



# Improving Generic Science Skills through an Interactive Web-Based STEM-PjBL Hybrid Model in Materials Physics with a Deep Learning Approach (A Review)

Aris Doyan<sup>1\*</sup>, Susilawati<sup>1</sup>, Syarful Annam<sup>2</sup>, Linda Sekar Utami<sup>3</sup>, Muhammad Ikhsan<sup>4</sup>, Nuraini Rachma Ardianti<sup>4</sup>

<sup>1</sup> Physics Education Department, FKIP, University of Mataram, Lombok, Indonesia.

<sup>2</sup> Sciences Education Department, Universitas Negeri Makassar, Makassar, Indonesia.

<sup>3</sup> Physics Education Department, Universitas Muhammadiyah Mataram, Lombok, Indonesia.

<sup>4</sup> Balai Publikasi Indonesia, Mataram, Lombok, Indonesia.

Received: December 06, 2025

Revised: January 10, 2026

Accepted: February 13, 2026

Published: February 28, 2026

Corresponding Author:

Aris Doyan

[aris\\_doyan@unram.ac.id](mailto:aris_doyan@unram.ac.id)

DOI: [10.29303/jppipa.v12i2.14257](https://doi.org/10.29303/jppipa.v12i2.14257)

 Open Access

© 2026 The Authors. This article is distributed under a (CC-BY License)



**Abstract:** The development of generic science skills is a crucial objective in contemporary science education to address the demands of 21st-century competencies. This study aims to explore the potential of a Hybrid STEM-Project-Based Learning (PjBL) model supported by web-based interactive learning environments and deep learning approaches in enhancing generic science skills within physics learning materials. A Hybrid Review methodology was employed, integrating a Systematic Literature Review (SLR) and a Bibliometric Review. A total of 30 peer-reviewed articles indexed in Scopus and SINTA, published between 2020 and 2026, were systematically analyzed. Bibliometric mapping was used to identify research trends, thematic clusters, and emerging research gaps, while the SLR examined instructional designs, learning outcomes, and pedagogical effectiveness. The results indicate that STEM-PjBL consistently improves students' generic science skills, including scientific reasoning, problem-solving, data interpretation, and conceptual modeling, particularly when supported by interactive web-based platforms. These platforms facilitate visualization, collaboration, and iterative inquiry processes that are essential in learning abstract physics concepts. Furthermore, the findings highlight that deep learning approaches offer strong potential to provide adaptive scaffolding, personalized feedback, and learning analytics to support students' inquiry processes, although their implementation in STEM-PjBL contexts remains limited. This study concludes that the integration of STEM-PjBL, web-based interactivity, and deep learning constitutes a promising and scalable framework for advancing generic science skills and provides important implications for future research and instructional design in science education.

**Keywords:** Deep learning in education; Generic science skills; Physics material learning; Project-based learning (PjBL); STEM education; Web-based interactive learning

## Introduction

The transformation of science education in the 21st century requires a fundamental shift in learning paradigms, moving beyond procedural concept mastery toward the development of generic science skills as core competencies for learners. Generic science skills

encompass indirect observation, modeling, logical inference, the use of scientific symbols and representations, causal reasoning, and the ability to integrate interdisciplinary concepts in solving contextual problems (Wang & Shen, 2024). In physics learning, particularly materials physics, these skills are critically important due to the abstract,

### How to Cite:

Doyan, A., Susilawati, Annam, S., Utami, L. S., Ikhsan, M., & Ardianti, N. R. Improving Generic Science Skills through an Interactive Web-Based STEM-PjBL Hybrid Model in Materials Physics with a Deep Learning Approach (A Review). *Jurnal Penelitian Pendidikan IPA*, 12(2), 15-26. <https://doi.org/10.29303/jppipa.v12i2.14257>

multirepresentational, and application-oriented nature of the subject, which is closely linked to modern technological developments (Engelbrecht & Borba, 2024). However, numerous studies report that students' generic science skills remain at low to moderate levels across secondary and higher education contexts. Research by Bouchée et al. (2022) indicates that students commonly experience difficulties in conceptual modeling, scientific reasoning, and connecting theoretical physics concepts with real-world phenomena. This condition is exacerbated by the dominance of conventional instruction that emphasizes lectures and routine problem-solving, providing limited opportunities for students to construct deep and meaningful conceptual understanding (Sihombing & Yohandri, 2025).

In response to these challenges, the Science, Technology, Engineering, and Mathematics (STEM) approach has gained increasing attention in both national and international literature. STEM education emphasizes interdisciplinary integration to foster scientific thinking, problem-solving abilities, and evidence-based decision-making skills (Chamo & Broza, 2025). Nevertheless, the effectiveness of STEM education is significantly enhanced when it is combined with experiential learning models, particularly Project-Based Learning (PjBL). The STEM-PjBL model engages students in authentic learning experiences through project activities that require the application of science and mathematics concepts in technological and engineering design contexts. These activities involve problem identification, experimental investigation, data analysis, and solution evaluation (Thohir et al., 2020). Numerous Scopus-indexed studies have demonstrated that STEM-PjBL is effective in improving scientific literacy, creativity, critical thinking, and scientific reasoning skills (Wu et al., 2024). In physics education, STEM-PjBL has been shown to enhance conceptual understanding and generic science skills through modeling and project-based problem-solving activities (Ladachart et al., 2022). In the Indonesian context, SINTA-indexed studies reveal similar findings.

