

Bibliometric Analysis of Research Trends in STEM Education and Higher-Order Thinking Skills (HOTS) in Physics Learning

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Article Info	Abstract
Article history: Received: June 2, 2025 Accepted: June 16, 2025 Published: July 31, 2025 Keywords: Bibliometric Higher-order thinking skills Physics learning STEM education This article is licensed under a creative commons attribution-share alike 4.0 international license © 2025 Jurnal ilmiah Pendidikan Fisika	This study presents a bibliometric analysis of research trends in STEM (Science, Technology, Engineering, and Mathematics) education and Higher-Order Thinking Skills (HOTS) within the context of physics learning. The aim is to identify dominant research themes, visualize their development over time, and uncover gaps in the integration of STEM and HOTS in physics education. A total of 147 articles published between 2017 and 2024 were retrieved from the Scopus database, with 96 articles selected for analysis. VOSviewer was used to generate three types of visualizations: network visualization to explore keyword relationships, overlay visualization to track thematic trends over time, and density visualization to examine research concentration. The results reveal that: (1) research on STEM, HOTS, and physics learning has grown significantly, especially since 2021; (2) overlay visualization indicates a shifting research focus toward integrating HOTS through STEM approaches in physics contexts; (3) density mapping shows that the integration of HOTS in STEM-based physics instruction remains relatively underexplored; (4) content analysis highlights that STEM is commonly connected with the development of essential thinking skills, the integration of student-centered learning models such as Project-Based Learning and Problem-Based Learning, and the use of digital learning media; and (5) recent studies have also begun to emphasize the importance of considering affective domains, such as students' scientific attitudes, motivation, and engagement, in the implementation of STEM-based learning. This study provides a structured overview of the STEM-HOTS research landscape, offering both theoretical insights and practical implications for advancing innovative, skill-oriented physics instruction.
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INTRODUCTION

The 21st century has marked a significant transformation in education due to the rapid evolution of technology, information, and industry. In response to global demands for innovation, productivity, and problem-solving abilities, education must prioritize the development of students' cognitive, creative, and adaptive skills ([Apkarian et al., 2021](#); [Yulianti et al., 2019](#)). One approach widely recognized for addressing these goals is STEM (Science, Technology, Engineering, and Mathematics) education, which offers

interdisciplinary and contextual learning experiences designed to bridge academic knowledge with real-world applications ([Khotimah et al., 2021](#); [Samsudin et al., 2020](#)).

STEM education is not only focused on disciplinary integration but also on cultivating essential 21st-century competencies, particularly Higher-Order Thinking Skills (HOTS), which include analyzing, evaluating, and creating ([Afriyanti et al., 2021](#); [Anderson & Krathwohl, 2001](#); [Sari et al., 2021](#)). HOTS are indispensable in equipping students to solve complex problems, innovate, and make informed decisions. Numerous studies have shown that STEM-based approaches, such as project-based learning, problem-solving models, and design-thinking, are effective in developing students' HOTS in physics contexts ([Fiteriani et al., 2021](#); [Martawijaya et al., 2023](#); [Mulyati et al., 2023](#)).

Physics, as a core STEM subject, demands abstract reasoning, conceptual understanding, and scientific modeling, all of which are strongly aligned with HOTS. The integration of STEM and HOTS in physics learning has been implemented through various instructional strategies, including the development of digital learning modules ([Afriyanti et al., 2021](#)), multimedia resources ([Diansah et al., 2021](#)), and augmented reality tools ([Rahmayani et al., 2024](#)), all aiming to enhance students' cognitive engagement. Moreover, physics learning environments that adopt STEM principles have been shown to improve not only conceptual understanding and critical thinking but also foster scientific literacy, creativity, and student motivation ([Parno et al., 2020](#); [Simeon et al., 2022](#); [Yuliati et al., 2021](#)).

Despite the growing body of literature on STEM and HOTS, current research remains fragmented. Some studies focus solely on the development of HOTS ([Yusuf & Widyaningsih, 2019](#)), while others emphasize the design of STEM-based media ([Sari et al., 2021](#)) or instructional models ([Solihin et al., 2021](#)). However, there is limited synthesis that systematically maps how STEM and HOTS are integrated in physics education, especially in terms of research trends, dominant themes, and thematic gaps over time. Furthermore, dimensions such as scientific attitudes ([Yulianti & Handayani, 2021](#)), student motivation ([Samsudin et al., 2020](#)), and engagement ([Solomon et al., 2022](#)) are often addressed peripherally rather than as core elements of STEM-HOTS integration.

To address this gap, this study conducts a bibliometric analysis to explore the development of research on STEM education and HOTS in physics learning. Bibliometric analysis allows for the visualization of knowledge structures and the identification of topic clusters, trends, and underexplored areas ([van Eck & Waltman, 2014](#)). Using metadata from articles indexed in Scopus between 2017 and 2024, this study analyzes keyword co-occurrence networks, overlay maps, and density distributions to: (1) identify dominant research themes; (2) examine the progression of STEM-HOTS integration over time; and (3) highlight potential areas for future investigation. The results of this analysis are expected to inform the development of future research, curriculum innovation, and instructional design that effectively integrates STEM education and higher-order thinking in physics learning.

METHOD

This study adopts a bibliometric analysis approach to explore research trends in STEM education and Higher-Order Thinking Skills (HOTS) within the context of physics learning. The method used in this analysis follows the procedures outlined by van Eck and Waltman ([van Eck & Waltman, 2014](#)). It aims to provide a structural representation of the scientific landscape and to identify the evolution of research over time, as well as uncover key themes related to the research focus ([Öztürk et al., 2024](#)). The bibliometric analysis procedure consists of four main stages: defining the research aim, collecting relevant

literature, analyzing and visualizing data, and interpreting the results. The procedure of bibliometric analysis is illustrated in Figure 1 (Öztürk et al., 2024):

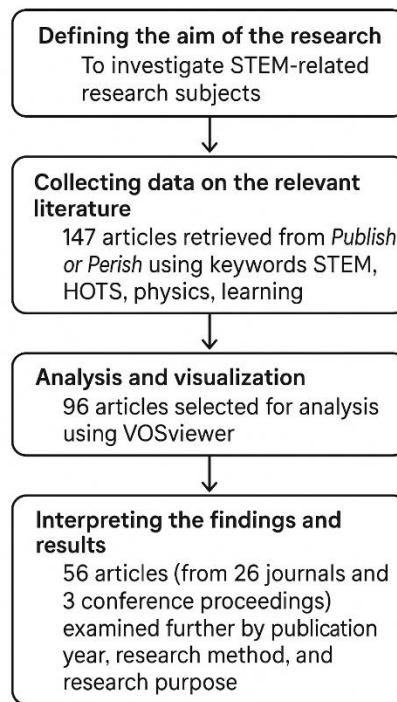


Figure 1 The bibliometric analysis procedure

A bibliometric review was conducted using a database of publications from 26 journals and three conference proceedings to investigate STEM-related research subjects, particularly those that integrate higher-order thinking skills and physics learning. These journals were selected because some of them are pioneers in the field of STEM and are also indexed in Scopus. This review aims to explore research trends, dominant themes, and opportunities for further study within the scope of STEM education.

