



Journal of Educational Sciences

Journal homepage: <https://jes.ejournal.unri.ac.id/index.php/JES>



P-ISSN
2581-1657
E-ISSN
2581-2203

Trends in the Development of Innovative Science Teaching Materials for Earth Science Education: A Semantic Literature Review (2020–2025)

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ARTICLE INFO

Article history:

Received: 28 Nov 2025

Revised: 19 Des 2025

Accepted: 24 Des 2025

Published online: 05 Jan 2026

Keywords:

Flipbook Interaktif,
Innovative,
Science Education Earth.
Second keyword

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Article Doi:

<https://doi.org/10.31258/jes.10.1.p.1405-1418>

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ABSTRACT

The development of science and technology in the 21st century has brought about major changes in the world of education, especially in science learning. Science education has a strategic role in shaping a generation that is able to think critically, creatively, and environmentally. This study aims to explore and analyze trends in the development of innovative science teaching materials in the field of Earth Science Education during the period 2020–2025 using a semantic literature review approach. Semantic analysis was conducted on a number of journal articles indexed in Scopus, ERIC, and Google Scholar. The results of the study show a significant shift in the design and implementation of teaching materials towards technology-based and learner-centered learning approaches. The methods used in this review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, with the literature search process conducted through several academic databases such as Scopus and Google Scholar. Of the total 179 articles found, 39 studies met the inclusion criteria and were analyzed further. Innovations such as interactive e-modules, digital flipbooks, augmented reality (AR), virtual laboratories, and gamified learning environments have been dominant trends in the last five years.

1. Introduction

The development of science and technology in the 21st century has brought about major changes in the world of education, particularly in science learning. Science education plays a strategic role in shaping a generation that is capable of critical thinking, creativity, and environmental awareness. In this context, Earth Science Education has become an important branch that emphasizes understanding natural

phenomena, earth dynamics, and environmental sustainability issues. However, various studies show that Earth Science learning in schools still faces challenges, including the use of conventional teaching materials that are not interactive and do not make optimal use of technology, thereby failing to increase student participation (Bybee, 2013; Mayer, 2020; Jonassen, 2011; UNESCO, 2022).

Teaching materials play an important role in the learning process as a link between scientific concepts and student learning experiences. According to several experts, good teaching materials should be able to foster motivation, increase engagement, and facilitate students' conceptual understanding of complex scientific phenomena. Bybee (2013) emphasizing that science education should be directed towards developing scientific literacy that enables students to understand and apply science in their daily lives. Mayer (2020) adding that interactive multimedia-based teaching materials can improve cognitive representation and optimize the learning process. The next, Jonassen (2011) emphasizes that technology-based learning media can create a constructivist learning environment where students actively build their own knowledge through exploration and experience. In line with this, UNESCO (2022) also highlights the importance of integrating technology in education to support Education for Sustainable Development (ESD) and improve students' digital literacy. Thus, innovation in the development of science teaching materials is a must in responding to the challenges of 21st-century education.

Innovation in the development of science teaching materials is an urgent need to adapt to the characteristics of 21st-century students who are familiar with digital technology. The use of innovative teaching materials such as interactive e-modules, digital flipbooks, virtual laboratories, augmented reality (AR), and gamified learning has been proven to increase student engagement and conceptual understanding of scientific phenomena. Innovative teaching materials not only serve as a medium for conveying information, but also as a means of building meaningful learning experiences. According to Mayer (2020), interactive multimedia can strengthen students' cognitive representations of complex concepts, while Jonassen (2011) asserts that digital media enables constructivist-based learning in which students construct knowledge through exploration and reflection. This opinion is in line with Bybee's (2013) view that modern science education must develop scientific literacy so that students are able to think systemically and actively participate in global environmental issues. In addition, UNESCO (2022) emphasizes the importance of integrating Education for Sustainable Development (ESD) and digital literacy in science education to foster sustainable ecological sustainability.

On the other hand, previous studies show dynamic developments in the development of science teaching materials over the past five years, especially on Earth Science topics. Ariani and Haryanto (2021) state that the use of digital-based teaching materials can increase learning motivation and facilitate the visualization of abstract concepts that are difficult to explain conventionally. However, with the emergence of numerous innovations and publications, a study approach is needed that can systematically map the direction of development and research trends. In this case, semantic literature review is a relevant method because it can analyze the

semantic relationships between topics and concepts in scientific literature. According to Chen (2017), semantic analysis not only traces keywords or term frequencies, but also reveals conceptual meanings and patterns of relationships between concepts in a field's knowledge map. These findings are in line with the results of international studies conducted by Ertmer and Ottenbreit-Leftwich (2019), Wu et al. (2020), Mayer (2020), and Chen (2017), which show that digital teaching material innovation has a positive effect on student learning engagement, conceptual understanding, and scientific reasoning in science learning. Thus, it can be concluded that research trends during 2020–2025 indicate a paradigm shift in science education towards a more interactive, technology-based, and environmentally literate approach (Ertmer & Ottenbreit-Leftwich, 2019; Mayer, 2020; Rahmawati et al., 2023; Ariani & Haryanto, 2021; Putra & Kurniawati, 2021; Chen, 2017; Wu et al., 2020).