Sarjani et al. (2023) and Oise et al. (2025) reported that integrating STEM and PjBL in physics instruction significantly improves higher-order thinking skills (HOTS) and generic science skills. Furthermore, Purwaningsih et al. (2020) found that STEM-PjBL-based physics instructional materials effectively enhanced students' modeling abilities and scientific reasoning. Despite these promising outcomes, most STEM-PjBL implementations remain predominantly face-to-face and have not fully leveraged interactive web-based technologies (Syukri et al., 2023). Advances in digital technology and online learning environments offer substantial opportunities for developing interactive

web-based physics instruction. Digital learning media such as e-workbooks, interactive simulations, and online learning platforms facilitate the visualization of abstract materials physics concepts, promote self-directed learning, and support flexible and adaptive instruction (Nurwina et al., 2025). Empirical evidence reported by Rahma et al. (2025) indicates that STEM-based digital physics learning significantly improves students' generic science skills, with high normalized gain scores ( $N\text{-Gain} > 0.7$ ). These findings suggest that integrating STEM-PjBL with interactive web-based media can effectively address the inherent challenges of teaching materials physics.

Beyond instructional models and technology, the deep learning approach has emerged as a critical pedagogical perspective in contemporary education. In this context, deep learning is not merely associated with artificial intelligence technologies but refers to a learning approach that emphasizes deep conceptual understanding, interconnected knowledge structures, critical reflection, and the transfer of learning to new situations (Fergusson, 2022). This approach aligns strongly with project-based learning, as it encourages students to go beyond task completion and engage in sustained meaning-making and scientific reasoning. Recent studies indicate that integrating deep learning principles into PjBL significantly enhances students' scientific reasoning, critical thinking, and complex problem-solving abilities (Kamaluddin et al., 2023; Taufik et al., 2025) further emphasized that project-based learning oriented toward deep learning is more effective than surface learning approaches in improving the quality of science understanding. However, research that systematically integrates deep learning principles within a web-based STEM-PjBL model, particularly in the context of materials physics, remains limited in both Scopus- and SINTA-indexed literature.

Based on this analysis, a clear research gap exists regarding the need for an innovative instructional model that holistically integrates STEM-PjBL, interactive web-based learning, and a deep learning approach to enhance students' generic science skills. Materials physics, which requires multiscale reasoning, metarepresentational thinking, and strong conceptual integration, provides a highly relevant context for the development of such a model (Chaiarwut et al., 2025). Therefore, a study is needed regarding the Hybrid Web-Based STEM-PjBL Model with a Deep Learning Approach as an innovative solution for enhancing generic science skills in materials physics learning. This hybrid model is expected to contribute theoretically to the advancement of contemporary science education models and practically to support educators in designing meaningful, contextual, and future-oriented physics learning experiences aligned with 21st-century educational

demands. Therefore, this research aims to examine research trends in improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach.

## Method

### *Research design*

This study employed a hybrid review methodology, integrating a Systematic Literature Review (SLR) and a Bibliometric Review, to comprehensively analyze the development of web-based Hybrid STEM-Project-Based Learning (STEM-PjBL) models with a deep learning approach for enhancing generic science skills in materials physics education. The hybrid review design enables both qualitative synthesis of evidence and quantitative mapping of the intellectual structure of the field, which cannot be achieved through a single review method alone (Tranfield et al., 2003; Snyder, 2019; Donthu et al., 2021). The SLR component was used to identify, critically evaluate, and synthesize relevant empirical and conceptual studies, while the bibliometric component quantitatively examined publication trends, influential authors, collaboration networks, and thematic structures (Zupic & Čater, 2015; Aria & Cuccurullo, 2017). This methodological integration is increasingly recommended in educational research to enhance analytical depth and rigor.

### *Data Sources and Research Strategy*

The literature data were retrieved from two authoritative databases: Scopus and SINTA (Science and Technology Index Indonesia) via Google Scholar. The Google Scholar database was chosen as a source for document retrieval because Google Scholar applies consistent standards in selecting documents to be included in its index, and Google Scholar displays more documents than other top databases, especially research in the field of education (Hallinger & Chatpinyakoo, 2019). Scopus was selected due to its comprehensive international coverage and strict indexing standards, while SINTA was included to ensure representation of high-quality national studies relevant to the Indonesian educational context. The literature search covered publications from 2020 to 2026, aligning with recent developments in STEM education and digital learning research. Search strings were constructed using Boolean operators and controlled keywords derived from prior systematic reviews (Budgen & Brereton, 2006) including: “STEM education” OR “STEM-PjBL” OR “Project-Based Learning” AND “web-based learning” OR “digital learning” OR “interactive learning media” AND

“deep learning approach” AND “generic science skills” OR “scientific reasoning” OR “higher-order thinking skills” AND “physics education” OR “materials physics”

The search was limited to peer-reviewed journal articles and conference proceedings published in English or Indonesian. To identify research trends in recent years, app.dimensions.ai was also used to filter the data collected via Publish or Perish. The researchers used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

### *Inclusion and Exclusion Criteria*

To ensure relevance, quality, and transparency, explicit inclusion and exclusion criteria were applied following established SLR guidelines (Petticrew & Roberts, 2006; Page et al., 2021). Inclusion criteria consisted of: publications between 2020 and 2026; articles indexed in Scopus or SINTA; studies focusing on STEM education, PjBL, or integrated STEM-PjBL models; research incorporating digital or web-based learning environments; and studies addressing generic science skills, scientific reasoning, or higher-order thinking skills. Exclusion criteria included: non-peer-reviewed documents (e.g., editorials, opinion papers); studies outside science or physics education; articles lacking methodological transparency; and duplicate records across databases.

