International Journal of Technology in Education and Science

www.ijtes.net

Analysis of the Influence of Utilizing STEM-Based Physics Learning Media: A Systematic Literature Review

Nurhasana [1], Dadan Rosana [2], Heru Kuswanto [3] *

[1] Department of Physics Education, Faculty of Mathematics and Natural, Yogyakarta State University, Indonesia, 0009-0006-3877-4185
[2] Department of Physics Education, Faculty of Mathematics and Natural, Yogyakarta State University, Indonesia, 0000-0003-4987-7420
[3] Department of Physics Education, Faculty of Mathematics and Natural, Yogyakarta State University, Indonesia, 0000-0002-2693-8078
* Corresponding author: Heru Kuswanto (herukus61@uny.ac.id)

Article Info

Article History

Received:
12 September 2025

Revised:
2 January 2026

Accepted:
13 February 2026

Published:
13 March 2026

Keywords

21st-century education
STEM
Learning media
Physics learning
Literature review

Abstract

21st-century education offers numerous benefits to society across various sectors, including the field of education itself. The STEM (Science, Technology, Engineering, and Mathematics) approach is designed to support teachers in realizing effective education in the 21st century. This study examines 40 articles published between 2018 and 2024, which have undergone a filtering stage based on inclusion criteria. The method used in this research is a literature review. The main objective of this study is to identify the variables that influence the use of STEM-based physics learning media. The most frequent publication years for the articles were 2021 and 2022. The academic level with the most prevalent use of STEM-based learning media is the high school level. The most dominant research method used in the analyzed articles is the quasi-experiment, as this method tends to be easier in evaluating student learning outcomes. The material most frequently taught using the STEM approach is electrical circuits. The most widely used learning media with the STEM approach is prototypes, as prototypes are easily accessible and can utilize existing school facilities. The most frequently used instrument in the research is tests, as the dominant focus of measurement is on students' conceptual understanding.

Citation: Nurhasana, Rosana, D., & Kuswanto, H. (2026). Analysis of the influence of utilizing STEM-based physics learning media: A systematic literature review. *International Journal of Technology in Education and Science (IJTES), 10*(2), 344-359. https://doi.org/10.46328/ijtes.6658

Introduction

21st-century education has entered an era of rapid change and advancement in science and technology. This era offers numerous benefits to society across various sectors, notably in the field of education (Oktay et al., 2023). The Fourth Industrial Revolution (Industry 4.0) is also a hallmark of this century, bringing about significant shifts in societal life, including how we work and interact with one another. Its impact extends beyond the realms of economics and the arts, profoundly influencing the field of education (Sulaiman et al., 2023; Sunarti & Rusilowati, 2021; Zidatunnur & Rusilowati, 2021). In this age of rapid transformation, individuals are expected to equip themselves with the knowledge and skills that must be possessed in order to achieve learning in the 21st century. These essential skills include scientific process skills, critical thinking, design thinking, and production skills. By developing these competencies, individuals can effectively find solutions, generate innovative ideas, and address challenges using scientific concepts and approaches (Tekbıyık & Çakmakçı, 2018; Yulianti et al., 2019; Zollman, 2012; Sulaiman et al., 2023). One such approach that is grounded in science and aligns with the demands of 21st-century education is the STEM approach.

The benefits of the STEM approach, if implemented in learning, will encourage students to acquire new things or innovations in the form of knowledge (Permanasari, 2016; Sari & Kholiq, 2022). Advances in technology have provided opportunities for the STEM approach. In learning using the STEM approach, students will need computational skills, understanding and analyzing data, critical analysis, and scientific understanding based on mathematical principles (Sagala et al., 2019). The STEM approach is designed to support teachers in achieving successful 21st-century education (Sunarti & Rusilowati, 2021). Teachers who have the ability to apply the STEM approach in learning activities are included in an indicator that is very decisive in achieving the learning objectives of students in producing new ideas or innovations when overcoming a problem (Milaurrahmah et al., 2017; Yusuf & Widyaningsih, 2019). STEM-based learning has many benefits in the world of education, including helping students build character in understanding a concept and knowledge (Zidatunnur & Rusilowati, 2021; Tanel, 2019). The STEM approach also has several objectives, including providing students with the skills to work together interdisciplinarity, think systematically, communicate openly, have ethical values, be creative, and have problem-solving skills, especially in physics learning (Tanel, 2019).

One of the subjects in the Merdeka curriculum is physics. Physics is a science-based subject that explores physical matter, facts, and concepts (Sunarti & Rusilowati, 2021). Physics is also a part of natural science which is the basis for the development of technology and studies concepts related to nature and human life (Sapitri et al., 2016; Pahrudin et al., 2021). Research conducted by Nurhayati et al. (2019) states that physics is a subject that seems difficult because the concepts taught in it are very abstract. This is also supported by research conducted by Tanel (2019) which states that students often experience difficulties in understanding physics lessons and consider physics to be challenging. Therefore, students tend to be more passive when participating in physics learning. Students even consider physics to be one of the problems that cause low grades, motivation, and a negative attitude towards learning (Guido, 2013; Prima, Putri, & Rustaman, 2018; Yasin et al., 2018). The reasons why students tend to have difficulty understanding physics concepts include learning models, learning approaches, and conventional learning media that do not yet support students' learning styles today.

The selection of appropriate approaches and learning media during learning will help students understand a material and concept in physics learning. The use of learning media will encourage students to prepare themselves with the skills needed to face the advancement of technology-based education (Hanif et al., 2019; Yusuf et al., 2018). Based on literature studies in the article, many kinds of learning media have been developed, both in the form of e-learning, digital teaching materials, simulation software, and even using practicum tools (prototypes) found in school facilities. By presenting learning media during the learning process, students will play a more active role in learning. This is supported by research conducted by Taufiqy et al. (2016) in Zidatunnur and Rusilowati (2021) that the existence of digital-based learning media can increase students' understanding of the material provided and increase students' interest in learning physics. This will certainly affect the improvement of student learning outcomes. However, there are no articles that analyze the effect of physics learning media based on STEM as a whole based on the variables that affect physics learning.

The purpose of this literature review research is to identify and analyze the effect of STEM-based learning media on students' physics learning. Therefore, this study has several questions as follows:

- Q1: What are the moderating variables that influence the use of STEM-based learning media in students' physics learning?
- Q2: Do moderating variables influence the use of STEM-based learning media in students' physics learning?

Method

The research design used is a qualitative study with a systematic literature review method. Systematic literature review is a research method with content analysis. This method focuses on findings made by various other researchers published in the form of articles. The articles analyzed are both national and international articles. The articles analyzed will be carried out in several stages, the research stages will be carried out using the Prisma-P form. The stages of Prisma-P research are identification, screening, and inclusion (Heo et al., 2022). The stages of this research can be seen in Figure 1.