Article retrieval was conducted using *Publish or Perish* (PoP), selecting Scopus as the database. The titles and keywords used in the search were a combination of four terms: “STEM”, “HOTS”, “physics”, and “learning”, with the publication date range set from 2017 to 2024. The search via PoP yielded 147 articles. Articles downloaded between December 2024 and May 2025 included publications from the 26 journals and 3 conferences. After curation, 96 articles were selected and downloaded from the Scopus database. These articles were then imported into *Mendeley Reference Manager* and compiled into a single folder. The folder was exported into RIS file format so that both basic article information (such as author names, titles, publication years, journal names, volumes, issues, and pages) and additional information (such as abstracts, keywords, DOIs, ISBNs, and URLs) could be recorded and preserved for further analysis.

The exported metadata was then processed using the VOSviewer software, which is utilized to identify research topics that still offer potential for further investigation, as well as to discover the most frequently cited references within a specific field. The software provides three types of visualizations: network, overlay, and density visualization. The network visualization displays the relationships between terms in the form of a network. Meanwhile, the overlay visualization illustrates the progression or historical development

of research over time. The density visualization indicates the intensity or focus within certain research clusters, which can be used to identify relatively underexplored areas.

VOSviewer is capable of processing datasets from various sources, including Web of Science, Scopus, Dimensions, and PubMed. In addition, it supports dataset formats including RIS, EndNote, and RefWorks. Through its API feature, VOSviewer can access and retrieve data from several other databases, including Crossref, PubMed PMC, Semantic Scholar, OpenCitations Corpus (OCC), COCI, and Wikidata. In this study, the articles were retrieved from the Scopus database and exported in RIS format.

This tool was used to generate visualizations of exported metadata that were then processed using the software's embedded algorithm. Keywords or concepts that developed as study themes were taken from article titles and abstracts, as well as keywords submitted by the authors. The keywords were interpreted as study topics or themes.

The process began by launching the VOSviewer software. Once the program was open, the user navigated to the *File* tab and clicked the *Create* button to open the dialog box. In this dialog, the user selected the option to *create a map based on text data* and proceeded by clicking *Next*. For the data source, the option to *Read data from reference manager files* was chosen, followed by selecting the previously exported RIS file and continuing to the next step. The user then selected the *Title and abstract fields* to be extracted, ensuring that both available options were checked. In the following step, *Binary counting* was chosen as the counting method, and the threshold was set to 4 instead of the default 10. This adjustment resulted in 47 frequently occurring keywords being identified from a total of 851 terms. After clicking *Next*, the system automatically populated the subsequent field with a number representing 60% of those keywords, and the user proceeded by clicking *Next* again. At the final term verification stage, the keywords were sorted alphabetically, and less specific terms not directly related to STEM, such as "item," "difficult," "result," "focus," "thing," "model," "effect," and "characteristic"—were excluded. The process concluded by clicking *Finish*.

RESULTS AND DISCUSSION

This study produced a set of bibliometric visualizations using VOSviewer, which include network visualization, overlay visualization, and density visualization. In addition, a content analysis was performed on 56 selected articles (sourced from 26 journals and 3 conference proceedings), presented through descriptive tables summarizing the journals of publication, year of publication, research methods, and research purposes associated with STEM integration.

Bibliometric Visualizations

Bibliometric analysis was conducted by generating network, overlay, and density visualizations using VOSviewer to identify the bibliometric networks within the metadata of 96 selected articles. In the network visualization (Figure 2), each *node* (represented by circles) corresponds to a keyword or term derived from article titles and abstracts, while *edges* between nodes represent the co-occurrence relationships (Donthu et al., 2021). The distance between nodes reflects the strength of the relationship, with closer nodes indicating higher co-occurrence frequency.

Mapping and clustering are complementary processes in this visualization. Mapping provides an overview of the research field's structure, while clustering reveals thematic groupings within it. Frequently used terms are displayed with labels, and color coding represents different clusters. VOSviewer assigns RGB (red, green, blue) values to distinguish each cluster visually. According to van Eck and Waltman (2014), clustering in bibliometric analysis involves grouping closely related items, such as keywords or articles,

based on the strength of their co-occurrence links, to identify coherent topics or research areas ([van Eck & Waltman, 2014](#)). The clustering technique in VOSviewer utilizes modularity optimization to identify densely connected item groups, thereby facilitating the discovery of distinct thematic structures.

As in Figure 2, larger circles represent terms that appear in a greater number of articles. For example, the red-colored cluster indicates that the association between the *STEM approach* and *physics* is stronger, as evidenced by their proximity, whereas the relationship between the *STEM approach* and *higher-order thinking skills* appears weaker due to the greater distance between them. The network is categorized into two major clusters based on term co-occurrence and thematic relevance.

The first cluster, represented in red, includes terms such as *student*, *teacher*, *problem*, *project*, *STEM approach*, *higher-order thinking skill*, and *physics*. This cluster indicates a strong research emphasis on the instructional application of STEM to promote cognitive development, particularly in physics classrooms. This is reflected in studies that explore the use of STEM-based learning modules and student worksheets to enhance competence in physics learning ([Sari et al., 2019](#); [Selisne et al., 2019](#)). Other studies have also emphasized the value of hands-on STEM activities in fostering awareness of sustainability goals, as well as the integration of 3D modeling and printing technologies to support students' conceptual understanding in physics education ([Costa et al., 2023](#); [Usembayeva et al., 2024](#)).

The second cluster, shown in green, includes broader terms such as *STEM*, *STEM education*, *science*, *technology*, *engineering*, *mathematics*, *attitude*, and *learning*. This cluster represents a more conceptual orientation toward the structure, perception, and curriculum aspects of STEM education. Research in this group highlights how teachers perceive STEM integration and the challenges they face in its implementation ([Guan et al., 2020](#)). Other analyses have examined current bibliometric trends, conceptual developments, and research gaps related to STEM in physics learning ([Wibowo et al., 2024](#)). In addition, several reviews have mapped the evolution of STEM project-based learning (PjBL) in physics classrooms, underscoring the continued transformation of STEM as both a pedagogical model and a research domain ([Solihin et al., 2021](#)).