Based on this background, this study focuses on examining trends in the development of innovative science teaching materials in Earth Science Education during the period 2020–2025 using a semantic literature review approach. The objectives of this study are to (1) identify the direction and focus of current research on the development of innovative science teaching materials in Earth Science Education; (2) discover dominant thematic patterns and innovations in scientific literature; and (3) provide recommendations for future research directions relevant to the needs of 21st-century education. The benefits of this research are expected to contribute theoretically to enriching the literature on science learning innovation, while also providing a practical foundation for teachers, researchers, and curriculum developers in creating adaptive, contextual, and sustainable teaching materials.

2. Methodology

Research Design

This study uses the semantic literature review method, which is a systematic literature review (SLR) approach combined with semantic analysis or text-based meaning analysis (text mining). This approach aims to identify trends in the development of innovative science teaching materials in the field of Earth Science Education, analyze semantic relationship patterns between concepts that appear in the literature for the period 2020–2025, and map the direction of research development and research gaps for further research.

Data Sources and Time Range and Literature Search Strategy

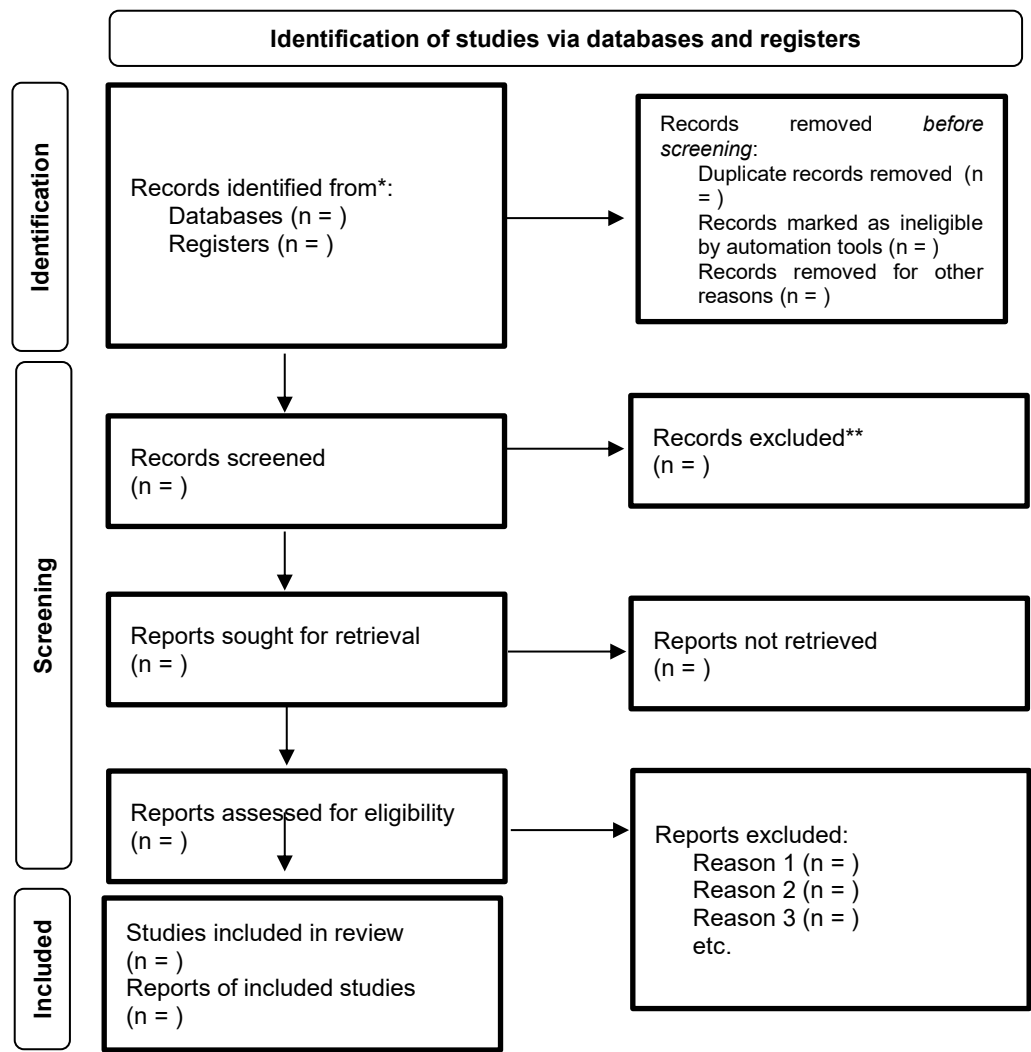
This study uses secondary data from scientific articles published between January 2020 and October 2025. The data sources were obtained from several reputable scientific databases, namely Scopus, Web of Science (WoS), ERIC (Education Resources Information Center), ScienceDirect (Elsevier), SpringerLink, and Google Scholar (as a supplement for open access literature). The search was conducted using a combination of keywords with Boolean operators:

("earth science" OR "geoscience" OR "earth system" OR "geology") AND("teaching material*" OR "learning material*" OR "instructional media" OR "educational resource*") AND("innovation" OR "interactive" OR "digital" OR "flipbook" OR "augmented reality" OR "virtual reality" OR "gamification" OR "STEM") AND ("science education" OR "earth science education").

Data Collection Procedure

The data collection steps used by researchers employ the systematic review research stages, namely Preferred Reporting Items for Systematic reviews and Meta-Analyses and network meta-analysis, which include four stages, namely Identification, Screening, Eligibility, and are abbreviated as PRISMA. The data collection process is carried out in accordance with Table 1:

Table 1. PRIMA Model Stages



Inclusion and Exclusion Criteria

Inclusion criteria are articles that discuss the development, innovation, or evaluation of science teaching materials in the context of geoscience education or Earth Science Education, articles that feature innovative approaches such as flipbooks, augmented reality (AR), virtual reality (VR), digital simulation, or STEM-based learning materials, articles published between 2020 and 2025. Exclusion Criteria include articles that only discuss geological content without a focus on education, non-scientific publications such as opinions or editorials, and articles without an abstract or full text that can be accessed.

Data Extraction Techniques

Data extracted from each article included author name, year, and country of origin; research objectives; type of teaching material or media developed; development model or approach (e.g., R&D, ADDIE, or Design Thinking); research methods and samples. Key results and findings, Keywords (for semantic analysis), Implications for science learning. All data is entered into a spreadsheet to facilitate descriptive and semantic analysis.

Data Analysis

The analysis was conducted in two major stages: bibliometric analysis and semantic analysis. Bibliometric Analysis: Analyzing the distribution of articles based on year, country, journal, and author, identifying publication trends and author collaboration patterns using software such as VOSviewer or Bibliometrix (R). Semantic Analysis: Semantic analysis was conducted to explore the meaning and relationships between concepts from a collection of keywords and article abstracts. The steps are: Text pre-processing (tokenizing, stopword removal, stemming/lemmatization), Analysis of keyword frequency and important terms, Co-word analysis to map the interrelationships between concepts, Topic Modeling (LDA – Latent Dirichlet Allocation) to find the main topic clusters, Interpretation of results by giving labels and meanings to each cluster, Analysis results are displayed in the form of: Thematic maps (semantic maps), Topic trend graphs per year, Matrix of relationships between themes

Data Validation and Validity and data Synthesis Procedure

To ensure the validity of the analysis results, source triangulation was conducted: comparing results from several databases; peer validation: preliminary results were consulted with science education experts; manual cross-checking: several key articles were analyzed manually to verify the semantic analysis results. The analysis results were synthesized through three approaches: Descriptive synthesis: describing publication trends, themes, and topic distribution; Semantic synthesis: interpreting patterns of meaning relationships between topics; Thematic synthesis: formulating major themes, challenges, and future directions for science teaching materials.

Research Output

This research produced a thematic map of the development of teaching materials in Earth Science Education (2020–2025), a semantic trend analysis of developing concepts and terms, and recommendations for future research directions based on the research gaps identified.

3. Results and Discussion

The results of the analysis of scientific publications on research trends in the development of innovative science teaching materials in the field of Earth Science Education during the period 2020–2025 were identified based on the number of scientific publications, country of origin, type of publication, field of science, research methods used, research subjects, types of instruments used, and types of arguments. The analysis using VOSviewer focused on three types of analysis, namely network visualization (Network Analysis), overlay visualization (Overlay Analysis), and density visualization (Density Analysis). The data can be seen in Figure 1.