As seen in Figure 1. the identification stage involves searching for articles to be analyzed. The article search uses databases indexed by Scopus, Google Scholar, and Eric. The article search on the Scopus site was conducted using the keywords "STEM based AND physics AND learning AND media" with 11 articles obtained. The article search on the Google Scholar site was conducted using the keywords "STEM-based physics AND learning media", in this search 131 articles were obtained. While the last site search on Eric used the keywords "STEM-based physics learning media", this obtained 552 articles. So the total search results for articles with keywords for STEM-based physics learning media were 694 articles with a publication year range of 2018-2024.

After the identification stage, the screening stage is carried out. This stage involves filtering the articles to be analyzed based on the inclusion criteria set by the researcher. The first inclusion criterion is open access articles. A total of 241 open access articles were obtained, while 453 articles were eliminated that were not categorized as open access. Next, filtering will be carried out based on inclusion criteria such as the media used in physics learning, academic level, and other variables. This resulted in 64 articles based on the inclusion criteria and 177

articles that were eliminated. Further screening was carried out based on quality, which was done through a review process, resulting in 40 articles and 24 articles being eliminated based on quality. The third stage is inclusion. This stage involves the articles that will be analyzed. There are 40 articles to be analyzed. The variables that will be analyzed from these 40 articles include the country of publication, year of publication, academic level, research method, physics learning material, learning media, research instruments used, abilities measured from cognitive, psychomotor and affective aspects, and the most frequent publication journals in the findings of this research article.

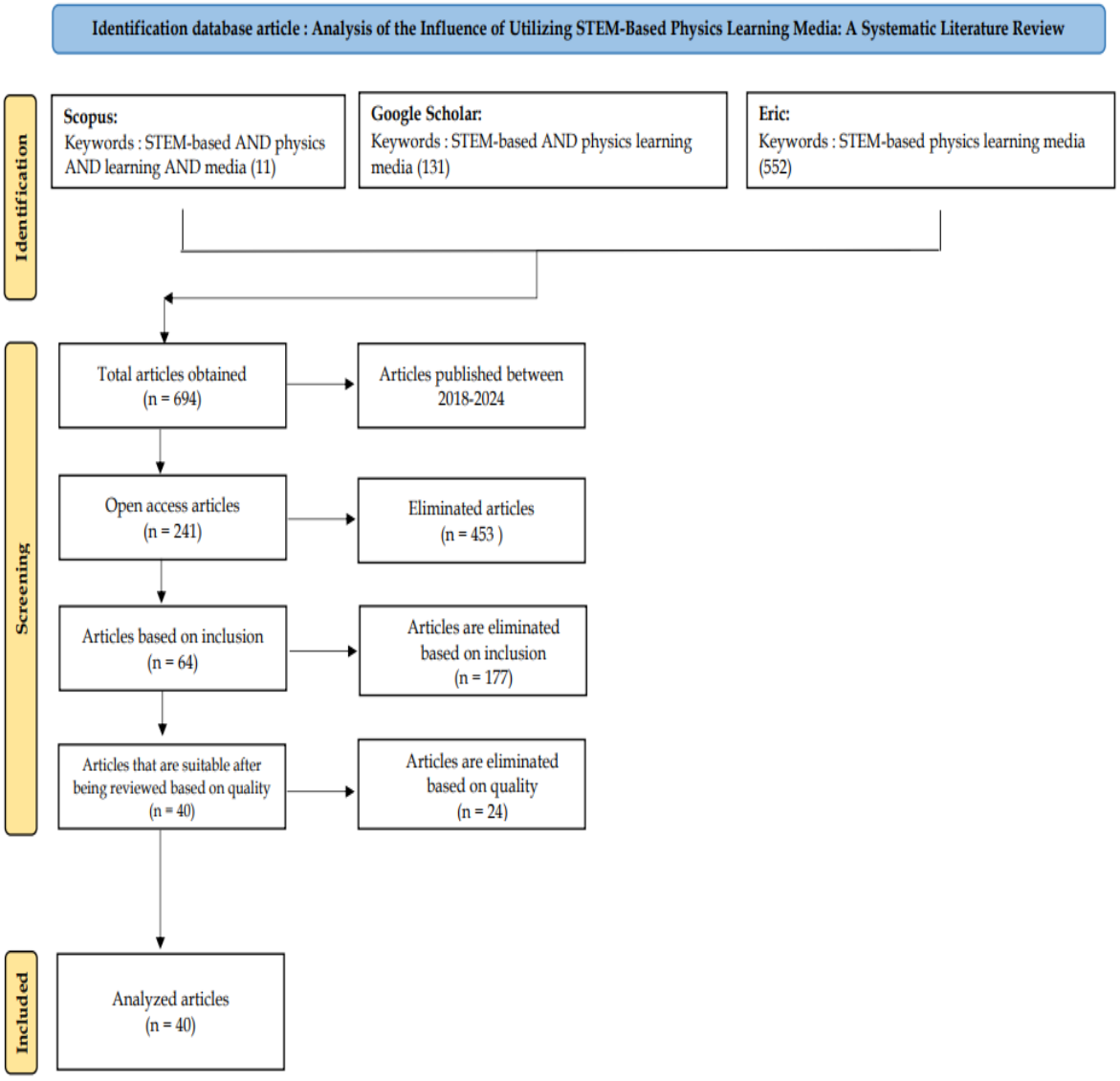

Figure 1. Prisma-P Research Stages

Results

Based on the results of the inclusion stage, 40 articles were obtained for analysis. The articles that have been analyzed will be synthesized. The synthesis of 10 articles can be seen in the following Table 1.

Table 1. Synthesis of 10 Articles

No	Author, years	Method	Sample	Findings
1.	Ashidiq et al., 2024	Quasi experimental	SMP	The use of a STEM Project-based learning model was able to improve students' critical thinking skills with an N-gain value of 0.718.
2.	Badmus & Jita, 2022	Quantitative	SMA	With the use of video-assisted STEM, students' spatial visualization abilities experience an increase in physics learning in terms of score level, gender and school of type
3.	Martaningsih et al., 2022	R & D	SD	There are differences in students' problem solving ability scores based on the results of the pretest and posttest using the STEM-PBL module.
4.	Uygur, 2022	Quasi experimental	SD	With the use of prototype-STEM based there is a significant difference in increasing students' STEM attitudes and students' attitudes towards science
5.	Kartini et al., 2021	Quantitative	SMP	Physics learning by applying the STEM Project Based learning model is highly recommended in improving students' Problem Solving Skills
6.	Kırıcı & Bakırcı, 2021	Quasi experimental	SMP	There is a significant difference in the results of students' scientific creativity tests with the application of STEM-based LKPD media in learning
7.	Pahrudin et al., 2021	Quasi experimental	SMA	Students' critical thinking abilities have increased with the implementation of STEM-based videos using inquiry models.
8.	Tanel, 2019	Semi-experimental	University students	The findings of this research are that there are significant differences in the experimental group in the learning outcomes of prospective teachers
9.	Sagala et al., 2019	Quasi experimental	SMA	The results of this research show that STEM-based ESciT learning with the help of LKPD is very supportive as a medium for increasing understanding of concepts
10.	Yusuf et al., 2018	Quasi experimental	University students	Students' HOTS ability in learning quantum physics obtained significant results using STEM-based e-learning with an N-gain value (0.7) in the high category

Country of Publication

Based on the analysis of 40 articles obtained from 2018-2024, several publishing countries were identified that conducted research using STEM-based learning media in physics education. This can be seen in Figure 2.