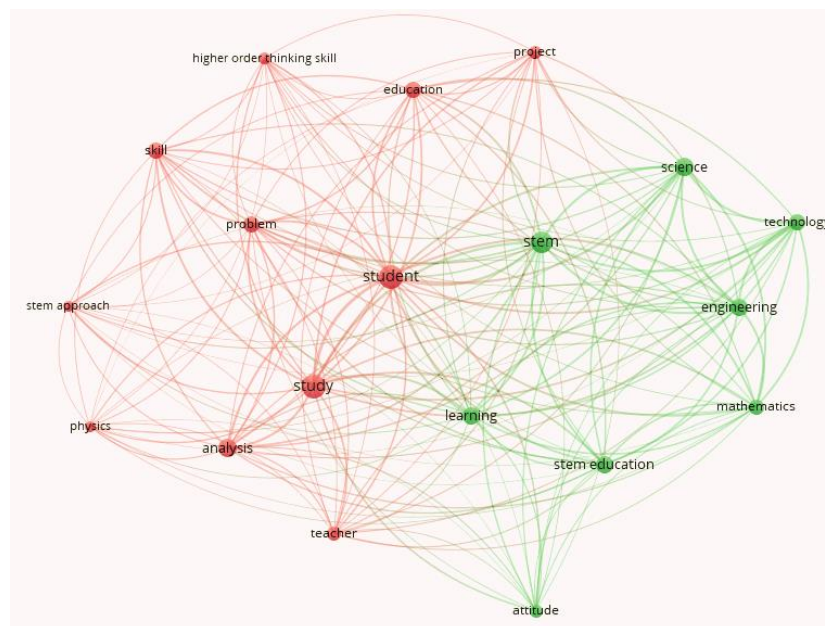


Figure 2 Mapping and Clustering

Following the discovery of STEM research mapping and clustering, a trend mapping was performed based on the publication years of the articles. The information collected from the overlay visualization can be utilized to detect and identify cutting-edge advances in STEM research over the last decade.

The analysis of the metadata input into VOSviewer produced an overlay visualization. In this visualization, each node label represents a keyword, and the node's color indicates the year in which the article containing that keyword was published. The darker the node color, the earlier the topic was discussed in the literature. As shown in Figure 3 below, topics related to *STEM education, technology, engineering, and mathematics* were predominantly discussed between 2017 and 2019. Topics including *STEM, science, education, project, and learning* were frequently addressed between 2019 and 2020. Meanwhile, topics such as *students, teachers, study, problems, and attitudes* appeared between 2020 and 2021. Topics related to *the STEM approach, analysis, skill, higher-order thinking skill, and physics* gained prominence closer to 2021. This reflects a growing research interest in connecting STEM learning with cognitive skill development, especially in physics (Wibowo et al., 2024).

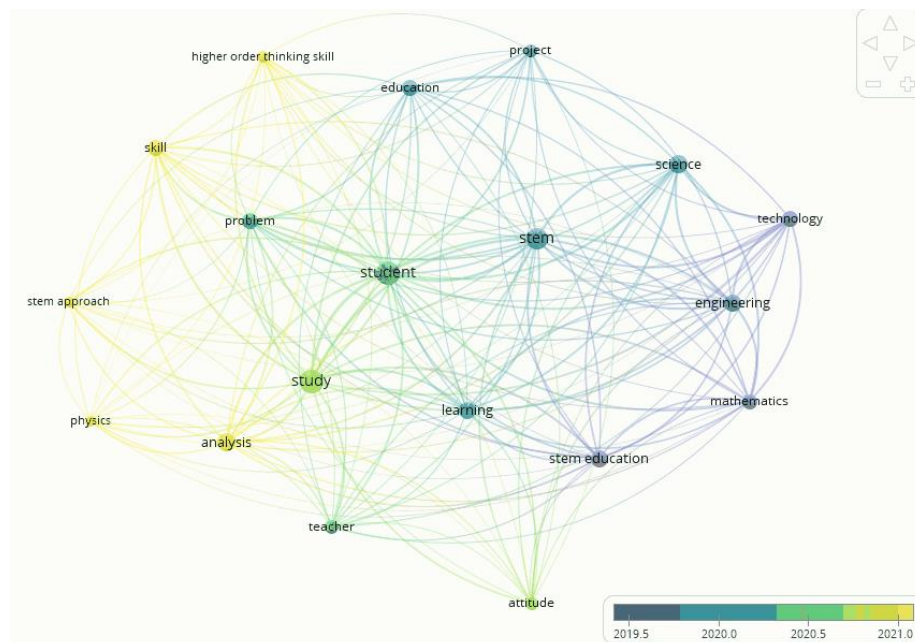


Figure 3 Overlay visualization

VOSviewer uses the red-green-blue (RGB) color scheme for each visualization it creates. The density visualization in Figure 4 shows that heavily inhabited areas have a high number of nodes that are close together. Furthermore, the level of saturation expressed by the frequency of recurrent keywords is signified by the presence of yellow hues surrounding the labels *STEM, STEM education, science, technology, engineering, mathematics, student, teacher, skill, and problem*. In other words, these areas represent topics that have been extensively researched.