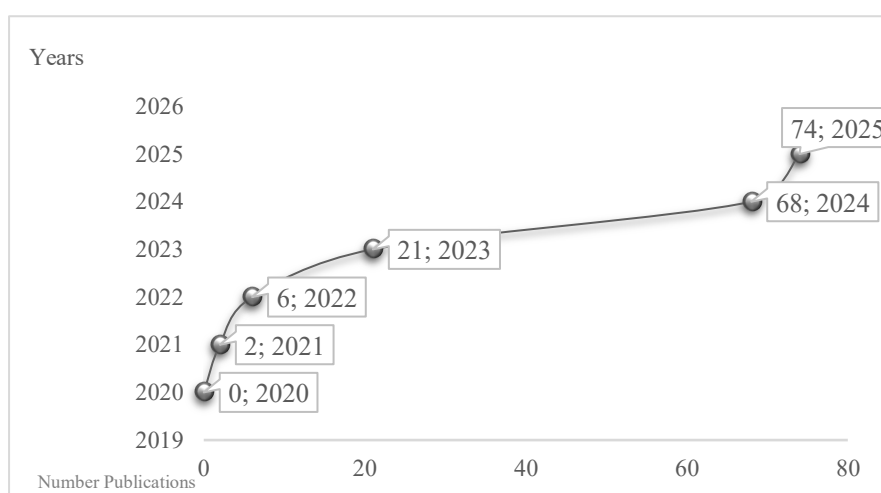


Figure 1. Scientific publications on trends in Innovative Science Teaching Material Development Research in the Field of Earth Science Education analyzed from 2020 to 2025 based on the number of articles.

Based on the analysis of Figure 1, it can be seen that the number of articles published between 2020 and 2025 fluctuated. The number of articles published each year increased from 2022 to 2025 and peaked in 2025. The data can be seen in Figure 2. Based on the results of the analysis by country, it can be seen that the number of scientific articles by country of origin is largely dominated by Indonesia and several other countries such as the United States, the United Kingdom, and Ireland, as shown in Figure 2. However, based on the analysis of Figure 3, most scientific publications originating from Indonesia come from conferences that bring together participants from various institutions to present results, share experiences, and discuss the latest scientific developments. It can therefore be concluded that

scientific publications in the form of journals are more dominant than those in the form of proceedings. The data can be seen in Figure 3.

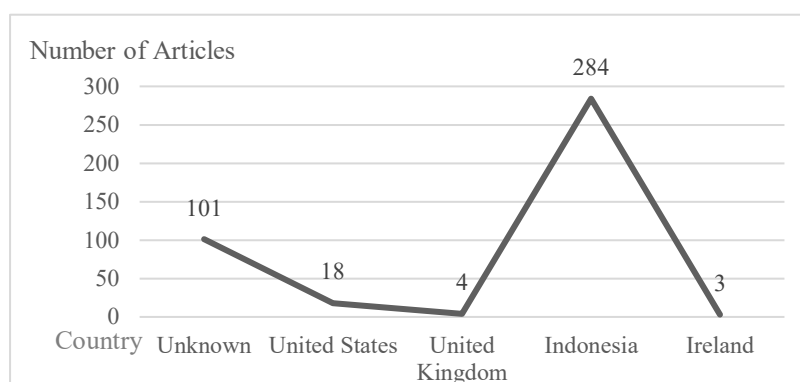


Figure 2 Scientific publications on trends in Innovative Science Teaching Material Development Research in the Field of Earth Science Education analyzed from 2020 to 2025 based on country of origin.

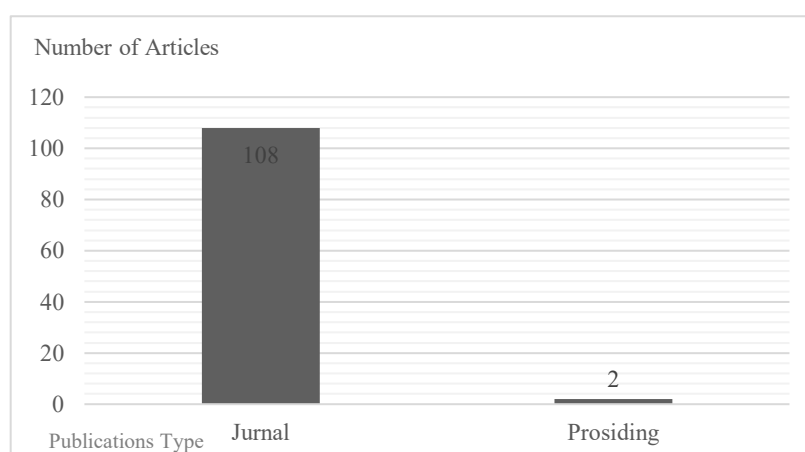


Figure 3. Scientific publications on trends in Innovative Science Teaching Material Development Research in the Field of Earth Science Education analyzed from 2020 to 2025 based on publication type.

