also been proven to improve understanding of learning content and allows learning to be tailored to individual student needs.
Susanti, E., Septiana, S., Meilinda, S., & Rosa, I. M. (2023)	**Findings:** Based on research results, Google Sites-based e-modules can be an effective learning medium to facilitate and develop students' critical thinking skills through a structured and interactive approach.
Nusroh, H., Khalif, M. A., & Saputri, A. A. (2022)	**Findings:** Augmented Reality learning media has been successfully developed on optical materials. The feasibility test results show that Augmented Reality-based physics learning media is suitable for use as learning media, with a feasibility score percentage of 78.79% (valid) based on media experts and 90% (very (very valid) based on material experts.

Source	Review
Sinaga, P., & Setiawan, W. (2022)	**Findings:** Students responded positively to EITM stored and operated on their cellphones while improving their critical thinking skills.
Faridi H, Tuli N, Mantri A, Singh G, Gargrish S. (2021)	**Findings:** AR-based learning has a significant positive impact on students' critical thinking skills and learning gains in physics learning.

Discussion

Based on the case study analysis obtained using EFA analysis, the need for learning using digital technology is very high. It was found that the factors that influence students' needs are the learning process factors (PB) which have the highest average value, explaining that students' needs are very basic in process needs. The process in question is teaching and learning activities in class, by knowing the realization of activities or learning processes in class, students can consciously analyze the needs they want, these needs are in line with the needs of digital technology in learning physics. Apart from that, students' motivation and interest in future learning received the maximum response that students need interactive learning with the help of interesting digital media to increase interest and motivation (Lu & Rameli, 2023).

In producing technology-integrated learning here, innovative learning is assisted by digital media. The literature review found many uses of E-books, E-modules, Augmented Reality (AR), or Virtual Reality (VR). in digital technology-based learning media. This learning media is suitable for helping students acquire critical thinking skills, especially in physics. According to Prastyo (2021), digital teaching materials are one of the important components in achieving learning goals. In line with Riyasni's (2023) statement, digital teaching materials can communicate between teachers and students in virtual and face-to-face learning. Using digital teaching materials is effective for independent learning, so students can still learn even if they are not accompanied by a teacher (Mella, 2022). However, several previous studies have been on applying technology-based learning media, such as e-books, e-modules, augmented reality (AR), and virtual reality (VR). The use of digital teaching materials is minimal due to a lack of innovation and limited capabilities of individuals and resources.

Based on the literature review, using digital media in physics learning can also improve students' critical thinking skills. According to Safarati & Zuhra (2023), the physics learning model with AIR (Auditory Intellectually Repetition) assisted by e-learning can improve students' CTS (Critical Thinking Skills). This is also in line with the findings of Susanti et al. (2023), that E-Module learning media can facilitate and develop students' critical thinking skills. Khaeruddin and Bancong (2022) also explained that STEM Education through PhET simulations can improve students' critical thinking skills. These findings indicate that using digital media in physics learning activities in the classroom has successfully improved students' critical thinking skills.

Digital teaching materials need to be developed in physics learning. Using digital teaching materials is hoped to be a breakthrough in creating more interactive physics learning. Interactive learning assisted by digital teaching materials has a very high feasibility value and can be used in physics learning (Idris & Suhendi, 2021). Knowing how to improve students' abilities is essential when developing teaching materials and

digital media. Good learning media with integrated technology to improve the learning process (Jafnihirda, et al., 2023). The weakness of current digital media, which is often developed, lies in the virtual interactive aspect, which is less than optimal. Therefore, it is important to develop technology in learning media, primarily virtual simulations.

The development of virtual simulation technology in digital learning media is a necessary update. Regarding cost, time, space, and security alternatives, virtual simulations are needed to provide a learning experience rich in visual cues and instant feedback (Isra et al., 2023). So, by prioritizing virtual simulations, we can improve our understanding of concepts when they are used in interactive learning. This digital media provides an engaging and visual impression that increases students' enthusiasm for learning physics. Virtual simulation design from innovation media used in experience-based learning as a form of educational innovation by utilizing information technology provides a different atmosphere for students (Rizki et al., 2023). It is rare to develop virtual simulations in physics learning, so it is essential to develop effective learning using interactive digital media based on virtual simulation technology.