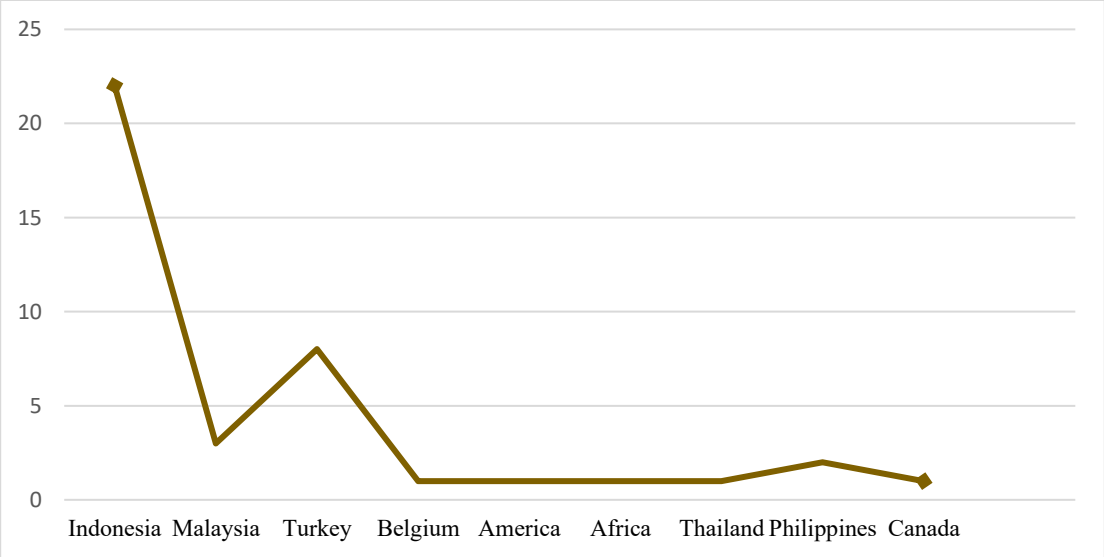

Figure 2. Country of Publication

Figure 2 shows that there are 9 countries that have published articles on STEM-based learning media, including Indonesia with 22 articles (Jannati et al., 2020; Fitria & Asrizal, 2021; Badaruddin et al., 2024), Malaysia with 3 articles (Sulaiman et al., 2023; Othman, 2022), Turkey with 8 articles, Belgium with 1 article, the United States with 1 article, Africa with 1 article, Thailand with 1 article, the Philippines with 2 articles, and Canada with 1 article. Based on this analysis, the country that publishes the most on STEM-based learning media in physics education is Indonesia. This is likely due to the surge of Coronavirus Disease-2019 (COVID-19) cases in Indonesia, which led to a temporary change in the implementation of learning systems until the disaster subsides and the learning system returns to normal. This change occurred not only at the elementary and junior high school levels but also across all academic levels from elementary school to university.

Due to the ongoing disaster, the learning system has been shifted online. Therefore, the learning used is learning that uses media with an integrated STEM approach (Sunarti & Rusilowati, 2021; Zidatunnur & Rusilowati, 2021). However, this shows that the country of publication does not influence the use of STEM-based learning media in physics education because all countries from various continents are conducting research and development regarding STEM-based learning media in physics education.

Year of Publication

Based on the inclusion criteria, the 40 articles to be analyzed were those published between 2018 and 2024. This resulted in the grouping of articles for each year, as shown in Figure 3.

