Trends and Perspectives in Web-Based Science Learning Research: Evidence from 2015–2025

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Abstract: This study aims to examine trends, challenges, and effectiveness in research on web-based science learning published between 2015 and 2025. A systematic literature review (SLR) method was employed. An initial pool of 150 articles was retrieved from international and national academic databases, including Web of Science, Scopus, and SINTA, using keywords related to web-based science education. Following relevance screening and the application of inclusion criteria, 104 articles were selected for in-depth analysis. The data were analyzed using thematic analysis with open coding to identify research trends, categorize technological innovations, and map challenges and opportunities associated with the implementation of web-based science learning. The findings reveal a substantial increase in research publications during the COVID-19 pandemic period, with Indonesia and Malaysia emerging as the primary contributors and physics being the most frequently studied subject area. Key challenges identified include limited digital infrastructure, low levels of digital literacy, underdeveloped instructional materials, and difficulties in conducting online assessments. In contrast, Learning Management Systems (LMS), virtual laboratories, and interactive digital media were found to be the most effective supporting technologies. These findings suggest that the success of web-based science learning depends on the integration of supportive policies, pedagogical innovation, appropriate technological tools, and international collaboration to develop an inclusive and adaptive digital science education ecosystem.

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Introduction

The development of digital technology in the era of the 4.0 industrial revolution has brought significant changes to the world of education, particularly in the teaching of natural sciences. One innovation that has grown rapidly is the use of websites as a learning medium. The trend of website-based science learning research is important to study because it can provide an overview of the effectiveness, challenges, and opportunities for learning transformation in the digital age (Almulla, 2020; Aria & Cuccurullo, 2017). Research in this field not only plays a role in developing more interactive learning media but also expands access to learning resources and improves students' digital literacy (Garrison & Kanuka, 2004).

The urgency of researching trends in website-based science learning includes identifying developments in approaches, models, and technologies used over the past ten years. The benefits of this research include identifying rapidly developing research areas, determining the effectiveness of learning innovations, and discovering research gaps for further development (Graham, 2011; Means et al., 2013). In addition, reviewing trends can map the challenges of implementing websites in science education, such as infrastructure

readiness, teacher competence, and student engagement factors (Chen et al., 2020; Ellegaard & Wallin, 2015).

However, a review of the literature shows that trends in science education research over the past decade have been dominated by topics such as STEM-based learning, inquiry, blended learning, and the use of digital media in general (Crompton & Burke, 2018; Lameras et al., 2017; Pellas et al., 2019). Studies on science trends still lack discussion of long-term analysis, bibliometric mapping, and interdisciplinary studies, resulting in limited and fragmented understanding of research developments. A more integrative and longitudinal approach is needed to enrich future research insights (Mekimah et al., 2024). Research that specifically discusses trends in website-based science learning is still relatively scarce compared to trends in the use of mobile applications, virtual labs, and augmented reality (Bower, 2017; Hwang et al., 2020). In fact, existing studies tend to focus more on product development aspects or evaluations limited to a single subject, such as biology or physics (Dhawan, 2020; Mohmmed et al., 2020). Thus, a more comprehensive review of research trends related to website-based science learning is needed to provide a complete picture of developments, gaps, and future prospects.

Website-based science learning has various benefits in the development of science and technology (S&T). Through the use of websites, the learning process can be more flexible, collaborative, and integrated with global scientific information sources (Rutten et al., 2012; Sahin & Yilmaz, 2020). Websites as learning media enable the integration of multimedia, simulations, and discussion forums that can improve students' critical thinking, problem-solving, and science literacy skills (Donthu et al., 2021; Mishra & Koehler, 2006; Zupic & Čater, 2015).

Based on this explanation, research on trends in website-based science learning between 2015 and 2025 is highly relevant. This decade is crucial because the acceleration of Industry 4.0 and the expansion of digital learning after the pandemic have driven major transformations in education, where technologies such as artificial intelligence, the Internet of Things, and big data are increasingly integrated into web-based learning. This not only improves the quality and accessibility of education, but also requires the development of new skills to adapt to rapid changes (Romi Siswanto, 2022). Tracking these trends can contribute to mapping developments, identifying research gaps, and recommending innovations in website-based science learning going forward.