Based on Figure 4, most of the research subjects were elementary school students. The least number of research subjects were university students. This data shows that research on trends in Innovative Science Teaching Material Development in the Field of Earth Science Education analyzed from 2020 to 2025 needs to be improved again on other research subjects in order to provide complete information about trends in the development of Innovative Science Teaching Materials in education. The data can be seen in Figure 4.

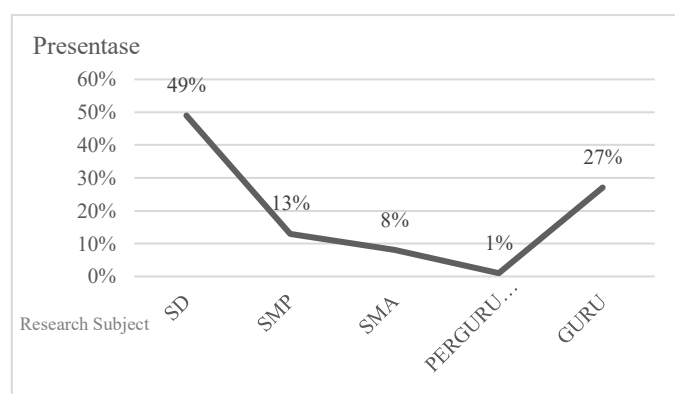


Figure 4. Scientific publications on trends in Innovative Science Teaching Material Development Research in the Field of Earth Science Education analyzed from 2020 to 2025 based on Research Subject.

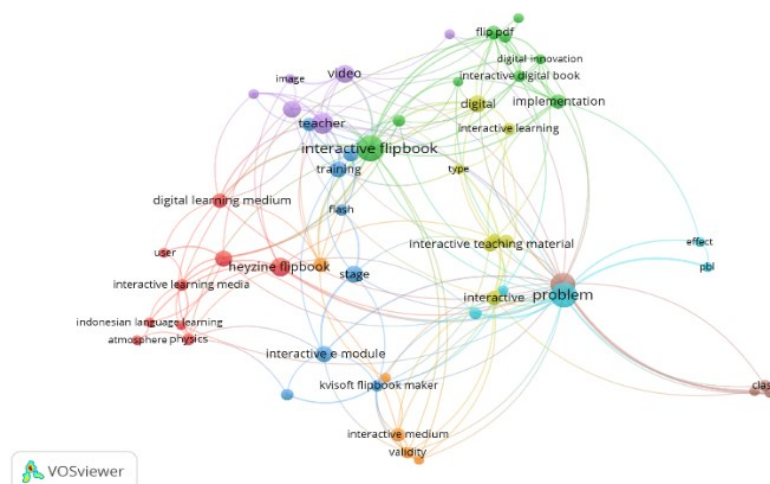


Figure 5. Visualization of the Innovative Science Teaching Materials Research and Development network in the field of Earth Science Education analyzed from 2020 to 2025

Based on Figure 5, the results of the analysis based on network visualization provide an overview of several topics that are frequently cited and are closely related to other topics. In general, there are five main topic groups that can be distinguished by color, namely green, red, yellow, blue, and purple. The trend of Innovative Science Teaching Material Development Research in the Field of Earth Science Education analyzed from 2020 to 2025 has many connections with other topics, allowing us to determine whether the trends in Innovative Science Teaching Material Development Research in Earth Science Education analyzed from 2020 to 2025 are popular in many research articles. The results of the analysis, based on the overlay visualization in Figure 6, show two main areas that are quite contrasting, namely yellow and dark blue. The trend in Innovative Science Teaching Material Development Research in the Field of Earth Science Education analyzed from 2020 to 2025 can be described as a research topic that has been extensively studied in

recent years, as indicated by the yellow or yellowish color. The difference between the two areas shows that several topics in the yellow area are trending topics.