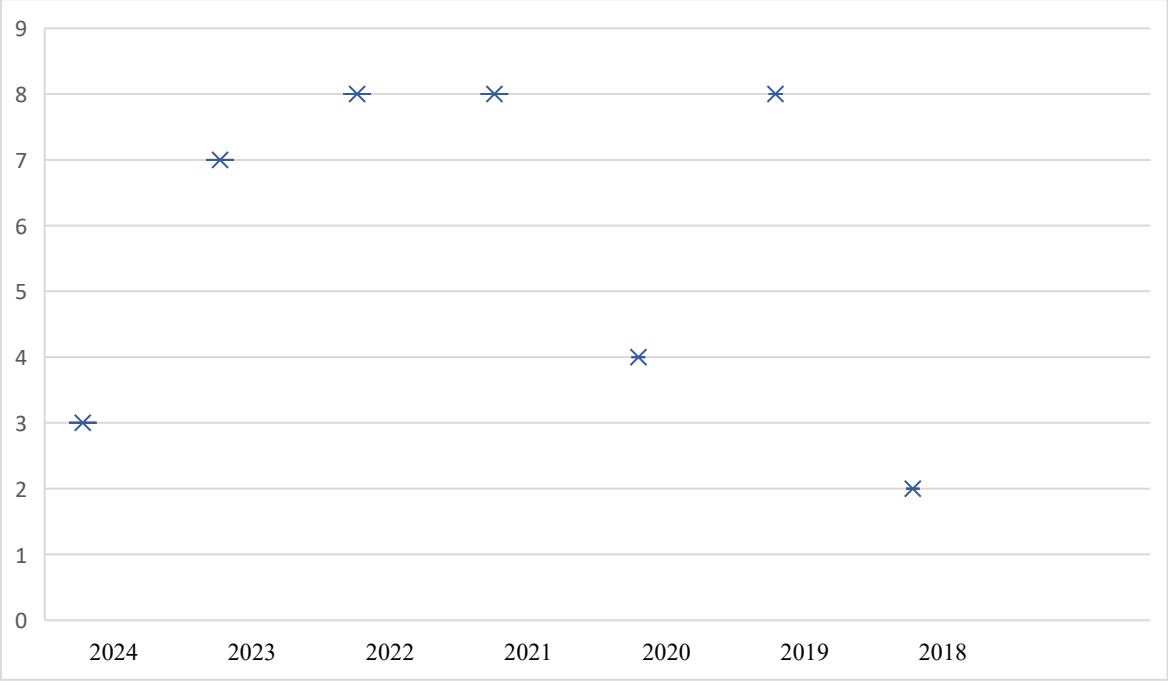

Figure 3. Year of Publication

The years with the most publications on STEM-based learning media in physics education are 2021 and 2022, with 8 publications each (Sanjaya et al., 2021; Kırıcı & Bakırcı, 2021; Bazelais et al., 2022; Badmus & Jita, 2022). 2021 and 2022 were marked by advancements in science and technology, and the end of the Covid-19 pandemic. As a result, there was a need for new and innovative learning approaches to support students in understanding learning concepts. This is supported by research conducted by Fitria and Asrizal (2021), who conducted observations at SMA Negeri 1 Gunuang Omeh. Their findings are based on the results of observations and interviews conducted with physics teachers, it turns out that the learning media that is still used is textbooks. This is an obstacle because students think that physics subjects are still difficult to understand concepts and formulas so that students are more likely to get bored, which will hinder their creative development. Creativity is one of the essential skills needed in 21st-century education. Therefore, one approach that can help students develop scientific creativity is the STEM approach. By possessing scientific creativity skills, students will be able to produce new products (Bakirci et al., 2022; Hu & Adey, 2002).

Academic Level

The analysis of the articles revealed four academic levels that were the subjects of these studies: elementary school, junior high school, high school, and university students. The grouping can be seen in Figure 4. The academic level with the highest number of publications on STEM-based learning media in physics education is high school, with 19 articles representing 39% of the total. Elementary school had 8% (4 articles), junior high school had 22% (11 articles), and university level had 31% (15 articles).

At the high school level, students are more prepared to face the era of globalization. Therefore, human resources in this era are encouraged to be literate and technologically skilled (Suwarma et al., 2019). Students are required

to be able to understand global issues related to STEM and also understand scientific and non-scientific explanations with evidence (Beybee, 2013).

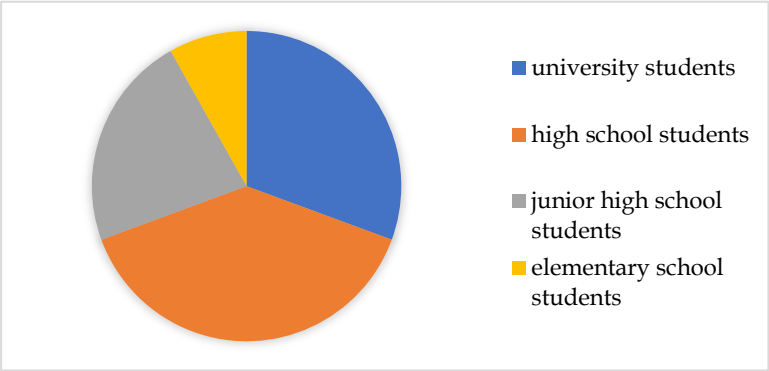

Figure 4. Academic Level

Research Method

The research methods analyzed in the data of this article yielded several method groupings. This can be seen in Figure 5.

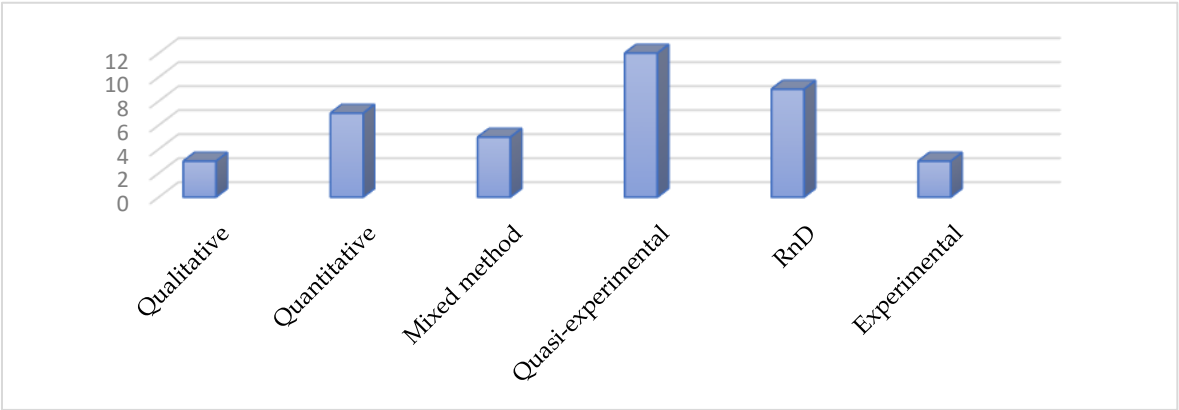

Figure 5. Research Method

The most widely used research method with the use of STEM-based learning media is the quasi-experimental research method, with 12 articles obtained. This is because the quasi-experimental method makes it easier for researchers to determine the effect of using STEM-based learning media in physics learning on the variables to be measured. This is supported by research conducted (Yulianti et al., 2019; Bazelais et al., 2022; Uygur, 2022) which used a quasi-experimental method by measuring students' critical thinking skills and conceptual understanding in physics learning.

Learning Material

The articles analyzed are articles that are relevant to physics learning material. In this analysis, various physics

materials were obtained which were carried out in research using STEM-based learning media. These will be grouped in Figure 6.

