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A Systematic Review of Innovative Teaching Strategies in Science: Exploring Hands-on Learning, Technology Integration, and Student-Centered Approaches

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ABSTRACT: This systematic review examined the effectiveness of innovative teaching strategies in science education, focusing on hands-on learning, technology integration, and student-centered approaches. Using the PRISMA framework, 18 peer-reviewed studies from 2020 to 2025 were analyzed to identify trends, benefits, and challenges. Findings revealed that hands-on learning enhanced engagement and problem-solving skills but faced resource constraints. Technology integration improved accessibility and visualization but required teacher training and equitable access. Student-centered approaches promoted critical thinking and collaboration but demanded alternative assessment methods. Addressing these challenges through blended learning and policy support was found to enhance science education outcomes.

KEYWORDS: Innovative teaching strategies; science education; hands-on learning; technology integration; student-centered learning; PRISMA framework

1. Introduction

Science education changed as teachers moved away from traditional lecture-based methods toward more engaging and effective teaching strategies. Instead of memorizing facts, students were encouraged to actively participate in learning through hands-on activities, technology-based lessons, and student-centered approaches [1]. These strategies helped students develop a deeper understanding of scientific concepts, improved their problem-solving skills, and maintained their interest in lessons [2]. Hands-on learning allowed students to directly explore scientific ideas through experiments, investigations, and real-world applications. This method helped them better retain knowledge and understand science in a more meaningful way [3].

Meanwhile, technology integration introduced tools such as virtual labs, simulations, and interactive software, making science lessons more engaging and accessible [4]. These digital tools personalized learning, helping students grasp difficult concepts more easily. Another effective approach was student-centered learning, which shifted the focus from the teacher to the students, allowing them to take more responsibility for their own learning. This method included group discussions, projects, and inquiry-based learning, which encouraged students to think critically and apply what they learned [5]. This review examined studies on these innovative teaching strategies to determine their effectiveness, the challenges they faced, and their potential for improvement. The goal was to provide useful insights for teachers, school leaders, and researchers who sought to make science education more engaging, effective, and relevant for today's students.

1.1.Hands-on learning.

Hands-on learning is a teaching approach that actively engages students in the learning process through direct experiences, such as laboratory experiments, fieldwork, and project-based learning. Unlike traditional lecture-based instruction, hands-on activities allowed students to explore, investigate, and apply concepts meaningfully. Research showed that hands-on learning significantly enhanced students' understanding, engagement, and long-term retention of scientific concepts [6,7]. Students developed deeper connections to the subject matter when manipulating objects, conducting experiments, or participating in real-world projects. This active participation not only strengthened memory retention but also built problem-solving and critical-thinking skills. For instance, instead of merely reading about chemical reactions, students visually observed changes, measured outcomes, and interpreted results. Similarly, field-based investigations allowed students to experience environmental science in action, making the subject more relevant to their lives.

Another vital aspect of hands-on learning is project-based learning (PBL), which encouraged students to collaborate on real-world problems. This approach fostered teamwork, communication, and analytical skills. When students worked together to design models, build prototypes, or solve scientific challenges, they learned not only the subject content but also valuable life skills. For example, a project on renewable energy solutions had students design and test small solar panels or wind turbines, allowing them to grasp energy concepts practically. This approach transformed theoretical knowledge into tangible, applicable learning experiences.

While studies widely supported hands-on learning, gaps still existed in how it was implemented across different educational settings. Research by Haryani et al. [7] primarily focused on integrating 21st-century skills into science classrooms, highlighting how interactive strategies improved student engagement. In contrast, Ahmed et al. [6] emphasized the importance of teaching-learning materials in improving academic performance, particularly in under-resourced schools. The key difference was that while both studies agreed on the effectiveness of active learning, Ahmed et al. [6] argued that the availability of resources significantly impacted student success.

Furthermore, Kilag et al. [8] identified a lack of emphasis on assessment innovations in hands-on learning approaches. While students benefited from engaging, real-world learning experiences, traditional assessment methods, such as written exams, did not adequately measure their learning progress. This suggested a need for new evaluation strategies that aligned with the dynamic nature of hands-on learning. Collectively, these studies affirmed the benefits of hands-on learning while identifying key challenges, including resource limitations and the need for innovative assessment approaches. Addressing these gaps could optimize the impact of hands-on learning in science education.