CONCLUSION

Fundamental Finding: Based on the case study analysis obtained using EFA analysis, the need for learning using digital technology is very high. The response of students' motivation and interest in future learning received the maximum response that students need interactive learning with the help of engaging digital media, one of which is virtual simulation, which is relevant in improving critical thinking skills. **Implication:** The development of technology in digital learning media has an impact in terms of alternative costs, time, space, and security by providing a rich learning experience with visual cues and instant feedback, which is needed to improve critical thinking skills. **Limitation:** The literature review provided is limited, with a research focus on physics learning technology and critical thinking skills. **Future Research:** Knowing that it is rare to develop virtual simulations in physics learning, it is essential to develop effective learning by utilizing interactive digital media based on virtual simulation technology.

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

Agyei, P., Abukari, M. A., Dorsah, P., Tindan, T. N., Najah, A. N., & Gonyalug, I. A. (2023). PhET simulation instruction and its effects on students' motivation to learn physics. *Great Britain Journals Press*, *23*(15), 21-32.

Almarashdi, H. S., & Jarrah, A. M. (2023). Assessing tenth-grade students' mathematical literacy skills in solving pisa problems. *Social Sciences*, *12*(1). https://doi.org/10.3390/socsci12010033

Alperi, M. (2020). Peran bahan ajar digital sigil dalam mempersiapkan kemandirian belajar peserta didik. *Jurnal Teknodik*, (1), 99–110. https://doi.org/10.32550/teknodik.v0i1.479

Anggraeni, P., Sunendar, D., Maftuh, B., Sopandi, W., & Puspita, R. D. (2022). Why 6 cs? The urgency of learning at elementary school. *Proceedings of the 4th International*

Conference on Educational Development and Quality Assurance (ICED-QA 2021), 650, 35–41. https://doi.org/10.2991/assehr.k.220303.008

Azriyanti, R., & Syafriani. (2023). Validation of the physics e-module based on problem based learning as independent teaching material to improve critical thinking skills of class XI high school students. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 10223–10229. https://doi.org/10.29303/jppipa.v9i11.5809

Bahar, W. P., Hunaidah, H., & Hamimu, L. (2023). Pengembangan e-modul model cinqase berbasis canva untuk meningkatkan keterampilan individual critical thinking (inct) pada materi gelombang mekanik kelas XI SMA. *Jurnal Biofiskim: Pendidikan Dan Pembelajaran IPA*, *5*(2). Retrieved from https://journal.uho.ac.id/index.php/biofiskim/article/view/639

Black, C. M. (1988). Thinking skills instruction: Concepts and techniques. In *NASSP Bulletin* (Vol. 72, Issue 508). https://doi.org/10.1177/019263658807250830

Faridi H, Tuli N, Mantri A, Singh G, Gargrish S. (2021). A framework utilizing augmented reality to improve critical thinking ability and learning gain of the students in Physics. *Comput Appl Eng Educ*, 29, 258–273. https://doi.org/10.1002/cae.22342

Fathurohman, A., Oklilas, A. F., Marlina, L., Kurdiati, L. A., Susiloningsih, E., Azhar, A., & Samsuryadi, S. (2023). Effectiveness of using the mobile learning app for STEM-based high school physics materials as Indonesian student learning resources on learning outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1018–1023. DOI: https://doi.org/10.29303/jppipa.v9i3.2991

Fatmawati, I., Darmono, P.B., & Purwoko, R.Y. (2020). Analisis kemampuan berpikir kritis dalam pemecahan masalah matematika. *EKSAKTA: Jurnal Penelitian dan Pembelajaran*, *5*(2), 196-201. DOI: 10.31604/eksakta.v5i2.196-201

Fauziah, A. D., Susila, A. B., & Susanti, D. (2023). Pengembangan e-modul fisika berbasis android dengan pendekatan stem pada materi fluida dinamis. In prosiding seminar nasional penelitian dan pengabdian kepada masyarakat (SNPP) (Vol. 2, pp. 112-121). Retrieved from https://journal.ikippgriptk.ac.id/index.php/snpp/article/view/5124

Firdaus, V.S. and Sujatmiko, B. (2023). Literature study of the effect of inquiry learning method on critical thinking ability of vocational high school students. *IT-Edu: Jurnal Information Technology and Education*, *8*(1), 61-72.