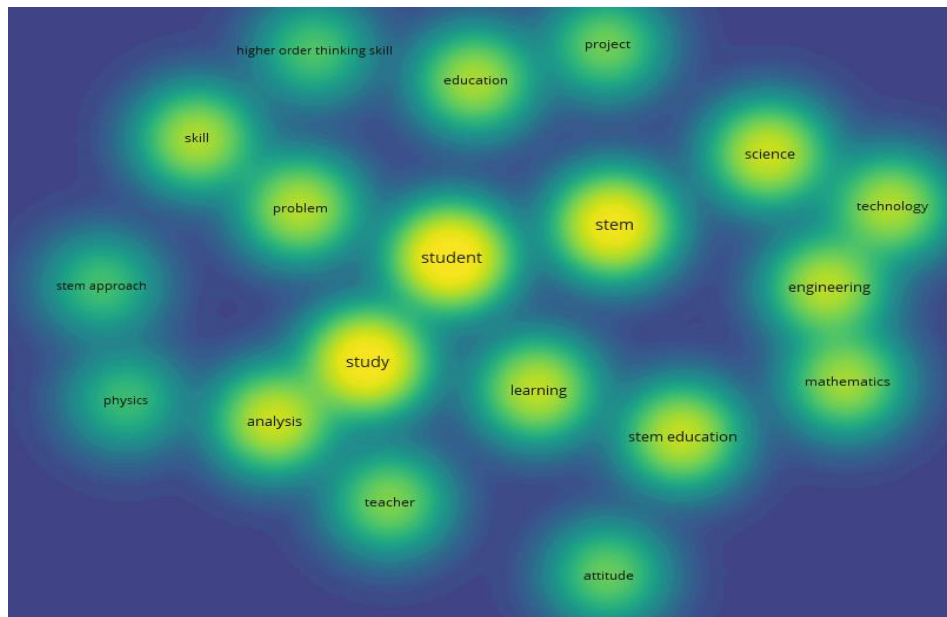


Figure 4 Density visualization

In contrast, topics surrounded by green hues, such as *STEM approach*, *higher-order thinking skills*, *attitude*, and *physics*, indicate lower research intensity. These topics have not been as widely explored, indicating the presence of a research gap in the current STEM literature. Consequently, there remains significant potential for further research on these emerging topics. These findings confirm that the integration of HOTS in STEM-based physics learning remains a relatively underdeveloped area, offering opportunities for further research ([Diansah et al., 2021](#)).

Sources of Publication and Journal Impact

The following section presents an overview of 26 journals and 3 conference proceedings, from which a total of 56 articles were selected for further analysis.

Table 1 26 Journals and 3 conference proceedings ranked by h-index

No	Journal name	Q	H-index	Subject	Article author
1	PLoS ONE	1	467	1	(Apkarian et al., 2021)
2	Frontiers in Psychology	2	212	1	(Dere, 2024)
3	Sustainability (Switzerland)	1	207	1	(Wahono & Chang, 2019)
4	Science Education	1	142	1	(Martín-Páez et al., 2019)
5	Journal of the Learning Sciences	1	115	1	(Calabrese Barton & Tan, 2019)
6	Journal of Physics: Conference Series*	No	110	10	(Admawati & Jumadi, 2021 ; Afriyanti et al., 2021 ; Bakri et al., 2023 ; Khotimah et al., 2021 ; Made Astra et al., 2023 ; Rustaman, 2021 ; Samsuar et al., 2021 ; Sutaphan & Yuenyong, 2019 ; Thahir et al., 2020 ; Wahyu et al., 2020)

No	Journal name	Q	H-index	Subject	Article author
7	AIP Conference Proceedings*	No	90	2	(Ashari et al., 2021 ; Soros et al., 2018)
8	Journal of Science Education and Technology	1	85	1	(Rizki & Suprpto, 2024)
9	Advances in Physiology Education	2	78	1	(Crawford et al., 2021)
10	Thinking Skills and Creativity	1	75	2	(Eltanahy et al., 2020 ; Kuo et al., 2019)
11	Education Sciences	1	68	2	(Dare et al., 2021 ; Smith et al., 2022)
12	Eurasia Journal of Mathematics, Science and Technology Education	2	63	2	(Lin et al., 2018 ; Shahali et al., 2017)
13	International Journal of STEM Education	1	63	8	(Chittum et al., 2017 ; Li et al., 2020 ; Margot & Kettler, 2019 ; Rosenzweig et al., 2024 ; Thomas & Larwin, 2023 ; Wahono et al., 2020 ; Wang et al., 2022 ; Wu et al., 2018)
14	International Journal of Science and Mathematics Education	1	60	1	(Fan et al., 2021)
15	International Journal of Technology and Design Education	1	60	2	(Fan & Yu, 2017 ; Lin et al., 2020)
16	IOP Conference Series: Earth and Environmental Science*	No	58	3	(Diansah et al., 2021 ; Sari et al., 2021 ; Sari et al., 2021)
17	Frontiers in Education	2	55	1	(Pont-Niclès et al., 2024)
18	Asia-Pacific Education Researcher	1	50	1	(Ting et al., 2023)
19	Computer Applications in Engineering Education	1	48	1	(Juškevičienė et al., 2021)
20	Journal of Intelligence	1	32	1	(Berkowitz & Stern, 2018)
21	Jurnal Pendidikan IPA Indonesia	3	30	2	(Martawijaya et al., 2023 ; Parno et al., 2020)
22	Journal of Baltic Science Education	2	29	2	(Li & Ma, 2024 ; Yıldırım & Sidekli, 2018)
23	International Journal of Evaluation and Research in Education	3	28	3	(Agussuryani et al., 2022 ; Perdana et al., 2021 ; Pratama et al., 2022)
24	Journal of Turkish Science Education	2	27	1	(Baran et al., 2021)

No	Journal name	Q	H-index	Subject	Article author
25	International Journal of Innovation in Science and Mathematics Education	3	19	1	(Sheffield et al., 2018)
26	Disciplinary and Interdisciplinary Science Education Research	1	19	1	(Hiwatig et al., 2024)
27	Journal for STEM Education Research	1	18	1	(Fitzgerald et al., 2024)
28	Journal of Education and e-Learning Research	3	14	1	(Zainil et al., 2023)
29	European Journal of STEM Education	1	9	1	(Thibaut et al., 2018)

*Conference proceedings

A total of ten articles (18%) were published in the *Journal of Physics: Conference Series*, followed by eight articles (14%) in the *International Journal of STEM Education*. Both the *International Journal of Evaluation and Research in Education* and *IOP Conference Series: Earth and Environmental Science* contributed three articles each (5%).

Journals with a higher H-index, such as the *International Journal of STEM Education*, are generally associated with stronger academic influence. Their inclusion indicates that the articles selected in this study are published in sources with credible impact and quality, reinforcing the validity of the bibliometric findings.

The 56 articles mentioned above are classified based on their publication years from 2017 to 2024, as shown in Table 2.

Table 2 Articles organized by publication year

Year	The Number of Publications
2017	3
2018	7
2019	6
2020	7
2021	16
2022	4
2023	6
2024	7

The highest number of articles was published in 2021, totaling 16 publications (29%). This indicates that research on STEM, HOTS, and physics learning peaked during that year. The surge is closely linked to the educational disruptions caused by the COVID-19 pandemic, which prompted a global shift to remote learning and accelerated the need for innovative teaching strategies. In this context, the integration of STEM and the focus on developing higher-order thinking skills have become increasingly relevant to ensure that learning remains meaningful, applicable, and oriented toward real-world problem-solving. The pandemic spurred the adoption of STEM-based approaches in online education, aiming to enhance students' HOTS, foster creativity, and promote greater learning independence ([Yulianti et al., 2022](#)).