### *Systematic Literature Review Procedure*

The SLR procedure adhered strictly to the PRISMA 2020 guidelines to ensure methodological rigor and replicability. The review process involved four stages: identification, screening, eligibility, and inclusion. During the identification stage, 132 records were retrieved from Scopus (n = 78) and SINTA (n = 54). After removing 34 duplicate records, 98 articles remained for title and abstract screening. Subsequently, 63 articles were excluded based on relevance, resulting in 35 full-text articles assessed for eligibility. Finally, 30 articles met all inclusion criteria and were included in the qualitative synthesis, consistent with best practices in educational SLRs. Data extraction followed a structured protocol capturing publication year, research design, educational level, learning model characteristics, digital platform features, deep learning indicators, and reported outcomes related to generic science skills.

### *Bibliometric Review Procedure*

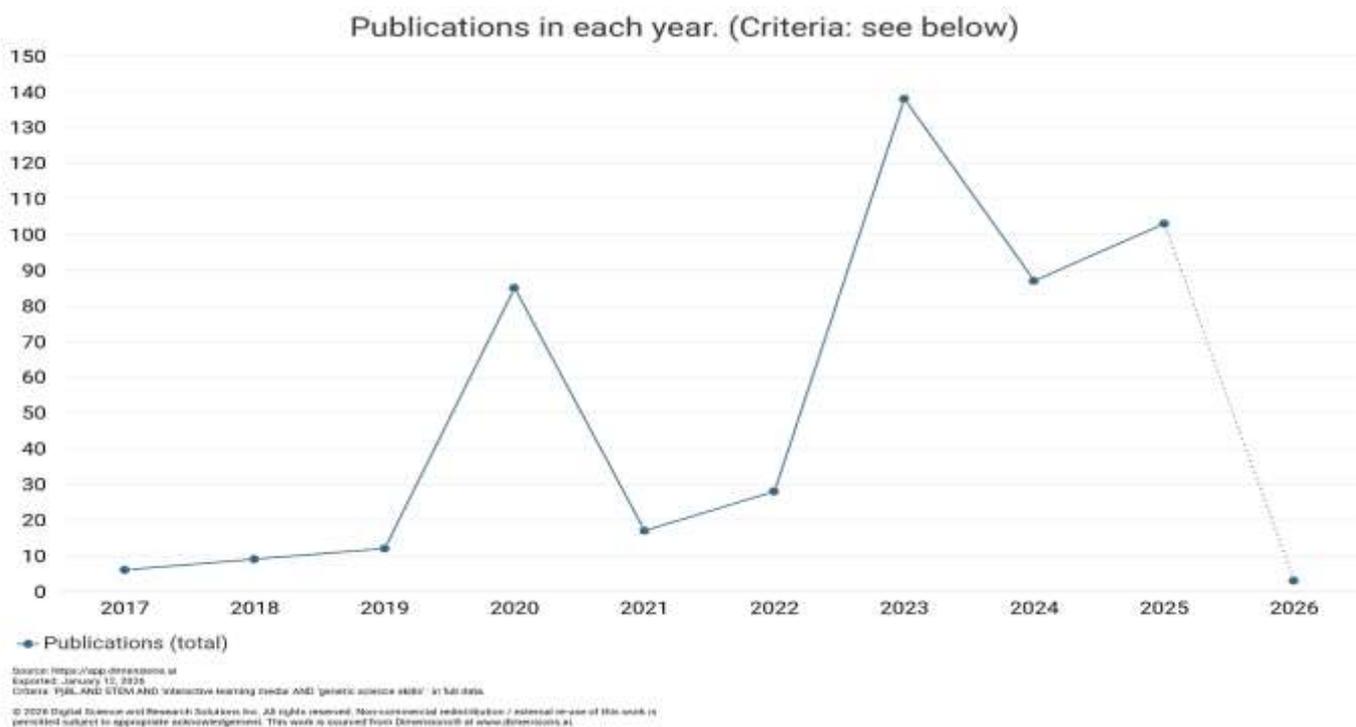
Bibliometric analysis was conducted to quantitatively explore the intellectual structure and evolution of research on STEM-PjBL, digital learning, and generic science skills. Bibliographic data (titles, abstracts, keywords, authors, affiliations, citations, and references) were exported in compatible formats from

Scopus and SINTA databases. The analysis included: annual publication trends, keyword co-occurrence analysis, author and institutional collaboration networks, and source analysis of core journals. Visualization and network mapping were performed using VOSviewer, which is widely used for bibliometric network construction and clustering (Van Eck & Waltman, 2014). This tool facilitated the identification of dominant and emerging research themes related to STEM-PjBL and deep learning in physics education.

### Results and Discussion

This research aims to describe research trends on improving generic science skills through an interactive

web-based STEM-PjBL hybrid model in materials physics with a deep learning approach. Figure 1 is presented below regarding research trends on improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach over the last ten years (obtained from app.dimensions.ai). Figure 1 shows that the trend in research on improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach has experienced fluctuations. Below, Table 1 also presents research on improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach, based on the type of publication.