Fitri, E. A., Karyadi, B., Johan, H., & Farid, M. (2023). Model E-Booklet fisika terintegrasi mitigasi bencana tsunami pada materi gelombang untuk siswa di Pulau Enggano. *Jurnal Pendidikan Fisika*, *11*(1), 79-93.

Hanafi, I., & Sumitro, E. A. (2019). Perkembangan kognitif menurut jean piaget dan implikasinya dalam pembelajaran. *Alpen: Jurnal Pendidikan Dasar*, *3*(2), 87-93. http://dx.doi.org/10.24127/jpf.v11i1.6753

Haqiqi, L. N. U., Akhdinirwanto, R. W., & Maftukhin, A. (2020). Pengembangan media pembelajaran modul fisika berbasis software sigil berekstensi EPUB untuk meningkatkan keterampilan berpikir kritis. *SPEKTRA: Jurnal Kajian Pendidikan Sains*, *6*(2), 125-133. DOI: http://dx.doi.org/10.32699/spektra.v6i2.146

Hardani, Ustiawaty, J., Andriani, H., Fatmi Utami, E., Rahmatul Istiqomah, R., Asri Fardani, R., Juliana Sukmana, D., & Hikmatul Auliya, N. (2020). Metode Penelitian Kualitatif dan Kuantitatif. In *Yogyakarta: CV. Pustaka Ilmu* (Issue Maret).

Hasibuan, A., Puspita, D.A., Sabila, K., Iqbal, M., & Nuraini, T. (2023). Analisis kebijakan pendidikan dalam peningkatan profesi guru. *Jurnal Pendidikan dan Konseling (JPDK), 5*(1), 3289–3294. https://doi.org/10.31004/jpdk.v5i1.11518

Hastuti, H., Giatman, G., Muskhir, M., Effendi, H., & Ghoer, F. R. (2023). Pengembangan multimedia interaktif pada pembelajaran menganalisis rangkaian listrik. *Jurnal Basicedu*, *7*(1), 241–249. https://doi.org/10.31004/basicedu.v7i1.4300

Himawan, N., & Ariswan, A. (2023). Physics learning E-Module integrated with practicing pancasila values on momentum and impulse: Is it effective to improve students' critical thinking skill and hard work character?. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, *8*(1), 30-41. *https://dx.doi.org/10.26737/jipf.v8i1.3128*

Idris, S., & Suhendi, H. (2023). Pengembangan media pembelajaran interaktif GEMBI untuk meningkatkan keterampilan berpikir kritis siswa. *DIFFRACTION: Journal for Physics Education and Applied Physics*, *5*(1), 24-36. https://doi.org/10.37058/diffraction.v5i1.7460

Irmayanti, R., Rusdi, M., & Yusnaidar, Y. (2023). The rasch model: Implementation of physics learning evaluation instrument based on higher order thinking skills. *Integrated Science Education Journal*, *4*(2), 62–68. https://doi.org/10.37251/isej.v4i2.325

Isra, Rania Atara & Mufit, Fatni. (2023). Students' conceptual understanding and causes of misconceptions on Newton's Law. *International Journal of Evaluation and Research in Education, 12*(4), 1914 – 1924. DOI: 10.11591/ijere.v12i4.25568

Jafnihirda, L., Suparmi, S., Ambiyar, A., Rizal, F., & Pratiwi, K. E. (2023). Efektivitas perancangan media pembelajaran interaktif e-modul. *Innovative: Journal Of Social Science Research*, *3*(1), 227–239. https://doi.org/10.31004/innovative.v3i1.2734

Kennedy, T. J., & Sundberg, C. W. (2020). 21st Century Skills. In B. Akpan & T. J. Kennedy (Eds.), *Science Education in Theory and Practice: An Introductory Guide to Learning Theory* (pp. 479–496). Springer International Publishing. https://doi.org/10.1007/978-3-030-43620-9_32