Table 3 Research methodology

Research Method	The Number of Articles
Quantitative	32
Qualitative	9
Literature Review	7
Mixed Method	4
R&D	4

Table 3 presents the distribution of research methods employed in the 56 selected studies, which include quantitative, qualitative, literature review, mixed methods, and research and development (R&D) approaches ([Khotimah et al., 2021](#)). The quantitative methods encompassed quasi-experimental, descriptive quantitative, and survey designs, with quasi-experimental being the most commonly used. The qualitative studies involved case studies and narrative inquiries. The literature review category comprised narrative reviews, systematic literature reviews (SLR), and bibliometric analyses; some SLRs also integrated meta-analyses where statistical synthesis of quantitative data was possible. The mixed-methods studies adopted explanatory or exploratory sequential designs. Meanwhile, the R&D studies consisted of preliminary research, needs analysis, and product development phases, resulting in outputs such as mobile learning applications, student worksheets, e-modules, and educational games.

Table 4 Research purposes

Purposes	Number of Occurrences
Learning Models (PjBL, PBL)	13
HOTS	10
Thinking Skills (critical, creativity, problem-solving, collaborative)	7
Learning Media (digital game, m-learning, practicum tool, augmented reality, digital worksheet, e-module)	7
Scientific Attitude	5
Physics, static & dynamic fluid, water & wind energy	5
Student Engagement, Motivation	4
Scientific Literacy	3

Table 4 presents the classification of research purposes identified in the 56 selected studies. The purposes were categorized into eight thematic areas: learning models, higher-order thinking skills (HOTS), thinking skills, learning media, student engagement, scientific attitude, physics content, and scientific literacy. Additionally, a ninth category, instructors' views, was included to account for studies that focused on teacher perceptions or resources developed specifically for educators. It is important to note that most articles addressed multiple research aims rather than a single focus.

The table highlights three dominant themes across the selected studies: HOTS, scientific attitude, and learning models. The frequent appearance of HOTS-related objectives indicates that this remains a central focus in educational research, particularly in the context of physics learning ([Diansah et al., 2021](#); [Sari et al., 2021](#)). The implementation of the STEM approach in learning has been shown to effectively foster students' abilities in communication, collaboration, critical thinking, problem-solving, creativity, and innovation, thereby equipping them to face global challenges ([Kuo et al., 2019](#); [Lin et al., 2018](#); [Rizki & Suprpto, 2024](#); [Yulianti & Handayani, 2021](#)). Moreover, the STEM approach can be integrated with various learning models, such as project-based learning

and problem-based learning, to support further the development of students' 21st-century skills (Ashari et al., 2021; Baran et al., 2021; Smith et al., 2022).

These findings provide valuable insights into current trends in STEM education and underscore the potential of STEM-based instructional strategies to support the development of HOTS in physics learning.

CONCLUSION

This bibliometric analysis offers a structured and comprehensive overview of research trends in STEM education and higher-order thinking skills (HOTS) within the context of physics learning. The findings show a marked increase in publication volume since 2021, reflecting growing scholarly interest in the integration of STEM and HOTS. Thematic visualizations generated through VOSviewer reveal that recent research has increasingly focused on promoting students' critical thinking, problem-solving, creativity, and innovation through STEM-based instructional models, particularly Project-Based Learning and Problem-Based Learning, as well as the integration of digital learning media.

Although these developments are encouraging, the density visualization indicates that research specifically targeting the integration of HOTS in STEM-oriented physics instruction remains limited. In addition, the analysis highlights a shift toward recognizing the importance of affective domains, such as students' scientific attitudes, engagement, and motivation, as integral to effective STEM learning.

However, this study is subject to several limitations. It is based solely on metadata retrieved from 29 sources (journals and conferences) indexed in the Scopus database, and the analysis was conducted using only VOSviewer. As such, the results may not capture the full breadth of global research on this topic. Future bibliometric studies should consider incorporating multiple databases, such as Web of Science, ERIC, or PubMed, to broaden the scope and improve the diversity of sources. The use of additional analytical tools, such as RStudio or Bibliometrix, is also recommended to enable more interactive and advanced visualizations.

From a practical perspective, this study highlights the importance for physics educators to design learning environments that explicitly support the development of students' higher-order thinking skills, including analysis, evaluation, and creation. Furthermore, curriculum developers and teacher training programs should emphasize the integration of real-world contexts and STEM-based approaches to foster meaningful, future-oriented physics instruction.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

All writers contributed to the conceptualization, technique, formal analysis, study, and writing of this work.

REFERENCES

- Admawati, H., & Jumadi, J. (2021). The impact of STEM PjBL on students' engineering practice, scientific practice, and scientific attitude. *Journal of Physics: Conference Series*, 1882(1). <https://doi.org/10.1088/1742-6596/1882/1/012151>
- Afriyanti, M., Suyatna, A., & Viyanti. (2021). Design of e-modules to stimulate HOTS on static fluid materials with the STEM approach. *Journal of Physics: Conference Series*, 1788(1). <https://doi.org/10.1088/1742-6596/1788/1/012032>