The purpose of this study is to analyze trends in website-based science learning research between 2015 and 2025. This study aims to contribute to identifying the future direction of website-based science learning research and to provide recommendations for education practitioners, researchers, and policy makers on optimizing the use of website technology for science learning. The novelty of this research lies in its comprehensive and longitudinal systematic review of web-based science learning trends, challenges, and effectiveness over a full decade (2015–2025), across multiple countries and science subjects. Unlike previous studies that were fragmented or focused on single subjects or technologies, this study provides an integrative analysis that maps gaps and future directions in website-based science education research.

Research Method

This study applies a qualitative approach using a systematic literature review method that aims to synthesize literature related to website-based science learning. This process begins with an in-depth review of the literature, identifying the main ideas from each article,

and writing them in a paraphrased style to produce a comprehensive analysis (Mahmud et al., 2023). Literature was collected from various leading academic databases such as Web of Science (WoS), SINTA (Science and Technology Index), and SCOPUS, covering publications from 2015 to 2025. The keywords used in the search included "website-based learning," "web-based learning," "website-based science learning," "science learning website," "e-learning science," "digital science education," as well as "science education."

The literature search strategy was conducted in a structured manner using a combination of relevant keywords to obtain broad and in-depth literature coverage. Selected articles must meet the following selection criteria: (1) Indexed in SSCI, SCI, SCIE, or EI; (2) Included in the field of education and educational research; (3) Written in English; (4) Have a significant impact factor; and (5) Discuss the implementation of website technology in science learning at various levels of education. The search process was expanded with keyword variations covering aspects of web technology, learning methodologies, and the context of science education, thereby identifying more specific and relevant research trends (Ramli et al., 2024). The results of the journal and article search process can be seen in Table 1 below.

Table 1. Article Search Table

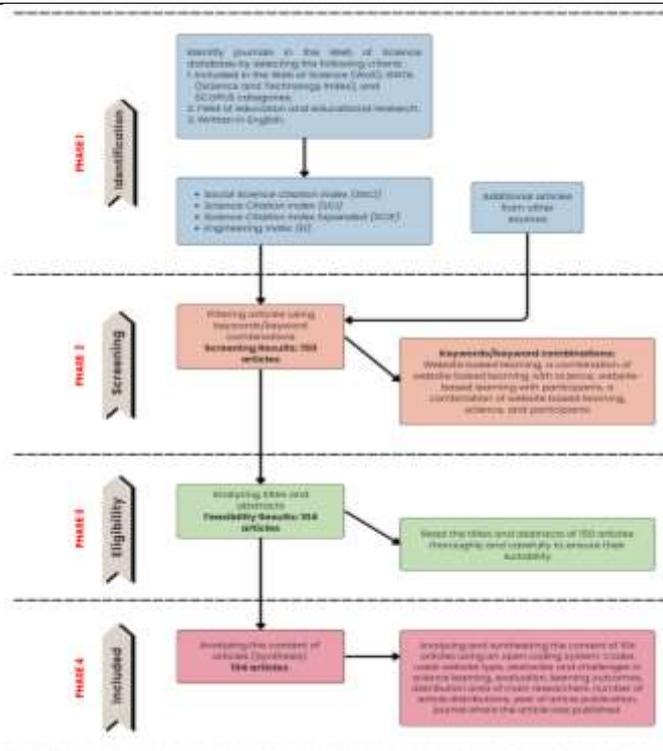| Scientific Journal Index Database	Search Results	Relevant Search Results
Social Sciences Citation Index (SSCI)	4	2
Science Citation Index (SCI)	2	1
Science Citation Index Expanded (SCIE)	12	6
Engineering Index (EI)	1	1
SCOPUS	63	40
Science and Technology Index (SINTA)	63	54
Others	5	0
Number	150	104