Khaeruddin, K., & Bancong, H. (2022). STEM education through PhET simulations: An effort to enhance students' critical thinking skills. *Jurnal ilmiah pendidikan fisika Al-Biruni, 11*(1), 35-45. http://dx.doi.org/10.24042/jipfalbiruni.v11i1.10998

Komariyah, S., Fatmala, A., & Laili, N. (2018). Pengaruh kemampuan berpikir kritis terhadap hasil belajar matematika. *Jurnal Penelitian Pendidikan dan Pengajaran Matematika*, *4*(2), 55-60. https://doi.org/10.37058/jp3m.v4i2.523.

Kuswinardi, J. W., Rachman, A., Taswin, M. Z., Pitra, D. H., & Oktiawati, U. Y. (2023). Efektivitas pemanfaatan aplikasi augmented reality (AR) dalam pembelajaran di sma: sebuah tinjauan sistematis. *Jurnal Review Pendidikan Dan Pengajaran (JRPP), 6*(3), 556–563. https://doi.org/10.31004/jrpp.v6i3.19127

Le, S. K., Hlaing, S. N., & Ya, K. Z. (2022). 21st-century competences and learning that Technical and vocational training. *Journal of Engineering Researcher and Lecturer*, *1*(1), 1–6. https://doi.org/10.58712/jerel.v1i1.4

Lilia Ellany Mohtar, Rozi, N. E., Ayop, S. K., & Hidayati, H. (2024). Students' self-regulated learning in physics: exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). *Semarak International Journal of Innovation in Learning and Education*, *3*(1), 9–21. https://doi.org/10.37934/sijile.3.1.921

Lintangesukmanjaya, R., Prahani, B., Marianus, M., Wibowo, F., Costu, B., & Arymbekov, B. (2024). Profile of students' critical thinking skills in 3D module learning material on gas kinetic theory with inquiry model. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, *12*(1), 77-94. doi: https://doi.org/10.24815/jpsi.v12i1.33877

Lu, Q., & Rameli, M.R.M. (2023). How academic self-efficacy influences online learning engagement: The mediating role of boredom. *International Journal of Interactive Mobile Technologies*, *17*(24), 115–135. https://doi.org/10.3991/IJIM.V17I24.44759

Madyani, I., Yamtinah, S., Utomo, S.B., Saputro, S., & Mahardiani, L. (2020). *Profile of Students' Creative Thinking Skills in Science Learning*, *397*(Icliqe 2019), 957–964. https://doi.org/10.2991/assehr.k.200129.119

Mahardika, A. I., Pamuji, R., Wulandari, T., Syifa, L.N., & Suryandari, T. W. (2023). Pelatihan pengembangan materi ajar digital menggunakan topworksheets untuk mendukung optimalisasi pembelajaran berbasis teknologi. *Jurnal Pendidikan Dan Pengabdian Masyarakat*, *6*(4), 264–269. https://doi.org/10.29303/jppm.v6i4.5859

Maysyaroh, S., & Dwikoranto, D. (2021). Kajian pengaruh model project based learning terhadap keterampilan berpikir kreatif peserta didik pada pembelajaran fisika. *ORBITA: Jurnal Kajian, Inovasi Dan Aplikasi Pendidikan Fisika*, *7*(1), 44. https://doi.org/10.31764/orbita.v7i1.4433

Mella, B., Wulandari, I. G. A. A., & Wiarta, I. W. (2022). Bahan ajar digital interaktif berbasis problem based learning materi keragaman budaya. *Jurnal Penelitian Dan Pengembangan Pendidikan, 6(*1), 127–136. https://doi.org/10.23887/jppp.v6i1.46368.