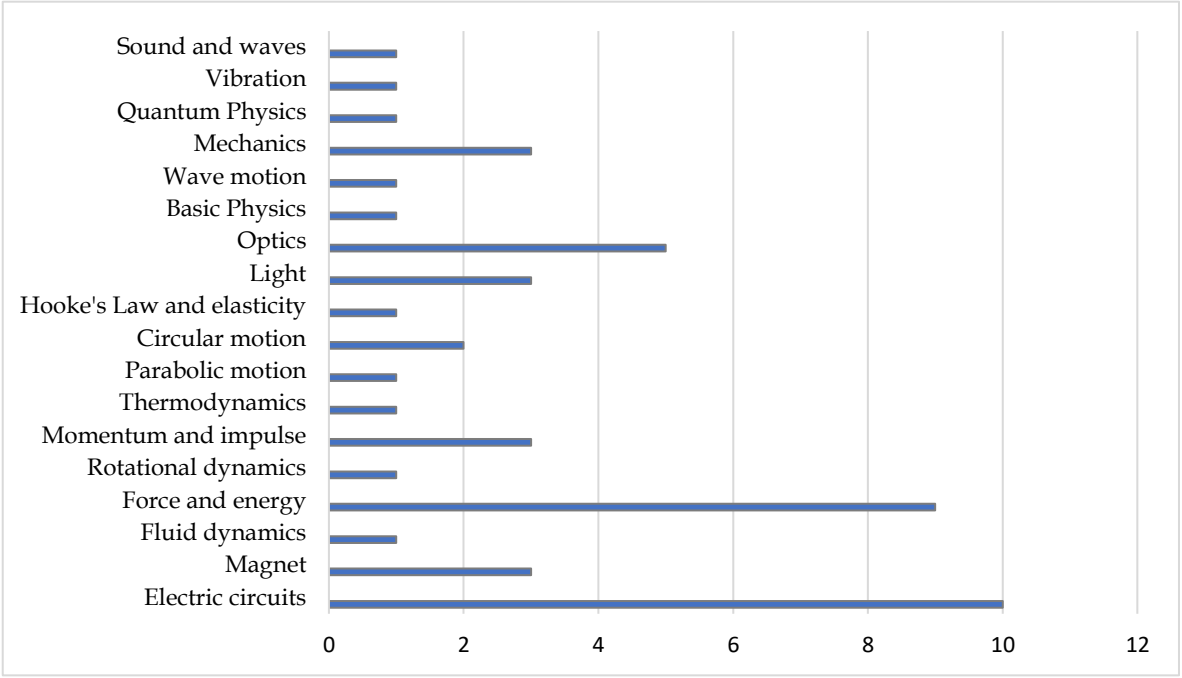

Figure 6. Learning Material

Based on the analysis results, 18 physics subjects were studied from elementary school to university levels. From the grouping in the figure above, the most researched topic is electrical circuits, with 10 articles obtained. Difficulties were found for students in the topic of electrical circuits. This is supported by research conducted by Yasin et al. in 2018, which states that electrical circuits are one of the physics topics whose problems involve very complex and abstract concepts. Students also have difficulty explaining the role of electric fields when conducting electrical circuit experiments (Cao & Brizuela, 2016; Yasin et al., 2018). Electrical circuits also require concepts related to circuit diagrams, graphs, and vectors, thus requiring spatial visualization skills (McCunn & Cilli-Turner, 2020; Lowrie et al., 2019; Badmus & Jita, 2022). Thus, learning using the STEM approach in electrical circuit material can increase students' interest in learning science, which will be able to provide a deep understanding and be able to interpret learning and improve students' skills (Anwari et al., 2015; Yasin et al., 2018).

Learning Media

Based on the analysis of the article data, various learning media were used in physics learning using the STEM approach, including worksheets, e-modules or modules, simulations/software, student worksheets, prototypes, e-books, e-learning, and videos. This can be seen in Figure 7. The most widely used STEM-based learning media is the prototype, with 13 articles obtained (Akkoyun et al., 2023; Yakob et al., 2021; Samsudin et al., 2020; Hanif et al., 2019; Apriyani et al., 2019). Prototyping is the development of a new product or design with the aim of testing a concept or material to be studied. Prototypes can be created using experimental tools found in school laboratories.

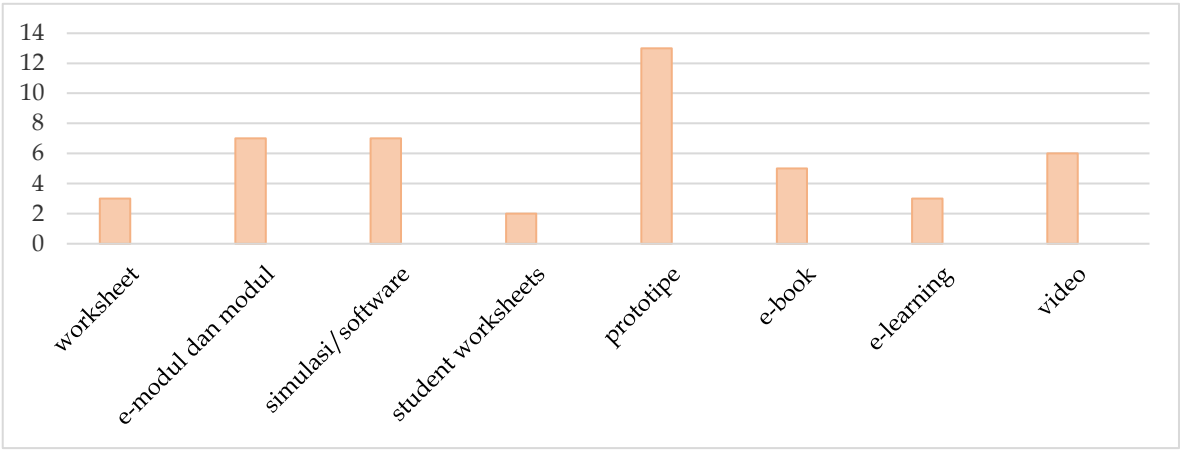

Figure 7. Learning Media

Research Instrument

The research instruments obtained based on the analysis results include tests, questionnaires, observation, interviews, perception, and some that were not mentioned. The grouping can be seen in Figure 8.