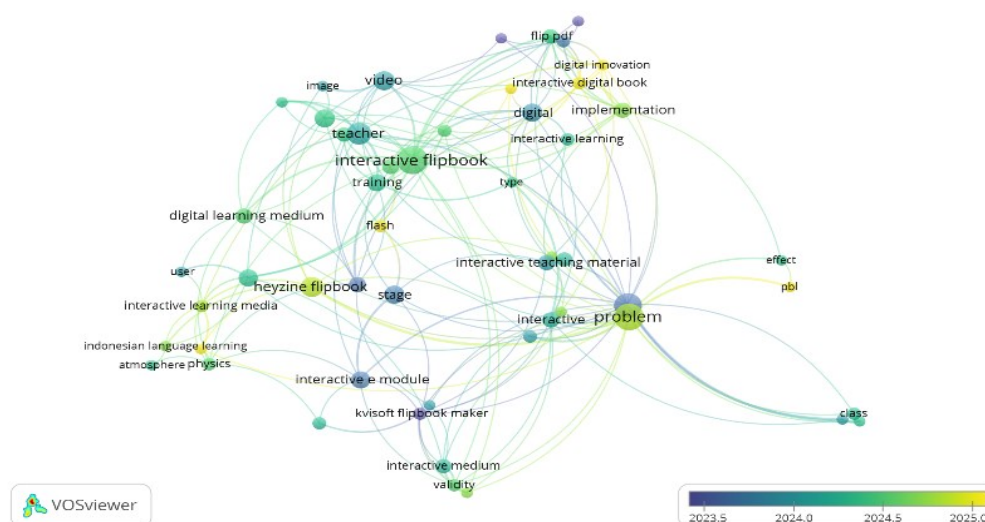


Figure 6. Visualization of overlapping trends in research on Innovative Science Teaching Materials Development in the Field of Earth Science Education analyzed from 2020 to 2025.

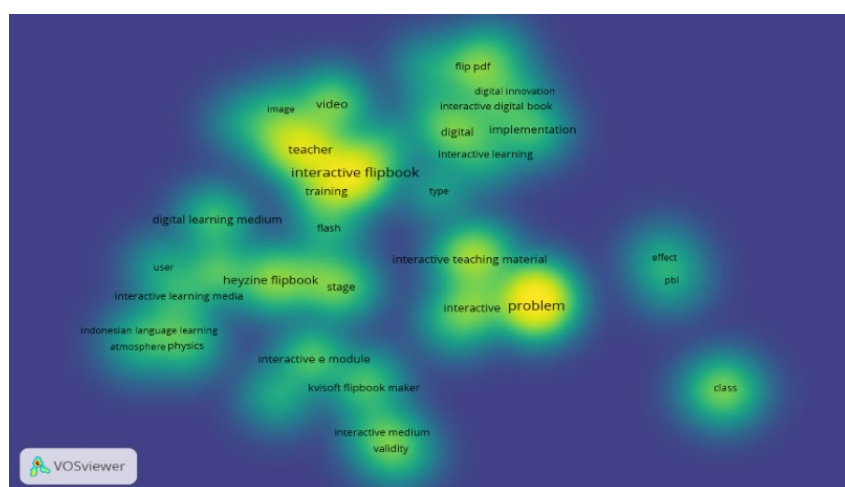


Figure 7. Visualization of the density of research trends in Innovative Science Teaching Material Development in the Field of Earth Science Education analyzed from 2020 to 2025.

In general, we can distinguish the results of the analysis based on Figure 7 by color. The yellow area indicates that the terms in that color have received a lot of attention from researchers, while the blue area indicates areas that have received less attention from researchers. Researchers pay great attention to interactive flipbook media that are directly related to teachers, problems, and training. Thus, these results provide information about research gaps that we can develop in relation to current research trends.

Discussion

The results show that the trend of developing innovative science teaching materials in the field of Earth Science Education experienced rapid growth in the period 2020–2025. This trend is marked by an increase in the number of scientific publications focusing on the use of digital technology, interactive media, and constructivist approaches in science learning.

1. Publication Growth and Regional Dominance

Based on bibliometric analysis, publications on the development of innovative science teaching materials show a significant increase, especially from 2022 to 2025. This indicates growing academic interest in the integration of technology in science education. Indonesia ranks first in terms of the number of publications, followed by the United States, the United Kingdom, and Ireland. This fact shows that Indonesia has made a major contribution to research on the development of digital-based learning media, although most of it is still published in conference proceedings. Thus, there is a need to encourage more publications in reputable journals so that local findings have a stronger international impact. global trends in interactive learning media research from 2021–2025 and found that the number of publications continues to increase year on year in the topic of educational technology, indicating growing academic interest in digital learning media. Razilu, Z., Sulfasyah, & Nappu, S. (2025), Salim, F., Anco, & Costu, B. (2025)