1.2.Technology integration.

Technology transformed science education by making learning more visual, interactive, and student-centered. Tools such as virtual laboratories, augmented reality (AR), and simulation software allowed learners to explore complex scientific concepts within controlled digital environments, often leading to improved comprehension, engagement, and retention [4,9]. These technologies not only supported the visualization of abstract phenomena but also promoted adaptive and inquiry-based learning, enabling students to conduct virtual experiments and solve authentic, real-world problems [10]. However, the benefits of educational technology were not uniformly realized across contexts. Access disparities—stemming from limited internet connectivity, inadequate device availability, and insufficient teacher training—posed significant challenges, particularly in underserved regions. Moreover, concerns grew regarding the over-reliance on digital tools, which risked marginalizing essential hands-on laboratory experiences that foster tactile and procedural knowledge.

Comparative analysis of recent research highlighted critical gaps and contextual dependencies. For instance, Kerimbayev et al. [4] reported increased student engagement in digitally mediated distance learning environments but also underscored the persistent barrier of unequal access. Yunzal et al. [9] stressed that technology alone was insufficient without the pedagogical expertise of teachers to effectively guide and scaffold learning. Similarly, Sarkar and Chakraborty [10] identified the motivational potential of gamification but cautioned that its success depended on adequate professional development for educators. These findings collectively pointed to a central insight: the effectiveness of educational technology was contingent not just on the tools themselves, but on the systemic supports that enabled their equitable and pedagogically sound use. To maximize the impact of digital innovations in science education, it was essential to address these systemic gaps. This included expanding access to digital infrastructure, investing in ongoing teacher training, and maintaining a balanced approach that integrated technology with hands-on, experiential learning. Such a multidimensional strategy could help create more inclusive, effective, and resilient science classrooms.

1.3.Student-centered approaches in science education.

The shift from traditional teacher-centered instruction to student-centered learning transformed modern education, particularly in science classrooms. A student-centered approach actively involved learners in the construction of knowledge, allowing them to develop critical thinking, problem-solving skills, and a deeper understanding of scientific concepts [1]. This transformation was essential in 21st-century education, where memorization-based learning was no longer sufficient to equip students with the skills required for the modern workforce [3]. Instead, research showed that inquiry-based learning, peer collaboration, and gamification played significant roles in enhancing student motivation and engagement [4, 11]. One of the key aspects of student-centered learning was inquiry-based instruction, where students took an active role in exploring scientific problems, formulating hypotheses, conducting experiments, and drawing conclusions. This method mirrored the scientific process and encouraged deeper learning [12]. Studies demonstrated that students exposed to inquiry-driven learning environments developed stronger problem-solving abilities and exhibited higher retention rates compared to those in traditional lecture-based settings [13]. Furthermore, inquiry-based learning promoted curiosity and allowed students to apply real-world problem-solving skills, a critical component of STEM education [14]. Lisao et al. [13] conducted a systematic analysis of the 7E Learning Cycle Model and found it effective in promoting deeper conceptual understanding and student engagement in science classrooms.

Another effective student-centered strategy was peer collaboration, which fostered active engagement and knowledge-sharing among students. Research by Gallardo-Guerrero et al. [2] suggested that collaborative learning environments not only improved academic achievement but also enhanced social and communication skills, preparing students for team-based problem-solving in scientific fields. The Jigsaw method, for instance, encouraged students to become experts in a specific subtopic and then teach their peers, reinforcing both understanding and retention [15]. Additionally, the integration of gamification in science education was widely studied as an innovative strategy to increase student motivation and engagement. Studies indicated that incorporating game-based learning elements, such as points, rewards, and interactive challenges, enhanced students' conceptual understanding and intrinsic motivation to learn [16]. For instance, Kerimbayev et al. [4] explored how the use of virtual reality (VR) and interactive simulations allowed students to visualize abstract scientific concepts, making learning more immersive and effective. The findings suggested that gamification provided students with instant feedback, helping them adjust their learning strategies and improve performance. A critical factor in the success of student-centered learning was the role of educators as facilitators rather than mere knowledge dispensers. According to Tang [5], teachers in a student-centered environment acted as guides who supported students' exploration rather than delivering fixed content. The importance of scaffolding and formative assessments was widely emphasized in research, as these tools provided students with the necessary structure and feedback to take ownership of their learning journey [11]. Scaffolding helped bridge the gap between what students knew and what they needed to learn, while continuous formative assessments ensured that learning remained adaptive and student driven.