**Figure 1.** Research trends in improving generic science skills through interactive web-based STEM-PjBL hybrid model of material physics with deep learning approach (app.dimensions.ai)

**Table 1.** Trends Research Based on Publication Types (app.dimensions.ai)

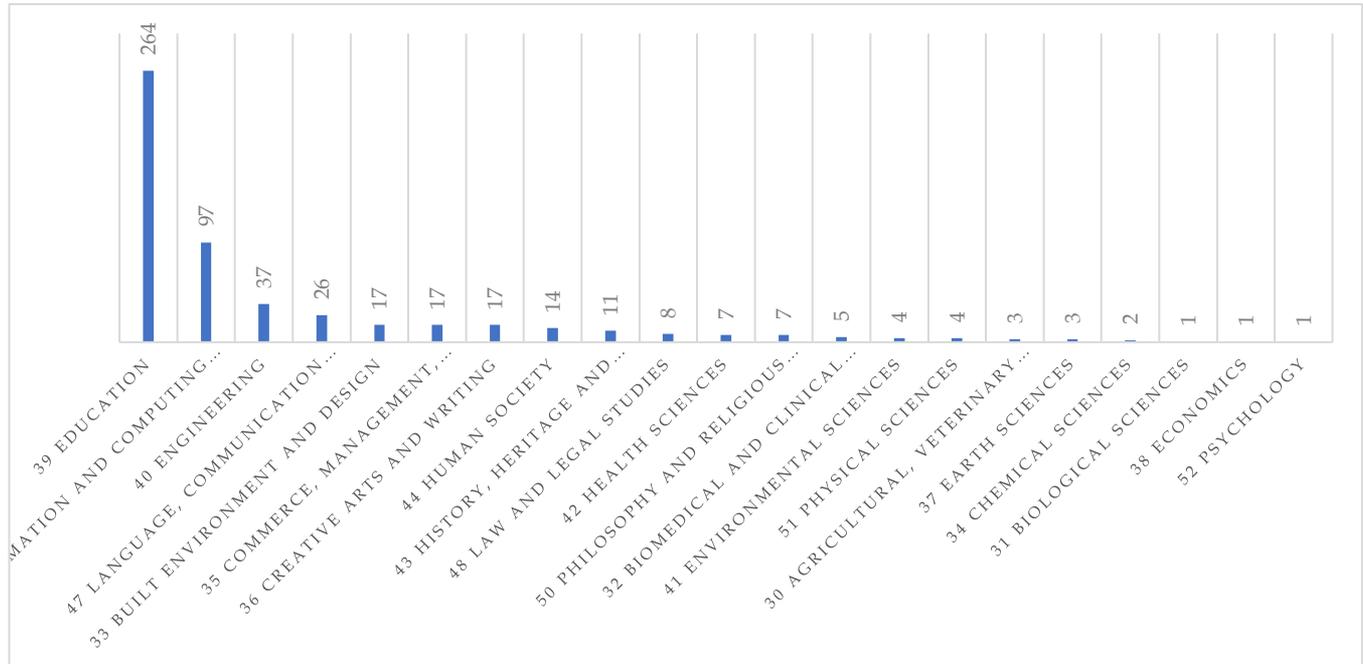
| Publication Type | Publications |
|------------------|--------------|
| Edited Book      | 208          |
| Article          | 129          |
| Chapter          | 128          |
| Monograph        | 25           |
| Preprint         | 9            |
| Proceeding       | 3            |

Based on Table 1, it is known that the research trends identified through app.dimensions.ai are categorized into six types of publications. In the form of articles, there were 129 documents; chapters, 128

documents; proceedings, 3 documents; edited books, 208 documents; 9 preprint publications; and 25 monographs. Research trends in article form represent the type of publication that contains the most research on improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach, compared to other types of publications. Meanwhile, the type of publication that contains the least number of research outputs on improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach is proceedings.

Research conducted by (2019) states that an article is a complete factual essay of a certain length created for publication in online or print media (via newspapers, magazines or bulletins) and aims to convey ideas and facts that can convince and educate. These articles are usually published in scientific journals both in print and

online (Suseno & Fauziah, 2020). Below, Figure 2 presents the research fields related to trends in improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach.



**Figure 2.** Research fields of trend improving generic science skills through interactive web-based STEM-PjBL hybrid model of material physics with deep learning approach research

Figure 2 shows that the most dominant field of research related to the trend of improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach is education, with 264 publications. The leading publisher is *Advances in Social Science, Education and Humanities Research* with 65 publications. The proceedings series *Advances in Social Science, Education and Humanities Research* aims to publish proceedings from conferences on the theories and methods in fields of social sciences, education and humanities. All proceedings in this series are open access, i. e. the articles published in them are immediately and permanently free to read, download, copy & distribute. The online publication of each proceeding is sponsored by the conference organizers and hence no additional publication fees are required.