2. Research Subjects and Focus

Most studies focus on elementary school students as the main subjects. This focus is in line with the need to strengthen the foundations of science literacy from an early age through interactive and contextual learning. However, the low number of studies at the secondary and tertiary levels indicates a research gap that could be an opportunity for further research. Analysis of science literacy research trends shows that the number of articles focusing on research in elementary schools is very dominant, indicating a major trend in science literacy at the elementary level. Janah, A. N., Darmayanti, M., & Saefudin, A. (2024), Kutlu-Abu, N. et al. (2023)

3. Teaching Material Innovation Trends

Semantic analysis reveals that the most dominant topics include digital flipbooks, interactive e-modules, augmented reality (AR), virtual laboratories, and gamified learning environments. This trend indicates a paradigm shift from conventional teaching materials to more engaging and participatory experiential learning. Innovative media such as interactive flipbooks are often associated with increased student motivation and conceptual understanding of abstract concepts in Earth Science. Meanwhile, the use of AR and virtual labs plays a major role in providing realistic learning experiences and supporting the understanding of geoscience phenomena that are difficult to observe directly. The Web-AR Flipbook Study emphasizes that the use of AR technology in digital flipbooks increases student engagement through the visualization of abstract concepts and interactive learning that supports immersive learning Fajariyanti (2025). A systematic review of AR in

science education shows that the use of AR in an educational context not only enhances the learning experience but also increases student motivation and learning processes, which is consistent with trends in innovative learning media Z Zufahmi (2025).

4. Network and Semantic Analysis Results

Network visualization using VOSviewer shows five main clusters of research themes, each focusing on digital media innovation, constructivist learning approaches, STEM and environmental literacy integration, interactive technology application, and teaching material effectiveness evaluation. The yellow color in the overlay visualization and density indicates the topics that have received the most attention in the last five years. One of the most prominent topics is interactive flipbook media, which is closely correlated with keywords such as teacher, training, and student engagement. This shows that teachers are central actors in implementing technology-based learning innovations. A bibliometric study using VOSviewer shows network visualization and the formation of research topic clusters based on keywords in AR research in education. The visualization map shows the relationships between terms associated with interactive technology and learning, as well as how these keywords are grouped thematically Saâ, P. (2024). A bibliometric analysis of digital comics as a learning medium using VOSviewer shows that keyword clusters can describe relationships between topics such as learning media, learning effectiveness, and teacher and student engagement. This is similar to the mapping of main themes and keyword relationships in your research Norkhalizah, N. (2025).

5. Research Implications

These findings have important implications for the world of education. First, there is a need to improve teachers' competence in the design and use of digital teaching materials. Second, cross-disciplinary collaboration between technology developers and science educators must be strengthened to create adaptive teaching materials oriented towards Education for Sustainable Development (ESD). In addition, the results of this study confirm that teaching material innovation not only improves learning effectiveness but can also shape students' digital literacy and ecological awareness.

6. Future Research Directions

Semantic analysis shows the potential for further development in areas that are still rarely researched, such as the integration of Artificial Intelligence (AI) and Virtual Reality (VR) in science teaching materials, the development of learning analytics-based evaluation to measure the effectiveness of digital media, and the implementation of innovative teaching materials in the context of sustainable education and climate change mitigation. Overall, this study shows that the 2020–2025 period is an important transition phase in science education towards more digital, interactive, and sustainability-oriented learning. Although research in Indonesia is quite developed, further efforts are needed to expand the scope of

research subjects and improve the quality of publications in order to make a significant contribution at the global level. Analysis of technology literacy trends (2021–2025) using VOSviewer found research clusters covering topics such as Artificial Intelligence and Virtual Reality, as well as their relationship with pedagogy and sustainability, indicating the direction of research development towards advanced technology and sustainability in education Syamsudin, F. I., Wiyono, K., Patriot, E. A., Ismet, I., & Saparini (2025). Another bibliometric analysis shows a growth trend in digital learning media related to sustainability awareness and conceptual understanding—topics relevant to the focus on developing learning media for sustainable education Fiandini (2025).

4. Conclusion

A semantic literature review of scientific publications from 2020 to 2025 shows that the development of innovative science teaching materials in the field of Earth Science Education has made significant progress in line with developments in educational technology. There has been a shift from conventional learning to interactive, technology-based learning that is centered on the learner. Innovations such as interactive e-modules, digital flipbooks, virtual laboratories, augmented reality (AR), and gamified learning have become major trends that increase student motivation, engagement, and understanding of geoscience concepts. Semantic analysis shows a strong correlation between the concepts of digital learning, STEM-based materials, student engagement, and scientific literacy, indicating that innovative teaching materials play an important role in strengthening 21st-century competencies, such as critical thinking, creativity, and environmental awareness. Overall, trends in the development of science teaching materials in Earth Science Education are leading to dynamic, collaborative, and future-oriented learning. The success and failure of research depend on improving teacher capacity, digital literacy, educational policy support, and the integration of sustainability values to create meaningful learning experiences that shape students' scientific literacy and ecological awareness.