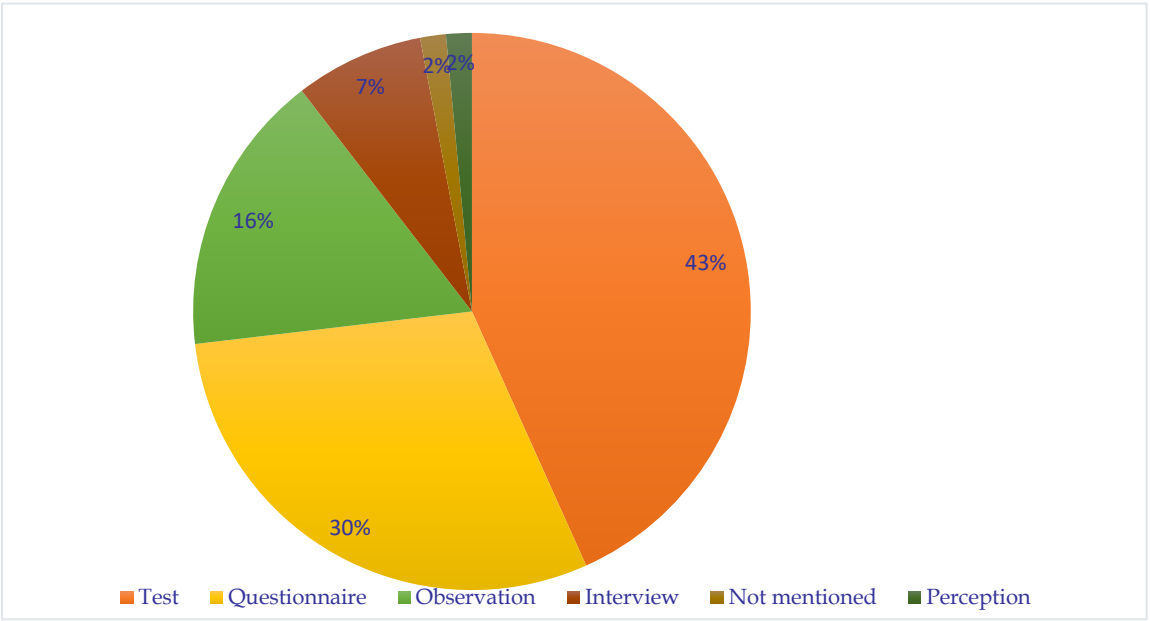

Figure 8. Research Instrument

The most widely used instrument in this research article is the test, with a percentage of 43%. Thus, it can be concluded that tests are instruments that can make it easier for researchers to obtain results or scores when measuring students' abilities. This is supported by research conducted by Bahtaji (2023) using the Force Concept Inventory (FCI), an instrument developed not only to measure students' conceptual understanding of Newtonian mechanics but also to help students overcome misconceptions in Newtonian mechanics. The developed instrument will undergo feasibility and reliability testing. The tested instrument shows good reliability.

Student Abilities

Based on the analysis of 40 articles, various abilities were measured using STEM-based learning media in physics learning. These abilities consist of cognitive, psychomotor, and affective aspects of the students. This grouping can be seen in Figure 9.

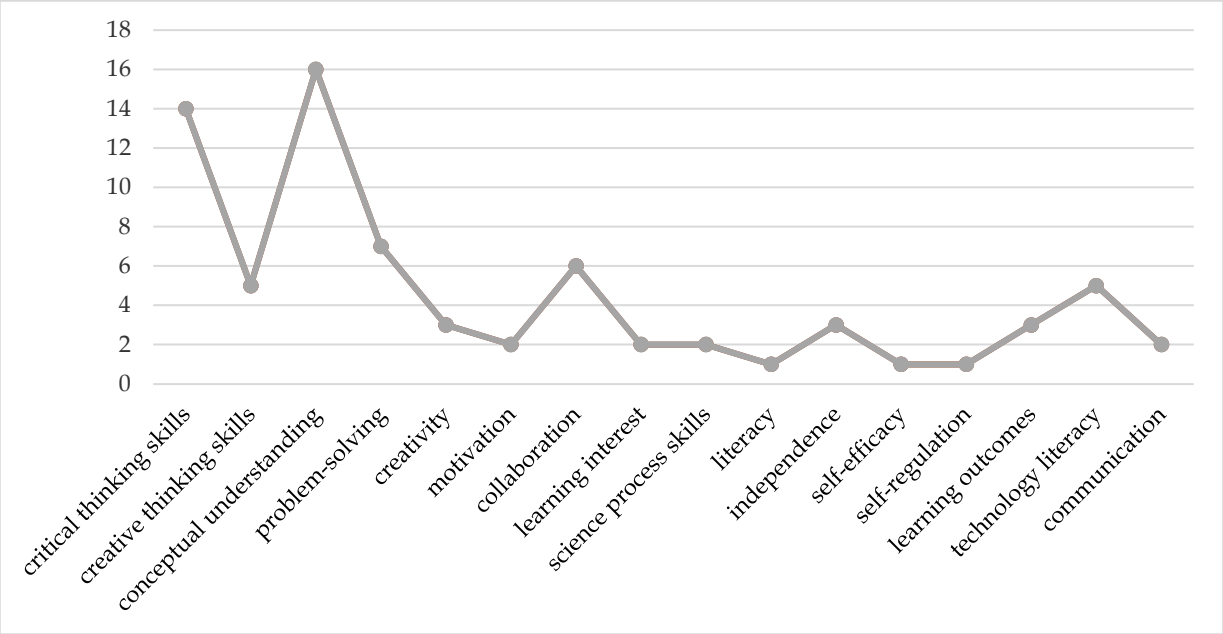

Figure 9. Student Abilities

The learning abilities of students in Figure 9 represent abilities relevant to the 21st century. However, the most researched ability in STEM-based learning, particularly in physics education, is conceptual understanding, with 16 articles acquired (Uzun & Şen, 2023; Serevina & Hamidah, 2022; Ladachart et al., 2022; Sanjaya et al., 2021; Modesto, 2018). The second most frequent ability is critical thinking, with 14 articles (Ashidiq et al., 2024; Akkoyun et al., 2023; Othman, 2022; Pahrudin et al., 2021). Problem-solving ability was addressed in 7 articles (Dignam, 2024; Martaningsih et al., 2022; Kartini et al., 2021). From the psychomotor domain, creativity was found in 3 articles (Kırıcı & Bakırcı, 2021; Hanif et al., 2019).

Meanwhile, from the affective domain, self-efficacy was found in 1 article (Samsudin et al., 2020). It can be concluded that the most frequently measured ability in this research is conceptual understanding. It is important to acknowledge that conceptual understanding in physics is crucial for students, as successful physics learning is indicated by a good understanding of concepts (Rose Amanda Puri & Riki Perdana, 2023). This research was conducted to determine whether there were significant differences in conceptual understanding abilities between the experimental and control groups in the pretest and posttest (Bakirci et al. (2022) conducted research implementing an inquiry-based STEM approach in learning physics, specifically on Work and Energy. The media used in this research was a worksheet. The results showed a significant difference in pretest and posttest results between the experimental and control classes, with a result of ($F1; 61 = 33.235$; $p<0.05$).

Most Frequent Publications

Based on the analysis of 40 articles, the top 5 articles with the most publications were identified. This can be seen in Table 2.

Table 2. Most Frequent Publications

No	Journal Name	N	Percentage
1.	Journal of Physics: Conference Series	6	15%
2.	Journal of Science Learning	6	15%
3.	Journal of Turkish Science Education	4	10%
4.	European Journal of Educational Research	3	7.5%
5.	Journal of Baltic Science Education	3	7.5%

Table 2 shows the top 5 publications with the most articles published, including the Journal of Physics: Conference Series (Jannati et al., 2020; Yusuf & Widyaningsih, 2019; Yulianti et al., 2019) and the Journal of Science Learning (Oktay et al., 2023; Kartini et al., 2021) with a percentage of 15% (N = 6). The publication ranked third is the Journal of Turkish Science Education with a percentage of 10% (N = 4) (Badmus & Jita, 2022; Yusuf et al., 2018). Publications ranked fourth and fifth are the European Journal of Educational Research (Pahrudin et al., 2021; Goovaerts et al., 2019) and the Journal of Baltic Science Education (Sulaiman et al., 2023; Tanel, 2019) with a percentage of 7.5% (N = 3). Thus, the most popular publications with the theme of STEM-based learning media are the Journal of Physics: Conference Series and the Journal of Science Learning.