Figure 1. Flowchart of Article Selection for the Review Process

During the identification stage, 150 articles were retrieved from three major electronic databases: Web of Science, SINTA, and SCOPUS. All articles were then screened based on their titles and abstracts to ensure their relevance to the topic of website-based science learning. From this screening process, 46 articles were excluded because they did not meet the inclusion criteria or discussed learning technologies that were not website-based. The remaining 104 articles were then evaluated in depth at the feasibility assessment stage by examining the full text versions. The selected articles were then categorized based on education level, focus of study (website features, learning methods, learning outcome evaluation), and research methodology used. This explanation can be seen in Figure 1.

Data analysis was conducted using a thematic analysis approach with an open coding system. This technique allows for the identification, organization, and interpretation of patterns or themes throughout the selected literature. Thematic coding was performed manually to group findings into main categories that were in line with the research objectives, such as features and characteristics of learning websites, science learning problems, website development methodologies, learning evaluation techniques, and student learning outcomes (Ristiana, 2023). The analysis process also included an evaluation of the implementation of formative and summative tests, student performance assessments, and collaborative-based authentic assessments. In addition, this study also identified implementation challenges such as limitations in technological infrastructure, digital literacy, content adaptation, student motivation, and other technical obstacles.

Results and Discussion

This study used a Systematic Literature Review (SLR) approach to synthesize findings from 104 articles on website-based science learning during 2015–2025. The synthesis showed that the use of Learning Management Systems (LMS), virtual laboratories, and visual media significantly improved the effectiveness of science learning by expanding access, increasing interactivity, and motivating students. However, there are differences in implementation between developing countries, which face challenges in infrastructure and digital literacy, and developed countries, which focus on personalization and advanced technology (Michos et al., 2022). In addition, there are contradictions regarding the evaluation of bold learning, where virtual laboratory simulations are effective if supported by adequate teacher training, emphasizing the importance of collaboration between technology, human resources, and adaptive policies for the success of website-based science learning.

Policy support and digital governance are important for overcoming the challenges of website-based science learning, especially those related to infrastructure limitations and uneven internet access. The government needs to take proactive steps through network development, educational technology subsidies, and teacher training to ensure optimal technology integration. In addition, data security regulations must be strengthened to protect student privacy. Policymakers need to build an inclusive, sustainable, and adaptive digital education ecosystem through cross-institutional collaboration to create a science learning platform that is safe and relevant to today's needs (Michos et al., 2022).
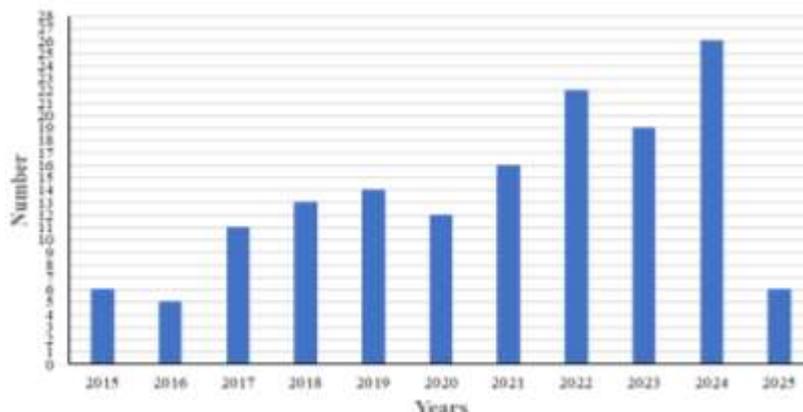
Figure 2. Distribution of Published Articles Focusing on Website-Based Science Learning Research