*Results of Systematic Literature Review (SLR)*

The SLR results demonstrate that STEM-PjBL consistently outperforms conventional and single-model instructional approaches in fostering students' generic science skills, including scientific reasoning, modeling, data interpretation, and problem-solving (Yasin et al., 2021). Across experimental and quasi-

experimental studies, effect sizes ranged from moderate to high, particularly when projects were contextualized and supported by digital tools (Umoke et al., 2025). Web-based interactive platforms were found to significantly enhance student engagement, self-regulation, and inquiry depth, especially in abstract physics topics such as material properties, elasticity, and molecular structure (Pratama, 2020). Interactive simulations, visualization tools, and asynchronous discussion features supported the development of core generic science skills by enabling iterative hypothesis testing and reflective learning cycles (Errabo et al., 2024). Nevertheless, the review identified a pedagogical gap: most studies employed static or rule-based digital platforms, lacking intelligent adaptation to learners' cognitive profiles and project progression stages. Only a limited number of studies incorporated machine learning or deep learning algorithms to personalize feedback or scaffold inquiry (Roll & Wylie, 2016; Chen et al., 2020).

*Bibliometric Results: Research Trends and Knowledge Structure*

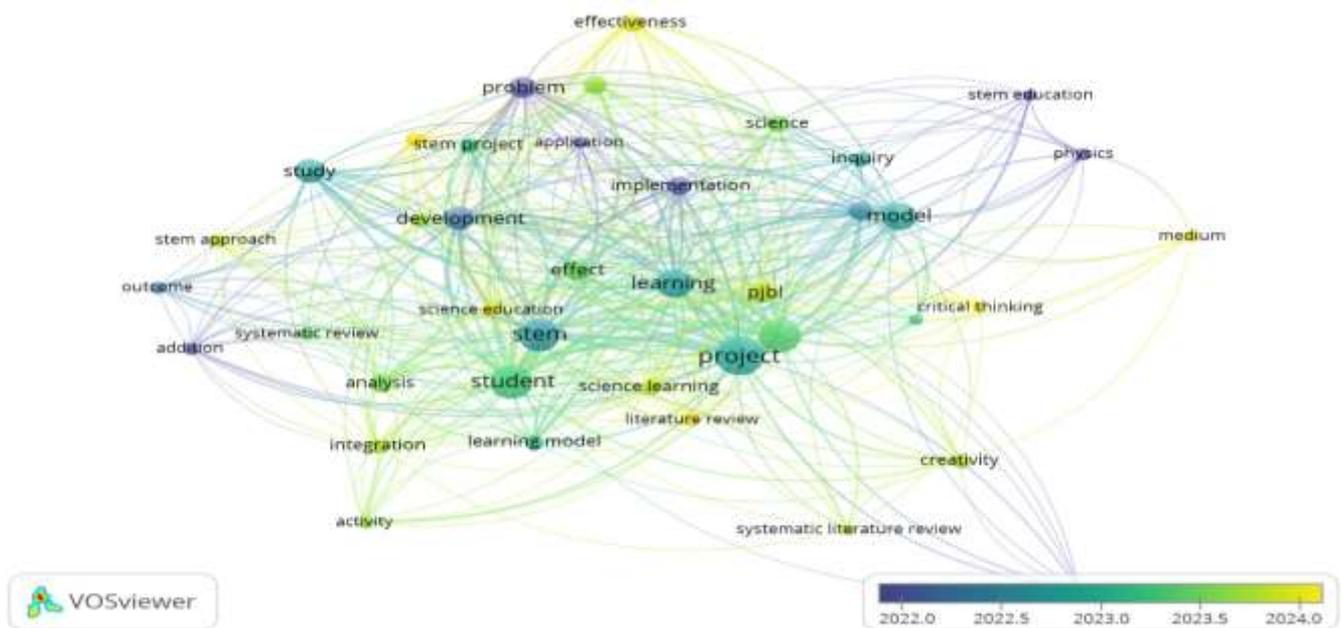
The bibliometric analysis based on Scopus and SINTA-indexed publications (n = 30) reveals a



Figure 3 above also shows that the network visualization illustrates the relationships between the visualized terms. Keywords classified into four clusters are arranged in a color chart showing the divisions and their interconnections. The results of this analysis can be used to determine keyword research trends in recent years. This analysis shows several keywords that are frequently used in research on improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach. The more keywords that appear, the broader the visualization displayed. Below, keywords related to improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach are also presented based on overlay visualization. Figure 4 shows the trend of keywords related to research on improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach in Google Scholar-indexed journals. Trends in article themes related to improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach, from the oldest to the most recent year, are marked in purple, blue, turquoise, dark green, light green, and yellow.

*Theoretical Integration: STEM-PjBL, Web Interactivity, and Deep Learning*

From a theoretical standpoint, the findings support the alignment of constructivist learning theory, situated cognition, and self-determination theory as foundational frameworks for Hybrid STEM-PjBL models (Hmelo-Silver, 2004; Paradelle, 2019; Doyan et al., 2024). PjBL situates learning within authentic problem contexts, while STEM integration ensures interdisciplinary coherence and real-world relevance. Web-based interactivity extends these foundations by enabling distributed cognition and collaborative knowledge construction, allowing learners to externalize reasoning through digital artifacts and simulations (Kimmerle et al., 2015). The addition of deep learning mechanisms represents a conceptual advancement, as it enables adaptive scaffolding, pattern recognition in learner behavior, and real-time analytics of inquiry performance (Tasiouli et al., 2025). Deep learning models—such as neural networks for learning analytics—can dynamically adjust project complexity, recommend resources, and provide formative feedback aligned with students’ evolving generic science skills (Gligorea et al., 2023). This theoretical synthesis positions the Hybrid STEM-PjBL model not merely as a pedagogical integration, but as an intelligent learning ecosystem.