Muflikhun, A. S., & Setyarsih, W. (2022). Characteristics of instruments and profile of creative thinking ability of students on work and energy material. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika dan IPA IKIP Mataram*, *10*(3), 726. https://doi.org/10.33394/j-ps.v10i3.5408

Nurlaelah, E., Sudihartinih, E., & Gozali, S. (2023). Pengembangan bahan ajar digital untuk pembelajaran hybrid pada mata kuliah teori grup. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *7* (1), 604-614. https://doi.org/10.31004/cendekia.v7i1.1954

Nurmaya, E., Rusilowati, A., & Sulhadi, S. (2023). Analisis asesmen diagnostik gaya belajar peserta didik MAN 1 Semarang untuk pembelajaran fisika berdiferensiasi materi teori kinetik gas. In Prosiding Seminar Nasional Pascasarjana, (Vol. 6, No. 1, pp. 232-238).

Nusroh, H., Khalif, M.A., & Saputri, A.A. (2022). Developing physics learning media based on augmented reality to improve students' critical thinking skills. *Physics Education Research Journal*, *4*(2), 23-28. https://doi.org/10.21580/perj.2022.4.1.10912

Ogara, D., & Hersan, H. (2023). Pengembangan bahan ajar digital berbasis STEM untuk meningkatkan kemandirian belajar. *Jurnal Pendidikan*, *6*(1), 5625-5643. https://doi.org/10.31004/joe.v6i1.3749

Sinaga, P., & Setiawan, W. (2022). The impact of electronic interactive teaching materials (EITMs) in e-learning on junior high school students critical thinking skills, *Thinking Skills and Creativity*, *46*(101066), 1871-1871, https://doi.org/10.1016/j.tsc.2022.101066

Suprapto, N. (2016). Students' attitudes towards STEM education: Voices from Indonesian junior high schools. *Journal of Turkish Science Education*, *13* (Specialissue), 75–87. https://doi.org/10.12973/tused.10172a

Suprapto, N. (2019). Demographic sources as a local wisdom: Potency of Indonesian physics education researchers in conducting survey research. *Journal of Physics: Conference Series*, *1171*(1). https://doi.org/10.1088/1742-6596/1171/1/012003

Sutrimo M.S., Sajdah, S.N., Sinambela, Y.V.F., & Bagas, R. (2024). Peningkatan literasi numerasi melalui model pembelajaran dan hubungannya dengan kemampuan self-efficacy: Systematic literatur review. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *7*(1), 61–72. https://doi.org/10.22460/jpmi.v7i1.21650

Prahestiningtyas, T., & Sulisworo, D. (2022). Pembelajaran fisika secara online dengan aplikasi seesaw berdasarkan scientific based learning untuk peningkatan kemampuan berpikir ilmiah. *Jurnal Penelitian Pembelajaran Fisika*, *13*(1), 81-94. https://doi.org/10.26877/jp2f.v13i1.11108

Pramudita, A.D., Rahmawati, E., Himmatul Ilmi, L., Amatullah, S., & Damayanti, Z. (2023). Analisis pengaruh kemampuan berpikir kritis terhadap pemahaman konsep gelombang elektromagnetik mahasiswa pendidikan fisika. *Jurnal Ilmiah Wahana Pendidikan*, *9*(14), 105–113. https://doi.org/10.5281/zenodo.8170616

Prastyo, E.B., Islam, M.N., & Putra, A.K. (2021). Development of STEM-based population mobility and employment digital teaching materials. *ASANKA: Journal of Social Science and Education*, *2*(2), 149-159.

Prayogi, S., & Verawati, N.N.S.P. (2020). The Effectiveness of e-learning usage in classroom teaching to promote critical thinking ability. *International Journal of Recent Contributions from Engineering, Science & IT (iJES)*, *8*(4), 61–68. https://doi.org/10.3991/ijes.v8i4.18023

Putri, S.J., & Prahani, B.K. (2024). Enhancing students' critical thinking skills through mobile technology: An analysis of problem-based learning implementation in heat material instruction. *Advances in Mobile Learning Educational Research*, *5*(1), 1242-1253. https://doi.org/10.25082/AMLER.2025.01.001

Qotrunnada, N.A., & Prahani, B.K. (2023). The effectiveness of using digital books on the problem-solving ability of high school students in physics learning. *SAR Journal, 6*(2), 83-88. https://doi.org/10.18421/SAR62-04