Based on Figure 2, Analysis of research articles on website-based science learning from 2015 to 2025 shows a fluctuating publication trend, with a significant surge in 2021–2024 due to the COVID-19 pandemic, which accelerated the adoption of digital learning and website use in science education (Jing et al., 2024). This increase aligns with global trends in digital competence and instructional design research. However, a sharp decline in 2025 indicates a shift in research focus toward new innovations like AI and adaptive learning. These dynamics reflect the academic community's adaptive response to educational and technological changes, emphasizing the importance of TPACK integration and marking a transition toward more inclusive and personalized digital education models (Zheng & Yano, 2007).
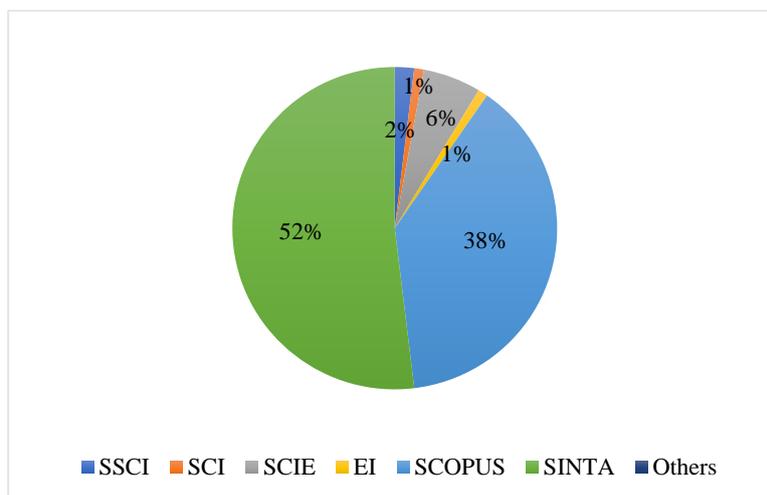

Figure 3. Distribution of the Number of Articles Published in Each Indexing Database of Scientific Journals Focusing on Website-Based Science Learning Research

The distribution of website-based science learning research publications is highly concentrated in SINTA (52%) and SCOPUS (38%), reflecting Indonesia's strong national research productivity and alignment with policies promoting digital education (Davies et al., 2023). While SCOPUS publications indicate growing internationalization and methodological rigor, penetration into other global indexes remains limited, highlighting the need for stronger theoretical frameworks and international collaboration to enhance global competitiveness (Huang & Pei, 2024; Urdanivia Alarcon et al., 2023; Makri et al., 2021; Ninaus et al., 2019).
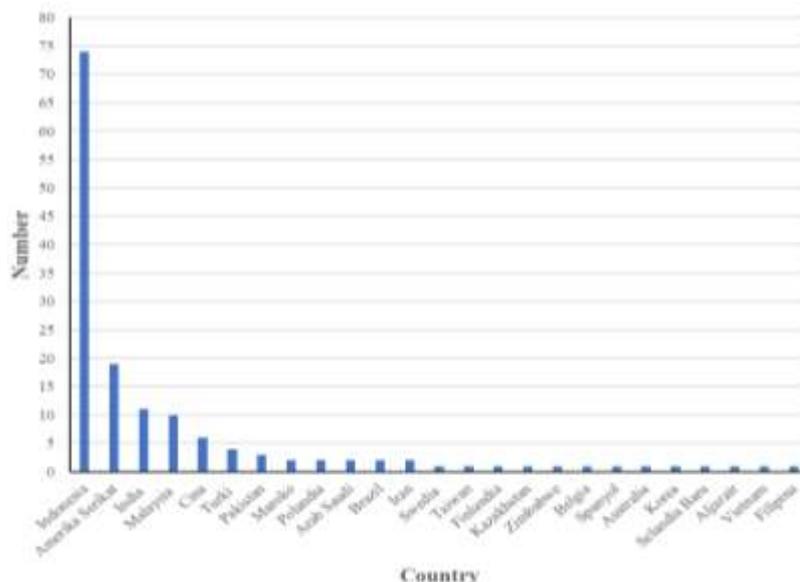
Figure 4. Distribution of Countries of Origin of Principal Investigators Focusing on Website-Based Science Learning Research