Conclusion

This research utilizes data from 40 articles (2018-2024) that have undergone a screening process based on inclusion criteria. The research method employed is a systematic literature review. The objective of this research is to identify the variables influencing the use of STEM-based physics learning media. After conducting the analysis, several influencing variables were identified. In this study, the country of publication did not influence the research, as article publications were widely distributed across various countries experiencing changes in their learning curricula, thus necessitating STEM-based learning media. The years with the most published articles were 2021 and 2022, marking the resumption of full face-to-face schooling after the COVID-19 pandemic. This period also saw a slight decline in students' understanding of physics due to the reduced effectiveness of online learning during the pandemic. The academic level with the most prevalent use of STEM-based learning media is high school. The most dominant research method used, due to its relative ease in assessing student learning outcomes, is the quasi-experimental method. The most dominant subject matter is electrical circuits, as this topic is considered abstract and challenging to comprehend. The most widely used learning media with a STEM approach is the prototype, due to its ease of acquisition by utilizing school facilities. The most frequently used instrument is the test, as the most commonly measured ability in the analyzed articles is conceptual understanding. The most popular publications are the Journal of Physics: Conference Series and the Journal of Science Learning, with a representation of 15%, comprising 6 articles.

Statements and Declarations

Acknowledgments: The researcher expresses gratitude to those who have contributed to the writing of this systematic literature review, especially to the Master of Physics Education Program at Yogyakarta State University and The Republic of Indonesia Education Fund Management Institute (LPDP) which has funded research activities and the preparation of articles.

References

Akkoyun, N., Yalcin, S. A., Cakir, Z., & Yalcin, P. (2023). The effect of STEM and STEM-based robotic activities on the development of students' perceptions of mental risk-taking and its predictors and their inquiry skills in science learning. *Asian Journal of Contemporary Education, 7*(1), 1–14. https://doi.org/10.55493/5052.v7i1.4752

Apriyani, R., Ramalis, T. R., & Suwarma, I. R. (2019). Analyzing students' problem-solving abilities of direct current electricity in STEM-based learning. *Journal of Science Learning, 2*(3), 85–91. https://doi.org/10.17509/jsl.v2i3.17559

Ashidiq, R. M., Winarno, N., Prima, E. C., Widodo, A., & Chang, C. (2024). Investigating the impact of STEM learning on students' critical thinking skills through hand-made projector activity. *Journal of Science Learning, 7*(2). https://doi.org/10.17509/jsl.v7i2.61549

Badaruddin, A., Budi, A. S., & Sumantri, M. S. (2024). The effectiveness of science encyclopedia-assisted project-based learning integrated with the STEM approach in enhancing pre-service elementary teachers' scientific literacy. *Journal of Education and E-Learning Research, 11*(3), 597–605. https://doi.org/10.20448/jeelr.v11i3.5928

Badmus, O. T., & Jita, L. C. (2022). Pedagogical implication of spatial visualization ability: A correlate of students' achievements in physics. *Journal of Turkish Science Education, 19*(1), 97–110. https://doi.org/10.36681/tused.2022.112

Bahtaji, M. A. A. (2023). Examining the physics conceptions, science engagement, and misconceptions of undergraduate students in STEM. *Journal of Baltic Science Education, 22*(1), 10–19. https://doi.org/10.33225/jbse/23.22.10

Bakirci, H., Kirici, M. G., & Kara, Y. (2022). The effectiveness of STEM-supported inquiry-based learning approach on conceptual understanding of 7th graders: Force and energy unit. *Journal of Science Learning, 5*(3), 452–468. https://doi.org/10.17509/jsl.v5i3.43647

Bazelais, P., Breuleux, A., & Doleck, T. (2022). Investigating a blended learning context that incorporates two-stage quizzes and peer formative feedback in STEM education. *Knowledge Management & E-Learning, 14*(4), 395–414. https://doi.org/10.34105/j.kmel.2022.14.021

Dignam, C. (2024). Harmonies on the string: Exploring the synergy of music and STEM. *International Journal of Technology in Education and Science, 8*(3), 491–521. https://doi.org/10.46328/ijtes.571

Fitria, Y., & Asrizal, A. (2021). Pengembangan bahan ajar elektronik energi dan momentum terintegrasi STEM untuk meningkatkan hasil belajar siswa SMA. *Jurnal Pendidikan Fisika dan Teknologi, 7*(2), 119–130. https://doi.org/10.29303/jpft.v7i2.3001

Goovaerts, L., De Cock, M., Struyven, K., & Dehaene, W. (2019). Developing a module to teach thermodynamics in an integrated way to 16-year-old pupils. *European Journal of STEM Education, 4*(1), 1–11. https://doi.org/10.20897/ejsteme/3964

Hanif, S., Wijaya, A. F. C., & Winarno, N. (2019). Enhancing students' creativity through STEM project-based learning. *Journal of Science Learning, 2*(2), 50–59. https://doi.org/10.17509/jsl.v2i2.13271

Jannati, E. D., Susandi, D., Rachmat, A., Kaniawati, I., & Siahaan, P. (2020). Design of STEM-based learning devices in direct current circuit section. *Journal of Physics: Conference Series, 1440*(1), Article 012053. https://doi.org/10.1088/1742-6596/1440/1/012053

Kartini, F. S., Widodo, A., Winarno, N., & Astuti, L. (2021). Promoting students' problem-solving skills through STEM project-based learning in earth layer and disasters topic. *Journal of Science Learning, 4*(3), 257–266. https://doi.org/10.17509/jsl.v4i3.27555

Kırıcı, M. G., & Bakırcı, H. (2021). The effect of STEM-supported research-inquiry-based learning approach on the scientific creativity of 7th grade students. *Journal of Pedagogical Research, 5*(2), 19–35. https://doi.org/10.33902/JPR.2021067921

Ladachart, L., Khamlarsai, S., & Phothong, W. (2022). Facilitating educationally disadvantaged students' learning of torque using a design-based activity. *Lumat, 10*(1), 151–181. https://doi.org/10.31129/LUMAT.10.1.1664

Marisda, D. H., Handayani, Y., & Hasin, A. (2024). Needs analysis in the development of basic physics practical e-module based on interactive flipbook with STEM approach. *Journal of Science Learning, 9*(3), 404–414.

Martaningsih, S. T., Maryani, I., Prasetya, D. S., Prwanti, S., Sayekti, I. C., Aziz, N. A. A., & Siwayanan, P. (2022). STEM problem-based learning module: A solution to overcome elementary students' poor problem-solving skills. *Pegem Eğitim ve Öğretim Dergisi, 12*(4), 340–348. https://doi.org/10.47750/pegegog.12.04.35

Oktay, O., Koçak, G., & Seven, S. (2023). The impact of STEM-based laboratory activities on pre-service science teachers' competence perceptions in 21st-century skills and STEM awareness. *Journal of Science Learning, 6*(3), 244–255. https://doi.org/10.17509/jsl.v6i3.54992

Othman, O. (2018). Examining student perception on mobile augmented reality. *Journal of Information Systems Research and Innovation, 35*(1), 2–12.