**Figure 4.** Overlay visualization on trend improving generic science skills through interactive web-based STEM-PjBL hybrid model of material physics with deep learning approach research

Research on improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach is one area of research that has developed rapidly in recent years. The following section also

presents keywords related to research on improving generic science skills through an interactive web-based STEM-PjBL hybrid model in materials physics with a deep learning approach, based on density visualization. Figure 5 shows the density visualization. The density of



## Conclusion

This study demonstrates that the integration of STEM education, Project-Based Learning (PjBL), and web-based interactive learning environments is highly effective in enhancing students' generic science skills, particularly scientific reasoning, problem-solving, and data interpretation. Through a Hybrid Review approach combining Systematic Literature Review and Bibliometric Review, this research confirms that STEM-PjBL provides a strong pedagogical foundation for inquiry-driven and competency-oriented science learning. The findings further indicate that web-based interactivity plays a crucial role in supporting conceptual understanding in materials physics learning by enabling visualization, collaboration, and iterative inquiry processes. Moreover, the incorporation of deep learning approaches represents a significant advancement by offering adaptive scaffolding and personalized feedback aligned with learners' cognitive development. Despite its strong potential, the application of deep learning in STEM-PjBL contexts remains limited, highlighting a clear research gap. In conclusion, the synergy of STEM-PjBL, interactive web technologies, and deep learning offers a promising and scalable framework for advancing generic science skills in science education. Future studies should focus on empirical validation and longitudinal implementation to strengthen the evidence base and expand the applicability of this hybrid model across educational contexts.

### Acknowledgments

Acknowledgments are expressed by the researchers to the team so that researchers can complete research in the form of journal publications.

### Author Contributions

Conceptualization, A. D.; methodology, S.; formal analysis, S. A.; investigation, L. S. U.; resources, M. I.; writing—preparation of original draft, N. R. A.; writing—reviewing and editing, A. D.; visualization, S.; supervision, S. A.; project administration, L. S. U.; obtaining funding, M. I. All authors have read and approved the published version of the manuscript

### Funding

No external funding.

### Conflicts of Interest

No conflict interest.

## References

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959–975.

- <https://doi.org/10.1016/j.joi.2017.08.007>
- Bouchée, T., De Putter - Smits, L., Thurlings, M., & Pepin, B. (2022). Towards a better understanding of conceptual difficulties in introductory quantum physics courses. *Studies in Science Education*, 58(2), 183–202.  
<https://doi.org/10.1080/03057267.2021.1963579>
- Budgen, D., & Brereton, P. (2006). Performing systematic literature reviews in software engineering. *Proceedings of the 28th International Conference on Software Engineering*, 1051–1052.  
<https://doi.org/10.1145/1134285.1134500>
- Budiarti, R. S., Harlis, & Siburian, J. (2023). Development Of STEM-Based PjBL E-Student Worksheet to Foster Character Building. *Jurnal Penelitian Pendidikan IPA*, 9(11), 9818–9828.  
<https://doi.org/10.29303/jppipa.v9i11.6169>
- Chaiarwut, S., Srikoon, S., Siritaratiwat, A., & Kwangmuang, P. (2025). Enhancing executive mathematics problem-solving through a constructivist digital learning platform: Design, development and evaluation. *Social Sciences & Humanities Open*, 11, 101338.  
<https://doi.org/10.1016/j.ssaho.2025.101338>
- Chamo, N., & Broza, O. (2025). Bridging Disciplines: Exploring Interdisciplinary Curriculum Development in STEM Teacher Education. *Education Sciences*, 15(8), 1064.  
<https://doi.org/10.3390/educsci15081064>
- Chen, L., Chen, P., & Lin, Z. (2020). Artificial Intelligence in Education: A Review. *IEEE Access*, 8, 75264–75278.  
<https://doi.org/10.1109/ACCESS.2020.2988510>
- 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>
- Doyan, A., Rahayu, S., Lugi, F., & Annam, S. (2024). Trends Research Problem Based Learning (PBL) Model to Improve Generic Science Skills in Students' Science Learning (2015-2024): A Systematic Review. *Jurnal Penelitian Pendidikan IPA*, 10(9), 621–630.  
<https://doi.org/10.29303/jppipa.v10i9.8370>
- Doyan, A., Susilawati, S., Harjono, A., Annam, S., Ikhsan, M., Ardianti, N. R., & Hakim, S. (2025). Development of Modern Physics Learning Media Based on Interactive Web Using the PjBL Model to Improve Critical Thinking Skills: A Systematic Review. *Jurnal Penelitian Pendidikan IPA*, 11(2), 60–70. <https://doi.org/10.29303/jppipa.v11i2.10388>
- Engelbrecht, J., & Borba, M. C. (2024). Recent developments in using digital technology in mathematics education. *ZDM - Mathematics*