Based on Figure 4, Research on website-based science learning is predominantly conducted by Indonesian researchers, who produced 55 publications, followed by Malaysia with 20, while contributions from other countries are minimal. This pattern highlights Southeast Asia's, especially Indonesia's, strong focus on integrating digital technology in education, driven by national policies after the pandemic (Abuhassna & Alnawajha, 2023). The uneven global distribution suggests that developing countries see digital education as a strategic opportunity, whereas developed countries with established digital ecosystems pay less attention to this topic. Additionally, low international collaboration remains a challenge for broader and more contextual application of website-based science learning.
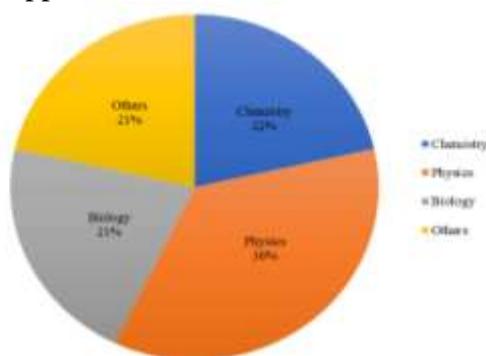

Figure 5. Proportion of Subjects in Website-Based Science Learning Research

Based on Figure 5, Website-based science learning research is mainly focused on physics (36%), likely because physics concepts are easier to visualize digitally through simulations, while chemistry and biology account for only 22% and 21%, respectively, and the remaining 21% covers other science themes. This imbalance suggests that digital learning media development is still centered on conceptual and easily visualized topics, with challenges remaining for chemistry and biology due to their complexity. Therefore, further digital innovation, such as 3D animations and virtual labs, is needed to ensure balanced development across all science branches (Wu et al., 2013).

Table 2. Table Describing the Materials Used

Subject	Topic
Chemistry	Substances and their changes, photosynthesis and respiration, chemical reaction processes
Physics	The solar system, energy and its changes, force, motion, light, and optics
Biology	Human organ systems, ecosystems and the environment, development of living things
Others	The application of science in everyday life, scientific process skills, modern scientific issues and innovations

Table 3. Table of Constraints and Challenges Faced in the Implementation of Website-Based Science Learning

Obstacles	Challenges
Internet Infrastructure and Access	Improving Student Motivation and Engagement
Digital Literacy for Teachers and Students	Development of Innovative Learning Materials
Quality of Learning Materials	Continuing Teacher Education
Difficulties in Evaluation and Practicum	Data Security and Privacy
Lack of Policy Support	Collaboration Between Countries

Based on Table 3 in the file, the implementation of website-based science learning faces five main obstacles: limited infrastructure and internet access, low digital literacy, simple learning materials, difficulties in evaluation and practical work, and insufficient policy support. These challenges are not only technological but also involve human resources and support systems. To optimize website-based science learning, it is crucial to improve student motivation, develop innovative materials, provide ongoing teacher training, ensure data security, and foster international collaboration. Therefore, a holistic approach that strengthens both digital infrastructure and human resource capacity, supported by inclusive policies, is essential for effective digital transformation in science education (Tondeur et al., 2017).

Table 4. Table of Supporting Technologies and Website Features that are Most Effective in Implementing Website-Based Science Learning

Technology/Features	Explanation	Effectiveness in Science Learning
Learning Management System (LMS) (e.g., Google Classroom, Moodle)	A platform for managing materials, assignments, and interactions between teachers and students online.	Increasing student interest and learning activity, facilitating material distribution and assessment.
Image and visualization media	The use of pictures, diagrams, and animations to explain science concepts.	Helping students understand abstract concepts and improving their learning outcomes.
Simulations and virtual laboratories	Web-based virtual laboratories and science experiment simulations.	Enables students to conduct experiments safely and interactively, improving their science process skills.
Interactive learning videos	Videos with interactive features such as quizzes or live explanations.	Facilitates understanding of complex material, increases motivation to learn.
Online discussion forum	Text- or video-based discussion features for Q&A and collaboration.	Encouraging collaboration, knowledge sharing, and joint problem solving.
Gamification (*Game-Based Learning*)	Integration of game elements (points, badges, leaderboards) into learning.	Improving students' motivation, engagement, and memory of science material.
Mobile access (*mobile friendly*)	A website that can be accessed easily via mobile devices.	Facilitates access to learning anytime and anywhere, increasing learning flexibility.
Online assessment	Features for creating and managing	Facilitates real-time evaluation of learning

(online quizzes and exams)	quizzes, exams, and automated feedback.	outcomes and personalization of learning.