Pahrudin, A., Misbah, M., Alisia, G., Saregar, A., Asyhari, A., Anugrah, A., & Susilowati, N. E. (2021). The effectiveness of science, technology, engineering, and mathematics-inquiry learning for 15–16-year-old students based on K-13 Indonesian curriculum: The impact on the critical thinking skills. *European Journal of Educational Research, 10*(2), 681–692. https://doi.org/10.12973/eu-jer.10.2.681

Puri, R. A., & Perdana, R. (2023). Analisis kemampuan pemahaman konsep fisika peserta didik SMA di Bantul pada materi fluida statis dan upaya peningkatannya melalui model pembelajaran visualization auditory kinesthetic. *MAGNETON: Jurnal Inovasi Pembelajaran Fisika UNWIRA, 1*(2), 93–101. https://doi.org/10.30822/magneton.v1i2.2463

Sagala, R., Umam, R., Thahir, A., Saregar, A., & Wardani, I. (2019). The effectiveness of STEM-based learning on gender differences: The impact on physics concept understanding. *European Journal of Educational Research, 8*(3), 753–761. https://doi.org/10.12973/eu-jer.8.3.753

Samsudin, M. A., Jamali, S. M., Zain, A. N. M., & Ebrahim, N. A. (2020). The effect of STEM project-based learning on self-efficacy among high school physics students. *Journal of Turkish Science Education, 17*(1), 94–108. https://doi.org/10.36681/tused.2020.15

Sanjaya, L. A., Nurkholis, I., Iswanto, B. H., Wibowo, F. C., Fidhyallah, N. F., Puspa, R. W. D., Ilmi, N., Pertiwi, W. A., Sianipar, L. K., & Rasmi, D. P. (2021). Website of physics instructional (WoPI): Learning physics from home during COVID-19. *Journal of Physics: Conference Series, 2019*(1), Article 012038. https://doi.org/10.1088/1742-6596/2019/1/012038

Sari, D. A. W., & Kholiq, A. (2022). Development of WEB-FIST (STEM-based physics web) to train students' critical thinking on the topic of parabolic motion. *Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram, 10*(3), 750–759. https://doi.org/10.33394/j-ps.v10i3.5574

Sari, U., Duygu, E., Şen, Ö. F., & Kirindi, T. (2020). The effects of STEM education on scientific process skills and STEM awareness in a simulation-based inquiry learning environment. *Journal of Turkish Science Education, 17*(3), 387–405. https://doi.org/10.36681/tused.2020.34

Serevina, V., & Hamidah, I. (2022). Science, technology, engineering, and mathematics (STEM)-based geothermal energy source digital module assisted by Canva application. *Journal of Physics: Conference Series, 2377*(1), Article 012063. https://doi.org/10.1088/1742-6596/2377/1/012063

Simon, A. (2000). Perceptual comparisons through the mind's eye. *Memory & Cognition, 23*(2), 635–647.

Sulaiman, F., Rosales, J. J., & Kyung, L. J. (2023). The effectiveness of the integrated STEM-PBL physics module on students' interest, sensemaking, and effort. *Journal of Baltic Science Education, 22*(1), 113–129. https://doi.org/10.33225/jbse/23.22.113

Sunarti, S., & Rusilowati, A. (2021). Pengembangan bahan ajar digital gerak melingkar berbantuan Scratch berbasis science, technology, engineering, and mathematics. *Unnes Physics Education Journal, 9*(3), 283–290. http://journal.unnes.ac.id/sju/index.php/upej

Suwarma, I. R., Kaniawati, I., & Kaniawati, D. S. (2019). Engaging students in STEM-based learning through media and technology. *Journal of Physics: Conference Series, 1204*(1), Article 012054. https://doi.org/10.1088/1742-6596/1204/1/012054

Tanel, R. (n.d.). Effect of STEM work–energy topics on academic achievement and prospective teachers' opinions on STEM activities. *Journal of Baltic Science Education*, 507–518.

Uygur, M. (2022). STEM-based course design: A way to develop attitudes toward STEM and science course. *Science Education International, 33*(4), 345–355. https://doi.org/10.33828/sei.v33.i4.1

Uzun, S., & Şen, N. (2023). The effects of a STEM-based intervention on middle school students' science achievement and learning motivation. *Journal of Pedagogical Research, 7*(1), 228–242. https://doi.org/10.33902/JPR.202319315

Yakob, M., Hamdani, H., Sari, R. P., Haji, A. G., & Nahadi, N. (2021). Implementation of performance assessment in STEM-based science learning to improve students' habits of mind. *International Journal of Evaluation and Research in Education, 10*(2), 624–631. https://doi.org/10.11591/ijere.v10i2.21084

Yaniawati, P., Maat, S. M., Supianti, I. I., & Fisher, D. (2022). [Makale başlığı belirtilmemiş]. *European Journal of Educational Research, 11*(1), 69–81.

Yasin, A. I., Prima, E. C., & Sholihin, H. (2018). Learning electricity using Arduino-Android-based game to

improve STEM literacy. *Journal of Science Learning, 1*(3), 77–84. https://doi.org/10.17509/jsl.v1i3.11789

Yulianti, D., Wiyanto, Rusilowati, A., Nugroho, S. E., & Pangesti, K. I. (2019). Science, technology, engineering, and mathematics (STEM)-based learning of physics to develop senior high school students' critical thinking. *Journal of Physics: Conference Series, 1321*(2), Article 022029. https://doi.org/10.1088/1742-6596/1321/2/022029

Yusuf, I., & Widyaningsih, S. W. (2019). HOTS profile of physics education students in STEM-based classes using PhET media. *Journal of Physics: Conference Series, 1157*(3), Article 032021. https://doi.org/10.1088/1742-6596/1157/3/032021

Yusuf, I., Widyaningsih, S. W., & Sebayang, S. R. B. (2018). Implementation of e-learning-based STEM in quantum physics subject to students' HOTS ability. *Journal of Turkish Science Education, 15*(Special Issue), 67–75. https://doi.org/10.12973/tused.10258a

Zidatunnur, S. F., & Rusilowati, A. (2021). Keterbacaan dan kepraktisan bahan ajar digital gerak melingkar berbantuan Scratch berbasis STEM untuk mahasiswa. *Unnes Physics Education Journal, 10*(2), 131–138. http://journal.unnes.ac.id/sju/index.php/upej