Acknowledgement

I would like to express my gratitude to those who have helped me, especially those who have helped me learn about publish or perish, Vos Viewer, and Mendeley.

References

- Ariani, D., & Haryanto, H. (2021). *Development of interactive digital teaching materials to improve elementary school students' motivation and understanding of science concepts. Journal of Science Learning Innovation*, 7(2), 85–95. <https://doi.org/10.31004/jips.v7i2.2104>
- Bybee, R. W. (2013). *The Case for STEM Education: Challenges and Opportunities*. National Science Teachers Association Press.
-

-
- Chen, C. (2017). *Science Mapping: A Systematic Review of the Literature*. Journal of Data and Information Science, 2(2), 1–40. <https://doi.org/10.1515/jdis-2017-0006>
- Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2019). *Teacher Technology Change: How Knowledge, Confidence, Beliefs, and Culture Intersect*. Journal of Research on Technology in Education, 42(3), 255–284. <https://doi.org/10.1080/15391523.2019.1078254>
- Jonassen, D. H. (2011). *Learning to Solve Problems with Technology: A Constructivist Perspective*. Routledge.
- Mayer, R. E. (2020). *Multimedia Learning* (3rd ed.). Cambridge University Press.
- Putra, A., & Kurniawati, L. (2021). *The use of interactive flipbook media in science learning to improve elementary school students' science literacy*. Journal of Educational Technology, 9(3), 121–130. <https://doi.org/10.33394/jtp.v9i3.3456>
- Rahmawati, N., Astuti, D., & Rahayu, S. (2023). *Integration of Education for Sustainable Development (ESD) in STEM-based teaching materials for science learning in elementary schools*. Indonesian Journal of Science Education, 11(1), 55–66. <https://doi.org/10.15294/jpsi.v11i1.4125>
- UNESCO. (2022). *Reimagining our futures together: A new social contract for education*. United Nations Educational, Scientific and Cultural Organization. <https://unesdoc.unesco.org>
- Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2020). *Current Status, Opportunities, and Challenges of Augmented Reality in Education*. Computers & Education, 62(1), 41–49. <https://doi.org/10.1016/j.compedu.2020.103856>
- Razilu, Z., Sulfasyah, & Nappu, S. (2025). *Mapping global research trends in interactive learning media: A bibliometric analysis of Scopus publications (2021–2025)*. PPSDP International Journal of Education.
- Salim, F., Anco, & Costu, B. (2025). *Trends in science learning media research in primary education: A bibliometric analysis*. Journal of Learning Innovation and Environment.
- Janah, A. N., Darmayanti, M., & Saefudin, A. (2024). *Kemampuan Literasi Sains di Sekolah Dasar: Systematic Literature Review dan Bibliometric Analysis Periode Tahun 2016–2023*. AR-RIAYAH: Jurnal Pendidikan Dasar.
- Kutlu-Abu, N., Bozgün, K., & Uluçınar-Sarigir, Ş. (2023). *Studies on scientific literacy in primary education: A bibliometric and content analysis*. Hungarian Educational Research Journal.
- Fajariyanti, N. (2025). *Immersive science learning: Flipbook Web-AR untuk visualisasi dan interaksi konsep IPA*. Jurnal Kajian Pendidikan IPA.
- Zufahmi, Z. (2025). *Augmented reality in science learning: A systematic review*. JPBI.
- Saâ, P. (2024). *Augmented Reality in Science Education Research Trends: A Bibliometric Analysis using VOSviewer*. Jurnal Penelitian Pendidikan IPA.
- Norkhalizah, N. (2025). *Bibliometric Analysis: Digital Comics as a Learning Media Using VOSviewer*. HEPI Journal.
- Syamsudin, F. I., Wiyono, K., Patriot, E. A., Ismet, I., & Sapparini (2025). *Trends in Technology Literacy Research (2021–2025): A bibliometric analysis with VOSviewer*. Jurnal Materi dan Pembelajaran Fisika.
-

Fiandini (2025). *Bibliometric analysis of research trends in conceptual understanding and sustainability awareness through AI and digital learning media. Indonesian Journal of Multidisciplinary Research.*

How to cite this article:

La Arfin., Liftiah., Subali, B., & Widiyatmoko, A. (2026). Trends in the Development of Innovative Science Teaching Materials for Earth Science Education: A Semantic Literature Review (2020–2025). *Journal of Educational Sciences*, 10(1), 1405-1418.