Rahmatika, F. F., Nasbey, H., & Budi, E. (2024). Rancangan modul digital "phyqsure" berbasis stad pada materi besaran fisika dan pengukuran. Prosiding Seminar Nasional Fisika (E-Journal), 12(1). https://doi.org/10.21009/03.1201.PF31

Riyasni, S., Purnama Yani, I., Kemala Sari, W., & Zulhendra, Z. (2023). Analisis kebutuhan pengembangan bahan ajar digital fisika berbasis project based learning terintegrasi pendekatan STEM. *Journal on Education*, *6*(1), 5849-5858. https://doi.org/10.31004/joe.v6i1.3775

Rizaldi, D.R., Jufri, A. W., & Jamaluddin, J. (2020). PhET: simulasi interaktif dalam proses pembelajaran fisika. *Jurnal Ilmiah Profesi Pendidikan*, *5*(1), 10–14. https://doi.org/10.29303/jipp.v5i1.103

Rizalia, S., & Wuriani, E. (2023). Pengembangan lembar kerja peserta didik (LKPD) berbasis literasi sains materi sistem ekskresi. *Kulidawa*, *4*(1), 36. https://doi.org/10.31332/kd.v4i1.7757

Rizki, I.A., Saphira, H.V., Alfarizy, Y., Saputri, A.D., Ramadani, R., & Suprapto, N. (2023). Integration of adventure game and augmented reality based on android in physics learning. *International Journal of Interactive Mobile Technologies*, *17*(1), 4–21. https://doi.org/10.3991/ijim.v17i01.35211

Rosyida, K.M.I., & Prahani, B.K. (2025). Enhancing students' critical thinking skills in physics: Exploring problem-based learning and mobile technology integration in rotational dynamics education. *Advances in Mobile Learning Educational Research*, *5*(1), 1301-1313. https://doi.org/10.25082/AMLER.2025.01.006

Safarati, N., & Zuhra, F. (2023). E-learning assisted AIR learning model to improve students' critical thinking skills. *Jurnal Inovasi Teknologi Pendidikan*, *10*(2), 181-188. https://doi.org/10.21831/jitp.v10i2.53648

Sahronih, S., Guntur, M., Sholeha, H.H., Ismuwardani, Z., Qudwatullathifah, R. N., Bito, G.S., Sariyyah, N., & Dole, F. B. (2023). Pelatihan dan pendampingan pembelajaran kolaboratif dengan mengembangakan bahan ajar digital berbasis learning management system (LMS). *Prima Abdika: Jurnal Pengabdian Masyarakat*, *3*(4), 383-389. https://doi.org/10.37478/abdika.v3i4.3254

Sari, F.F.K., & Atmojo, I.R.W. (2021). Analisis kebutuhan bahan ajar digital berbasis flipbook untuk memberdayakan keterampilan abad 21 peserta didik pada pembelajaran IPA sekolah dasar. *Jurnal Basicedu*, *5*(6), 6079-6085. https://doi.org/10.31004/basicedu.v5i6.1715

Siburian, V.F., Putri, D.H., & Medriati, R. (2022). Pengembangan e-modul materi fluida dinamis berbantuan flip pdf professional untuk melatihkan kemampuan berpikir kritis siswa sma. *Amplitudo: Jurnal Ilmu dan Pembelajaran Fisika*, *1*(2), 192-201. DOI: https://doi.org/10.33369/ajipf.1.2.192-201

Sitinjak, E.K., & Siahaan, F.E. (2021). Pengembangan bahan ajar interaktif mata kuliah fisika lanjutan untuk meningkatkan hasil belajar mahasiswa. *Mimbar Ilmu*, *26*(2), 315–323. https://doi.org/10.23887/mi.v26i2.38458

Sukma, A.K., & Kholiq, A. (2021). Pengembangan SI VINO (physics visual novel) untuk melatihkan berpikir tingkat tinggi siswa SMA. *Jurnal Ilmiah Pendidikan Fisika*, *5*(2), 123-137. https://doi.org/10.20527/jipf.v5i2.3313

Suliyanah, Deta, U.A., Kurniawan, F.K., Lestari, N.A., Yantidewi, M., Jauhariyah, M.N. R., & Prahani, B.K. (2021). Literature review on the use of educational physics games in improving learning outcomes. *In Journal of Physics: Conference Series* (Vol. 1805, No. 1, p. 012038). IOP Publishing. DOI: 10.1088/1742-6596/1805/1/012038

Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 11–21. https://doi.org/10.15294/jpii.v9i1.21754

Surahman, E. (2020). POE2WE model as an alternative for learning physics in industrial revolution 4.0 era. In 3rd International Conference on Learning Innovation and Quality Education (ICLIQE 2019) (pp. 1013-1022). Atlantis Press.