Based on Table 4, it can be interpreted that the effectiveness of website-based science learning implementation is highly dependent on the diversity and sophistication of the technology used. Learning Management Systems (LMS) such as Google Classroom and Moodle are the main backbone in managing materials, assignments, and interactions between teachers and students, thereby facilitating the process of learning distribution and assessment. The use of images, diagrams, and animations greatly helps students understand abstract concepts in science, which are often difficult to grasp through text alone. Simulations and virtual laboratories allow students to conduct experiments safely and interactively, without the limitations of physical laboratory equipment, thereby honing their scientific skills. Interactive learning videos that combine quiz features and direct explanations can increase student motivation to learn complex material. In addition, features such as online discussion forums, gamification, mobile access, and online assessment enrich the learning experience by increasing collaboration, curiosity, and real-time and personalized evaluation of learning achievements (Al-Fraihat et al., 2020; Martin & Bolliger, 2018; Perez-Sanagustín et al., 2017; Petersen et al., 2022).

The effectiveness of website-based science learning is largely determined by the integration of technology that emphasizes pedagogy and interactivity. LMS serves as the main platform that organizes all learning activities, while visual media and virtual laboratory simulations reinforce students' conceptual understanding and practical skills, which previously could only be achieved through direct experiments in physical laboratories (Michos et al., 2022). Gamification and interactive video features have been proven to support the theory of digital learning motivation by creating a more participatory and enjoyable learning atmosphere, in line with research results that emphasize the importance of innovation in digital learning design. Online assessment and mobile-friendly access are also important in supporting learning desires and smoothness, especially in the post-pandemic period where distance learning has become a primary need (Zhao et al., 2021). This shows that effective educational website design must focus on ease of access, personalization, and opportunities for collaboration in order to respond to the challenges of education in the digital era in a more inclusive and adaptive manner (Tondeur et al., 2017).

Conclusion

Research on website-based science learning from 2015 to 2025 highlights rapid growth driven by the COVID-19 pandemic, with a shift towards advanced technologies like AI, VR, and adaptive environments. Most research, dominated by physics and concentrated in Indonesian and Malaysian databases, underscores the need for greater international collaboration and innovation in chemistry and biology. Key challenges include infrastructure gaps, low digital literacy, and online assessment difficulties, which can be addressed through expanded access, ongoing teacher training, and innovative tools such as AR, VR, virtual labs, LMS, and gamification. Success depends on integrating policy, pedagogy, technology, and cross-country cooperation to create an inclusive, adaptive, and globally competitive science education ecosystem.

Recommendation

Based on an analysis of trends in website-based science learning research between 2015 and 2025, further research is recommended to emphasize the integration and

development of website-based learning media in chemistry and biology, which have received less attention than physics. Innovations such as the use of Augmented Reality (AR), Virtual Reality (VR), and virtual laboratories are essential to enhance the interactivity and contextuality of learning, especially in the face of limitations in practical experiments. Further research also includes strengthening continuous teacher training, expanding access to infrastructure and digital literacy, and enhancing international collaboration so that the research results can make a significant contribution to reputable global journals. The main obstacles that need to be anticipated include limited internet infrastructure, low digital literacy, difficulties in evaluation, and the need for data protection and student privacy, which are increasingly crucial in the digital era. Teachers are encouraged to expand the use of website-based learning especially in chemistry and biology by integrating innovative technologies (AR/VR, virtual labs), engaging in continuous professional development, advocating for better infrastructure, and addressing digital literacy and privacy challenges to ensure effective and equitable science education.

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