- Agussuryani, Q., Sudarmin, S., Sumarni, W., Cahyono, E., & Ellianawati, E. (2022). STEM literacy in growing vocational school student HOTS in science learning: A meta-analysis. *International Journal of Evaluation and Research in Education*, 11(1), 51–60. <https://doi.org/10.11591/ijere.v11i1.21647>
- Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives: complete edition*. Addison Wesley Longman, Inc.
- Apkarian, N., Henderson, C., Stains, M., Raker, J., Johnson, E., & Dancy, M. (2021). What really impacts the use of active learning in undergraduate STEM education? Results from a national survey of chemistry, mathematics, and physics instructors. *PLoS ONE*, 16(2 February). <https://doi.org/10.1371/journal.pone.0247544>
- Ashari, R. M. R., Suwono, H., & Fachrunnisa, R. (2021). Students HOTS in PjBL based STEM learning in biology classroom: An experimental analysis. *AIP Conference Proceedings*, 2330. <https://doi.org/10.1063/5.0043256>
- Bakri, F. P., Budi, E., & Rahmawati, Y. (2023). The integration of mobile learning in STEM-PjBL for Physics learning: A systematic literature review. *Journal of Physics: Conference Series*, 2596(1). <https://doi.org/10.1088/1742-6596/2596/1/012065>
- Baran, M., Baran, M., Karakoyun, F., & Maskan, A. (2021). The Influence of Project-Based STEM (PjBL-STEM) Applications on the Development of 21st-Century Skills. *Journal of Turkish Science Education*, 18(4), 798–815. <https://doi.org/10.36681/tused.2021.104>
- Berkowitz, M., & Stern, E. (2018). Which cognitive abilities make the difference? Predicting academic achievements in advanced stem studies. *Journal of Intelligence*, 6(4), 1–24. <https://doi.org/10.3390/jintelligence6040048>
- Calabrese Barton, A., & Tan, E. (2019). Designing for Rightful Presence in STEM: The Role of Making Present Practices. *Journal of the Learning Sciences*, 28(4), 616–658. <https://doi.org/10.2307/48545167>
- Chittum, J. R., Jones, B. D., Akalin, S., & Schram, Á. B. (2017). The effects of an afterschool STEM program on students' motivation and engagement. *International Journal of STEM Education*, 4(1). <https://doi.org/10.1186/s40594-017-0065-4>
- Costa, M. C., Ferreira, C. A. F., & Pinho, H. J. O. (2023). Physics of Sound to Raise Awareness for Sustainable Development Goals in the Context of STEM Hands-On Activities. *Sustainability (Switzerland)*, 15(4). <https://doi.org/10.3390/su15043676>
- Crawford, A. J., Hays, C. L., Schlichte, S. L., Greer, S. E., Mallard, H. J., Singh, R. M., Clarke, M. A., & Schiller, A. M. (2021). Retrospective Analysis of a STEM Outreach Event Reveals Positive Influences on Student Attitudes Toward STEM Careers but not Scientific Methodology. *Advances in Physiology Education*, 45(3), 427–436. <https://doi.org/10.1152/ADVAN.00118.2020>
- Dare, E. A., Keratithamkul, K., Hiwatig, B. M., & Li, F. (2021). Beyond content: The role of stem disciplines, real-world problems, 21st century skills, and stem careers within science teachers' conceptions of integrated stem education. *Education Sciences*, 11(11). <https://doi.org/10.3390/educsci11110737>
- Dere, Z. (2024). Do scientific attitude and intelligence affect motivation towards STEM? Structural equation modelling. *Frontiers in Psychology*, 15. <https://doi.org/10.3389/fpsyg.2024.1481229>
- Diansah, I., Suyatna, A., & Viyanti. (2021). STEM-based physics multimedia design for stimulating HOTS on water and wind energy topic: Physics teacher perception. *IOP Conference Series: Earth and Environmental Science*, 1796(1). <https://doi.org/10.1088/1742-6596/1796/1/012002>

- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285–296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
- Eltanahy, M., Forawi, S., & Mansour, N. (2020). Incorporating entrepreneurial practices into stem education: Development of interdisciplinary e-stem model in high school in the united arab emirates. *Thinking Skills and Creativity*, 37. <https://doi.org/10.1016/j.tsc.2020.100697>
- Fan, S. C., & Yu, K. C. (2017). How an integrative STEM curriculum can benefit students in engineering design practices. *International Journal of Technology and Design Education*, 27(1), 107–129. <https://doi.org/10.1007/s10798-015-9328-x>
- Fan, S. C., Yu, K. C., & Lin, K. Y. (2021). A framework for implementing an engineering-focused stem curriculum. *International Journal of Science and Mathematics Education*, 19(8), 1523–1541. <https://doi.org/10.1007/s10763-020-10129-y>
- Fiteriani, I., Diani, R., Hamidah, A., & Anwar, C. (2021). Project-based learning through STEM approach: Is it effective to improve students' creative problem-solving ability and metacognitive skills in physics learning? *IOP Conference Series: Earth and Environmental Science*, 1796(1). <https://doi.org/10.1088/1742-6596/1796/1/012058>
- Fitzgerald, M., Salimpour, S., McKinnon, D., Freed, R., & Reichart, D. (2024). Measuring career aspirations in science, technology, engineering, mathematics and education. *Journal for STEM Education Research*. <https://doi.org/10.1007/s41979-024-00134-z>
- Guan, N. H., Bunyamin, M. A. H., & Khamis, N. (2020). Perspectives of STEM education from physics teachers' points of view: A quantitative study. *Universal Journal of Educational Research*, 8(11 C), 72–82. <https://doi.org/10.13189/ujer.2020.082309>
- Hiwatig, B. M. R., Roehrig, G. H., & Rouleau, M. D. (2024). Unpacking the nuances: an exploratory multilevel analysis on the operationalization of integrated STEM education and student attitudinal change. *Disciplinary and Interdisciplinary Science Education Research*, 6(1). <https://doi.org/10.1186/s43031-024-00108-6>
- Juškevičienė, A., Dagienė, V., & Dolgopolas, V. (2021). Integrated activities in STEM environment: Methodology and implementation practice. *Computer Applications in Engineering Education*, 29(1), 209–228.
- Khotimah, R. P., Adnan, M., Ahmad, C. N. C., & Murtiyasa, B. (2021). Science, mathematics, engineering, and mathematics (stem) education in indonesia: A literature review. *Journal of Physics: Conference Series*, 1776(1). <https://doi.org/10.1088/1742-6596/1776/1/012028>
- Kuo, H. C., Tseng, Y. C., & Yang, Y. T. C. (2019). Promoting college student's learning motivation and creativity through a STEM interdisciplinary PBL human-computer interaction system design and development course. *Thinking Skills and Creativity*, 31, 1–10. <https://doi.org/10.1016/j.tsc.2018.09.001>
- Li, R. Y., & Ma, Y. Y. (2024). Knowledge and attitudes toward biotechnology in stem education as an indicator of scientific literacy. *Journal of Baltic Science Education*, 23(1), 76–89. <https://doi.org/10.33225/jbse/24.23.76>
- Li, Y., Wang, K., Xiao, Y., & Froyd, J. E. (2020). Research and trends in STEM education: a systematic review of journal publications. *International Journal of STEM Education*, 7(1). <https://doi.org/10.1186/s40594-020-00207-6>
- Lin, K. Y., Hsiao, H. S., Chang, Y. S., Chien, Y. H., & Wu, Y. T. (2018). The effectiveness of using 3D printing technology in STEM project-based learning activities. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(12). <https://doi.org/10.29333/ejmste/97189>
- Lin, K. Y., Yu, K. C., Hsiao, H. S., Chang, Y. S., & Chien, Y. H. (2020). Effects of web-based versus classroom-based STEM learning environments on the development of