- Education*, 56(2), 281-292. <https://doi.org/10.1007/s11858-023-01530-2>
- Errabo, D. D., Paguio, A. J., & Enriquez, P. A. (2024). Epistemic fluency in virtual laboratories as flipped classroom's innovative learning delivery. *Journal of Research in Innovative Teaching & Learning*, 17(2), 256-281. <https://doi.org/10.1108/JRIT-03-2024-0052>
- Fergusson, L. (2022). Learning by Knowledge and skills acquisition through work-based learning and research. *Journal of Work-Applied Management*, 14(2), 184-199. <https://doi.org/10.1108/JWAM-12-2021-0065>
- Gligorea, I., Cioca, M., Oancea, R., Gorski, A.-T., Gorski, H., & Tudorache, P. (2023). Adaptive Learning Using Artificial Intelligence in e-Learning: A Literature Review. *Education Sciences*, 13(12), 1216. <https://doi.org/10.3390/educsci13121216>
- Hallinger, P., & Chatpinyakoo, C. (2019). A Bibliometric Review of Research on Higher Education for Sustainable Development, 1998-2018. *Sustainability*, 11(8), 2401. <https://doi.org/10.3390/su11082401>
- Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, 16(3), 235-266. <https://doi.org/10.1023/B:EDPR.0000034022.16470.f3>
- Kamaluddin, K., Sani, N. K., Darmadi, I. W., & Nurgan, N. (2023). Analysis of Students Scientific Reasoning Ability and the Correlation to Students Cognitive Ability in Physics Learning. *Jurnal Penelitian Pendidikan IPA*, 9(11), 10173-10179. <https://doi.org/10.29303/jppipa.v9i11.5657>
- Kaur, S., Kumar, R., Kaur, R., Singh, S., Rani, S., & Kaur, A. (2022). Piezoelectric materials in sensors: Bibliometric and visualization analysis. *Materials Today: Proceedings*, 65, 3780-3786. <https://doi.org/10.1016/j.matpr.2022.06.484>
- Kimmerle, J., Moskaliuk, J., Oeberst, A., & Cress, U. (2015). Learning and Collective Knowledge Construction With Social Media: A Process-Oriented Perspective. *Educational Psychologist*, 50(2), 120-137. <https://doi.org/10.1080/00461520.2015.1036273>
- Ladachart, L., Phothong, W., Phornprasert, W., Suaklay, N., & Ladachart, L. (2022). Influence of an inquiry-based professional development on science teachers' orientations to teaching science. *Journal of Turkish Science Education*, 19(3), 979-996. <https://doi.org/10.36681/tused.2022.159>
- Liao, H., Tang, M., Luo, L., Li, C., Chiclana, F., & Zeng, X.-J. (2018). A Bibliometric Analysis and Visualization of Medical Big Data Research. *Sustainability*, 10(2), 166. <https://doi.org/10.3390/su10010166>
- Nurwina, A., Yani, A., & Arsyad, M. (2025). Development of Physics Teaching Materials Based on Google Sites to Improve Students' Collaboration Skills. *Jurnal Penelitian Pendidikan IPA*, 11(7), 359-370. <https://doi.org/10.29303/jppipa.v11i7.11871>
- Oise, G., Ejenarhome Otega Prosper, Oyedotun Samuel Abiodun, & Onwuzo Chioma Julia. (2025). Evaluating the Impact of Blended Learning Models on Higher Education Outcomes: A Multidimensional Analysis. *Journal Of Digital Learning And Distance Education*, 4(2), 1507-1519. <https://doi.org/10.56778/jdlde.v4i2.535>
- Oltarzhevskiy, D. O. (2019). Typology of contemporary corporate communication channels. *Corporate Communications: An International Journal*, 24(4), 608-622. <https://doi.org/10.1108/CCIJ-04-2019-0046>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, n71. <https://doi.org/10.1136/bmj.n71>
- Paradelle, M. (2019). Réflexions sur la rencontre de la recherche scientifique et de la fiction dans le contexte de la violence génocidaire. Autour du roman « Un Silence de pierre et de cendre » de Muriel Paradelle. *Revue Générale de Droit*, 49(1), 291-343. <https://doi.org/10.7202/1062173ar>
- Petticrew, M., & Roberts, H. (2006). *Systematic Reviews in the Social Sciences: A Practical Guide* (1st ed.). Wiley. <https://doi.org/10.1002/9780470754887>
- Pratama, N. D. S. (2020). The Effectiveness of Web-Based Assessment on Student's Understanding of Concepts on Equilibrium and Rotation Dynamics. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 6(2), 247-254. <https://doi.org/10.21009/1.06211>
- Purwaningsih, E., Sari, A. M., Yuliati, L., Masjukur, K., Kurniawan, B. R., & Zahiri, M. A. (2020). Improving the problem-solving skills through the development of teaching materials with STEM-PjBL (science, technology, engineering, and mathematics-project based learning) model integrated with TPACK (technological pedagogical content knowledge). *Journal of Physics: Conference Series*, 1481(1), 012133. <https://doi.org/10.1088/1742-6596/1481/1/012133>