Susanti, E., Septiana, S., Meilinda, S., & Rosa, I.M. (2023). The effectiveness of using google sites-based e-modules to optimize critical thinking skills: Student perceptions analysis. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 10555–10561. https://doi.org/10.29303/jppipa.v9i12.5887

Sutrio, S., Busyairi, A., Doyan, A., Kosim, K., & Hikmawati, H. (2023). The effectiveness of the problem based flipped classroom model with e-modules in improving critical thinking skills of pre-service physics teachers. *Jurnal Pendidikan Fisika Dan Teknologi*, 9(2), 274–283. https://doi.org/10.29303/jpft.v9i2.5826

Wardhani, S., Yusnita, D., & Astriani, M. (2025). Effectiveness of Electronic LKPD for PBL-Based Practical Work to Improve Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 374–381. https://doi.org/10.29303/jppipa.v11i1.9810

Widya, W., Andriani, R., Sudirman, S., Hidayat, A. T., & Elisyah, N. (2023). The effectiveness of physics e-modules based on creative problem-solving learning model integrated with 21st-century skills. *Indonesian Journal of Science and Mathematics Education*, *6*(1), 48-58. http://dx.doi.org/10.24042/ijsme.v6i1.14584

Yanti, Y., & Fauzi, A. (2022). Efektivitas e-book fisika sma/ma terintegrasi materi gempa bumi berbasis model problem based learning untuk meningkatkan sikap tanggap peserta didik. *Jurnal Penelitian Pembelajaran Fisika*, *8*(1), 82-89. https://doi.org/10.24036/jppf.v8i1.116536

Yuanata, B., Dwikoranto, D., & Setiani, R. (2023). Profile of the PhET assisted problem-based learning model for improving critical thinking skills of high school students. *Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram*, *11*(3), 870-880. https://doi.org/10.33394/j-ps.v11i3.8415

Yusuf, Y. (2022). Improving students' CTS against environmental problems: practicum mini project "understanding public perceptions of environmental problems". *Jurnal Penelitian Pendidikan IPA*, *8*(1), 209–215. https://doi.org/10.29303/jppipa.v8i1.1224

Rahmatta Thoriq Lintangesukmanjaya (Corresponding Author)
Postgraduate Programe of Physics Education,
Univeristas Negeri Surabaya,
Jl. Ketintang, Surabaya, East Java, 60231, Indonesia
Email: rahmattathoriq.20038@mhs.unesa.ac.id

Agusti Mahendra
Bachelor Programe of Physics Education,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya, East Java, 60213, Indonesia
Email: agusti.22067@mhs.unesa.ac.id

Sherlynggar Anugrah
Bachelor Programe of Physics Education,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya, East Java, 60213, Indonesia
Email: sherlynggar.23063@mhs.unesa.ac.id

Binar Kurnia Prahani
Lecturer in Physics Education Undergraduate and Master Study Programs,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya, East Java, 60213, Indonesia
Email: binarprahani@unesa.ac.id

Dwikoranto
Lecturer in Physics Education Undergraduate and Master Study Programs,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya, East Java, 60213, Indonesia
Email: dwikoranto@unesa.ac.id

Muhammad Satriawan
Lecturer in Physics Education Undergraduate and Master Study Programs,
Universitas Negeri Surabaya,
Jl. Ketintang, Surabaya, East Java, 60213, Indonesia
Email: muhammadsatriawan@unesa.ac.id

Iqbal Ainur Rizki
School of Education,
Victoria University of Wellington
Wellington, New Zealand
Email: iqbal.rizki@vuw.ac.nz