- collaborative problem-solving skills in junior high school students. *International Journal of Technology and Design Education*, 30(1), 21–34. <https://doi.org/10.1007/s10798-018-9488-6>
- Made Astra, I., Henukh, A., & Uskenat, K. (2023). The effectiveness of STEM-Based Science Teaching Materials in Improving elementary School Students' Science Literacy. *Journal of Physics: Conference Series*, 2582(1). <https://doi.org/10.1088/1742-6596/2582/1/012047>
- Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education*, 6(1). <https://doi.org/10.1186/s40594-018-0151-2>
- Martawijaya, M. A., Rahmadhanningsih, S., Swandi, A., Hasyim, M., & Sujiono, E. H. (2023). The effect of applying the ethno-stem-project-based learning model on students' higher-order thinking skill and misconception of physics topics related to lake tempe, indonesia. *Jurnal Pendidikan IPA Indonesia*, 12(1), 1–13. <https://doi.org/10.15294/jpii.v12i1.38703>
- Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science Education*, 103(4), 799–822. <https://doi.org/10.1002/sce.21522>
- Muliyati, D., Prastiawan, F., & Mutoharoh, M. (2023). Development of STEM project-based learning student worksheet for Physics learning on renewable energy topic. *Journal of Physics: Conference Series*, 2596(1). <https://doi.org/10.1088/1742-6596/2596/1/012078>
- Öztürk, O., Kocaman, R., & Kanbach, D. K. (2024). How to design bibliometric research: an overview and a framework proposal. *Review of Managerial Science*. <https://doi.org/10.1007/s11846-024-00738-0>
- Parno, Yulianti, L., Hermanto, F. M., & Ali, M. (2020). A case study on comparison of high school students' scientific literacy competencies domain in physics with different methods: PBL-stem education, PBL, and conventional learning. *Jurnal Pendidikan IPA Indonesia*, 9(2), 159–168. <https://doi.org/10.15294/jpii.v9i2.23894>
- Perdana, R., Apriani, A. N., Richardo, R., Rochaendi, E., & Kusuma, C. (2021). Elementary students' attitudes towards STEM and 21st-century skills. *International Journal of Evaluation and Research in Education*, 10(3), 1080–1088. <https://doi.org/10.11591/IJERE.V10I3.21389>
- Pont-Niclòs, I., Martín-Ezpeleta, A., & Echegoyen-Sanz, Y. (2024). Scientific creativity in secondary students and its relationship with STEM-related attitudes, engagement and work intentions. *Frontiers in Education*, 9. <https://doi.org/10.3389/feduc.2024.1382541>
- Pratama, R. A., Pratiwi, I. M., Saputra, M. A., & Sumargono. (2022). Integration of STEM education in history learning. *International Journal of Evaluation and Research in Education*, 11(1), 313–320. <https://doi.org/10.11591/ijere.v11i1.22064>
- Rahmayani, F., Kuswanto, H., & Rahmat, A. D. (2024). Development of e-book integrated augmented reality based on stem approaches to improve critical thinking and multiple representation skills in learning physics. *International Journal of Information and Education Technology*, 14(4), 632–641. <https://doi.org/10.18178/ijiet.2024.14.4.2087>
- Rizki, I. A., & Suprpto, N. (2024). Project-oriented problem-based learning through SR-STEM to foster students' critical thinking skills in renewable energy material. *Journal of Science Education and Technology*, 33(4), 526–541.
- Rosenzweig, E. Q., Chen, X. Y., Song, Y., Baldwin, A., Barger, M. M., Cotterell, M. E., Dees, J., Injaian, A. S., Weliweriya, N., Walker, J. R., Wiegert, C. C., & Lemons, P. P. (2024). Beyond STEM attrition: changing career plans within STEM fields in college

- is associated with lower motivation, certainty, and satisfaction about one's career. *International Journal of STEM Education*, 11(1). <https://doi.org/10.1186/s40594-024-00475-6>
- Rustaman, N. Y. (2021). System thinking as a sustainable competency in facilitating conceptual change through STEM based learning in biology. *Journal of Physics: Conference Series*, 1806(1). <https://doi.org/10.1088/1742-6596/1806/1/012223>
- Samsuar, S., Artika, W., Sarong, M. A., Rahmatan, H., & Pada, A. U. T. (2021). Smartphone microscope based on the STEM approach as a practicum tool to improve students' scientific attitudes on Animalia. *Journal of Physics: Conference Series*, 1882(1). <https://doi.org/10.1088/1742-6596/1882/1/012158>
- 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>
- Sari, P. M., Herlina, K., & Abdurrahman. (2021). Preliminary Research: Developing Physics Electronic Student Worksheet Based on ExPRession model with the STEM approach. *IOP Conference Series: Earth and Environmental Science*, 1796(1). <https://doi.org/10.1088/1742-6596/1796/1/012080>
- Sari, S., Suyatna, A., & Viyanti. (2021). Need assesment and design of e-modules to stimulate HOTS on dynamic fluid materials with the STEM approach. *IOP Conference Series: Earth and Environmental Science*, 1796(1). <https://doi.org/10.1088/1742-6596/1796/1/012003>
- Sari, Y. S., Selisne, M., & Ramli, R. (2019). Role of students worksheet in STEM approach to achieve competence of physics learning. *Journal of Physics: Conference Series*, 1185(1). <https://doi.org/10.1088/1742-6596/1185/1/012096>
- Selisne, M., Sari, Y. S., & Ramli, R. (2019). Role of learning module in STEM approach to achieve competence of physics learning. *Journal of Physics: Conference Series*, 1185(1). <https://doi.org/10.1088/1742-6596/1185/1/012100>
- Shahali, E. H. M., Halim, L., Rasul, M. S., Osman, K., & Zulkifeli, M. A. (2017). STEM learning through engineering design: Impact on middle secondary students' interest towards STEM. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(5), 1189–1211. <https://doi.org/10.12973/eurasia.2017.00667a>
- Sheffield, R., Koul, R. B., Blackley, S., & Fitriani, E. (2018). Transnational examination of stem education. *International Journal of Innovation in Science and Mathematics Education*. <https://www.researchgate.net/publication/329198227>
- Simeon, M. I., Samsudin, M. A., & Yakob, N. (2022). Effect of design thinking approach on students' achievement in some selected physics concepts in the context of STEM learning. *International Journal of Technology and Design Education*, 32(1), 185–212. <https://doi.org/10.1007/s10798-020-09601-1>
- Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., Mansfield, J., Ellerton, P., & Smith, T. (2022). Principles of problem-based learning (PBL) in STEM education: Using expert wisdom and research to frame educational practice. *Education Sciences*, 12(10), 728.
- Solihin, A., Wibowo, F. C., & Astra, I. M. (2021). Review of trends project based learning (PjBL) integrated STEM in physics learning. *Journal of Physics: Conference Series*, 2019(1). <https://doi.org/10.1088/1742-6596/2019/1/012031>
- Solomon, F., Champion, D., Steele, M., & Wright, T. (2022). Embodied physics: Utilizing dance resources for learning and engagement in STEM. *Journal of the Learning Sciences*, 31(1), 73–106. <https://doi.org/10.1080/10508406.2021.2023543>