- Rahma, M., Helmi, & Arafah, K. (2025). Development of STEM-Based Physics Learning Modules and Their Impact on Students' Scientific Literacy Skills. *Jurnal Penelitian Pendidikan IPA*, 11(11), 560-572. <https://doi.org/10.29303/jppipa.v11i11.13014>
- Rehman, N., Huang, X., Mahmood, A., AlGerafi, M. A. M., & Javed, S. (2024). Project-based learning as a catalyst for 21st-Century skills and student engagement in the math classroom. *Heliyon*, 10(23), e39988. <https://doi.org/10.1016/j.heliyon.2024.e39988>
- Roll, I., & Wylie, R. (2016). Evolution and Revolution in Artificial Intelligence in Education. *International Journal of Artificial Intelligence in Education*, 26(2), 582-599. <https://doi.org/10.1007/s40593-016-0110-3>
- Sarjani, L. P. W., Suastra, I. W., & Subagia, I. W. (2023). The Influence of Project-Based Learning Models on Collaboration Skills and Science Learning Outcome for Junior High School. *Jurnal Penelitian Pendidikan IPA*, 9(SpecialIssue), 1284-1292. <https://doi.org/10.29303/jppipa.v9iSpecialIssue.7243>
- Sihombing, F. S. A. & Yohandri. (2025). Towards Meaningful Physics Learning: Needs Analysis of an Inquiry-Based E-Module in Secondary Schools for Developing 21st-Century Students' Critical and Creative Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, 11(9), 338-350. <https://doi.org/10.29303/jppipa.v11i9.12371>
- Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333-339. <https://doi.org/10.1016/j.jbusres.2019.07.039>
- Sukmawati, F., Qodr, T. S., & Rutambuka, T. (2025). Integrating Digital Games into Project-Based Learning to Enhance Student Achievement in STEM Education. *IJORER: International Journal of Recent Educational Research*, 6(2), 294-315. <https://doi.org/10.46245/ijorer.v6i2.744>
- Suparmi, S., Sukmawati, F., Cahyono, B. T., Santoso, E. B., Prihatin, R., & Juwita, R. (2024). - Implementation of Project Based Learning Model in Vocational High School: A systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, 10(12), 890-901. <https://doi.org/10.29303/jppipa.v10i12.8847>
- Suseno, B. A., & Fauziah, E. (2020). Improving Penginyongan Literacy in Digital Era Through E-Paper Magazine of Ancas Banyumasan. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3807680>
- Syukri, M., Herliana, F., Maryono, M., Ngadimin, N., & Artika, W. (2023). Development of Physics Worksheet based on STEM integrating Engineering Design Process (EDP) through Guided Inquiry Model to Improve Students' Critical Thinking. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 9(2), 225-236. <https://doi.org/10.21009/1.09205>
- Tasiouli, G., Konstantakis, M., & Heliades, G. (2025). Exploring the Usability and Interaction Experience of the Artsteps Virtual Exhibition Platform by Preschool Children. *Electronics*, 14(13), 2690. <https://doi.org/10.3390/electronics14132690>
- Taufik, Nurtamam, M. E., Dewanto, & Santosa, T. A. (2025). The Effectiveness of Deep Learning based PjBL on Student's Scientific and Critical Thinking Skills at Indonesia. *Jurnal Penelitian Pendidikan IPA*, 11(9), 228-236. <https://doi.org/10.29303/jppipa.v11i9.12857>
- Thohir, M. A., Jumadi, J., & Warsono, W. (2020). The Effect of Transformative Blog Pages to Solve Real-World Physics Problems. *Journal of Turkish Science Education*, 3. <https://doi.org/10.36681/tused.2020.35>
- Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *British Journal of Management*, 14(3), 207-222. <https://doi.org/10.1111/1467-8551.00375>
- Umoke, C. C., Ayanwale, M. A., Nwangbo, S. O., Ezeoke, N. C., Abonyi, S. O., & Olatunbosun, S. O. (2025). Modeling instructional strategies and their transformative role in enhancing engagement and equity in computer studies: A quasi-experimental study. *Discover Education*, 4(1), 215. <https://doi.org/10.1007/s44217-025-00648-7>
- Van Eck, N. J., & Waltman, L. (2014). Visualizing Bibliometric Networks. In Y. Ding, R. Rousseau, & D. Wolfram (Eds.), *Measuring Scholarly Impact* (pp. 285-320). Springer International Publishing. [https://doi.org/10.1007/978-3-319-10377-8\\_13](https://doi.org/10.1007/978-3-319-10377-8_13)
- Wang, L., & Shen, Y. (2024). Evaluating Causal Reasoning Capabilities of Large Language Models: A Systematic Analysis Across Three Scenarios. *Electronics*, 13(23), 4584. <https://doi.org/10.3390/electronics13234584>
- Wu, T.-T., Asmara, A., Huang, Y.-M., & Permata Hapsari, I. (2024). Identification of Problem-Solving Techniques in Computational Thinking Studies: Systematic Literature Review. *Sage Open*, 14(2), 21582440241249897. <https://doi.org/10.1177/21582440241249897>
- Yanti, N., Rahmad, M., & Azhar. (2023). Application of PjBL (Project Based Learning) Based Physics Learning Model to Improve Collaboration Skills and Creative Thinking Ability of Students. *Jurnal Penelitian Pendidikan IPA*, 9(11), 9973-9978. <https://doi.org/10.29303/jppipa.v9i11.5275>

- Yasin, A. I., Rochintaniawati, D., & Prima, E. C. (2021). The development of web based inquiry as online science inquiry environment. *Journal of Physics: Conference Series*, 1806(1), 012141. <https://doi.org/10.1088/1742-6596/1806/1/012141>
- Zupic, I., & Čater, T. (2015). Bibliometric Methods in Management and Organization. *Organizational Research Methods*, 18(3), 429–472. <https://doi.org/10.1177/1094428114562629>