- Soros, P., Ponkham, K., & Ekkapim, S. (2018). The results of STEM education methods for enhancing critical thinking and problem solving skill in physics the 10th grade level. *AIP Conference Proceedings*, 1923. <https://doi.org/10.1063/1.5019536>
- Sutaphan, S., & Yuenyong, C. (2019). STEM Education Teaching approach: Inquiry from the Context Based. *Journal of Physics: Conference Series*, 1340(1). <https://doi.org/10.1088/1742-6596/1340/1/012003>
- Thahir, A., Anwar, C., Saregar, A., Choiriah, L., Susanti, F., & Pricilia, A. (2020). The Effectiveness of STEM Learning: Scientific Attitudes and Students' Conceptual Understanding. *Journal of Physics: Conference Series*, 1467(1). <https://doi.org/10.1088/1742-6596/1467/1/012008>
- Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., Boeve-de Pauw, J., Dehaene, W., Deprez, J., De Cock, M., Hellinckx, L., Knipprath, H., Langie, G., Struyven, K., Van de Velde, D., Van Petegem, P., & Depaep, F. (2018). Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education. *European Journal of STEM Education*, 3(1). <https://doi.org/10.20897/ejsteme/85525>
- Thomas, D. R., & Larwin, K. H. (2023). A meta-analytic investigation of the impact of middle school STEM education: where are all the students of color? *International Journal of STEM Education*, 10(1). <https://doi.org/10.1186/s40594-023-00425-8>
- Ting, F. S. T., Shroff, R. H., Lam, W. H., Garcia, R. C. C., Chan, C. L., Tsang, W. K., & Ezeamuzie, N. O. (2023). A meta-analysis of studies on the effects of active learning on asian students' performance in science, technology, engineering and mathematics (stem) subjects. *Asia-Pacific Education Researcher*, 32(3), 379–400. <https://doi.org/10.1007/s40299-022-00661-6>
- Usembayeva, I., Kurbanbekov, B., Ramankulov, S., Batyrbekova, A., Kelesbayev, K., & Akhanova, A. (2024). 3D modeling and printing in physics education: the importance of stem technology for interpreting physics concepts. *Qubahan Academic Journal*, 4(3), 45–58. <https://doi.org/10.48161/qaj.v4n3a727>
- van Eck, N. J., & Waltman, L. (2014). Visualizing bibliometric networks. In *Measuring Scholarly Impact* (pp. 285–320). Springer International Publishing. https://doi.org/10.1007/978-3-319-10377-8_13
- Wahono, B., & Chang, C. Y. (2019). Assessing Teacher's attitude, knowledge, and application (aka) on stem: An effort to foster the sustainable development of stem education. *Sustainability (Switzerland)*, 11(4). <https://doi.org/10.3390/su11040950>
- Wahono, B., Lin, P. L., & Chang, C. Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. *International Journal of STEM Education*, 7(1). <https://doi.org/10.1186/s40594-020-00236-1>
- Wahyu, Y., Sadia, I. W., Suarni, N. K., & Suastra, I. W. (2020). The effect of science learning bases-STEM assisted by augmented reality toward scientific attitudes and science outcomes. *Journal of Physics: Conference Series*, 1567(4). <https://doi.org/10.1088/1742-6596/1567/4/042015>
- Wang, L. H., Chen, B., Hwang, G. J., Guan, J. Q., & Wang, Y. Q. (2022). Effects of digital game-based STEM education on students' learning achievement: a meta-analysis. *International Journal of STEM Education*, 9(1). <https://doi.org/10.1186/s40594-022-00344-0>
- Wibowo, F. C., Prahani, B. K., Kurniawan, B. R., Brata, W. W. W., Budhi, H. S., Noor, F. M., Fawaida, U., Jamaludin, D. N., Jalil, M., & Ahmad, N. J. (2024). Challenges of STEM approach in physics learning: A bibliometric analysis. *AIP Conference Proceedings*, 3116(1), 070017.

- Wu, X., Deshler, J., & Fuller, E. (2018). The effects of different versions of a gateway STEM course on student attitudes and beliefs. *International Journal of STEM Education*, 5(1). <https://doi.org/10.1186/s40594-018-0141-4>
- Yildirim, B., & Sidekli, S. (2018). STEM applications in mathematics education: the effect of STEM applications on different dependent variables. *Journal of Baltic Science Education*, 17(2), 200. <http://oaji.net/articles/2017/987-1523526639.pdf>
- Yulianti, D., & Handayani, E. (2021). Enhancement of communication skills through physics learning with science, technology, engineering, and mathematics (stem) approach. *Journal of Physics: Conference Series*, 1918(5). <https://doi.org/10.1088/1742-6596/1918/5/052083>
- Yulianti, D., Sugianto, & Ngafidin, K. M. (2022). Scratch assisted physics learning with a stem approach in the pandemic era to develop 21st century learning skills. *Jurnal Pendidikan IPA Indonesia*, 11(1), 185–194. <https://doi.org/10.15294/jpii.v11i1.32607>
- 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 student's critical thinking. *Journal of Physics: Conference Series*, 1321(2). <https://doi.org/10.1088/1742-6596/1321/2/022029>
- Yulianti, L., Yogismawati, F., Purwaningsih, E., & Affriyenni, Y. (2021). Concept acquisition and scientific literacy of physics within inquiry-based learning for STEM Education. *Journal of Physics: Conference Series*, 1835(1). <https://doi.org/10.1088/1742-6596/1835/1/012012>
- 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). <https://doi.org/10.1088/1742-6596/1157/3/032021>
- Zainil, M., Kenedi, A. K., Rahmatina, Indrawati, T., & Handrianto, C. (2023). The influence of a STEM-based digital classroom learning model and high-order thinking skills on the 21st-century skills of elementary school students in Indonesia. *Journal of Education and E-Learning Research*, 10(1), 29–35. <https://doi.org/10.20448/jeelr.v10i1.4336>

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