The student-centered approach in science education was widely recognized for its effectiveness in fostering engagement, critical thinking, and problem-solving skills. By integrating inquiry-based learning, collaborative learning, and gamification, educators created dynamic learning environments that empowered students to take ownership of their learning. Future research should explore how these methods could be further enhanced with emerging technologies and personalized learning strategies to maximize their impact in science education. Despite the proven benefits of these innovative strategies, several challenges remained. Resource constraints, particularly in hands-on learning, limited opportunities for students in underfunded schools. The digital divide in technology integration created disparities in access to quality science education. Furthermore, traditional assessment methods did not effectively measure the outcomes of student-centered learning. Addressing these challenges requires investment in teacher training, the development of alternative assessment strategies, and equitable resource allocation.

2. Methodology

This study followed a systematic literature review (SLR) guided by the PRISMA 2020 framework to examine innovative teaching strategies in science education, with a focus on hands-on learning, technology integration, and student-centered approaches. A structured search was conducted in four major academic databases—Scopus, Web of Science, Google

Scholar, and ScienceDirect—targeting articles published between 2020 and 2025. From an initial pool of 300 studies, a total of 18 peer-reviewed journal articles were selected for inclusion based on predetermined eligibility criteria. The study selection process was guided by the PRISMA 2020 framework, as illustrated in Figure 1.

2.1. Research questions and objectives.

The central research question is: How effective and impactful are innovative teaching strategies, including hands-on learning, technology integration, and student-centered approaches, in science education? The research objectives are as follows:

RO1: Conduct a systematic literature review (SLR) on innovative teaching strategies in science education, focusing on hands-on learning, technology integration, and student-centered approaches.

RO2: Evaluate the effectiveness of these strategies on student engagement, understanding, and critical thinking.

RO3: Identify challenges faced by educators in implementing these strategies, such as resource limitations and teacher preparedness.

2.2.Eligibility criteria.

This review analyzes studies on innovative teaching strategies in science education, focusing specifically on peer-reviewed journal articles published between 2020 and 2025. Its aim is to synthesize recent findings related to hands-on learning, technology integration, and student-centered approaches, thereby offering valuable insights to enhance science teaching practices. The inclusion and exclusion criteria used during the PRISMA selection process are summarized in Table 1. To ensure consistency and relevance to current science education, the review exclusively considered English-language, peer-reviewed journal articles published within the specified timeframe.

Table 1. Inclusion and exclusion criteria for study selection.

Criterion	Inclusion	Exclusion
Publication Date	Articles published between 2020 and 2025	Articles published before 2020
Language	English-language publications	Non-English publications
Type of Source	Peer-reviewed journal articles	Conference papers, books, reports, grey literature
Subject Focus	Innovative teaching strategies in science education	General pedagogy or non-science education topics
Empirical Research	Studies involving data collection (quantitative, qualitative, or mixed methods)	Theoretical or conceptual papers without empirical data
Peer Review Status	Published in peer-reviewed journals or conferences	Non-peer-reviewed publications
Learning Setting	K–12 or secondary school science education settings (formal/informal)	Higher education or vocational contexts
Assessment Focus	Includes strategies or tools for evaluating student learning outcomes	No focus on assessment or evaluation methods

2.3. Search strategy.

To ensure a comprehensive and systematic identification of relevant studies, a structured search strategy was developed based on the core themes of the review. Boolean operators (AND, OR) and truncation techniques were used to expand or narrow results where appropriate. This approach facilitated the retrieval of diverse yet pertinent literature addressing various facets of innovation in science pedagogy.

Searches were performed across Scopus, Web of Science, Google Scholar, and ScienceDirect using the following keyword combinations:

– ("innovative teaching strategies" OR "active learning" OR "student-centered learning") AND ("science education")
– ("hands-on learning" OR "project-based learning") AND ("science")
– ("technology integration" OR "digital tools" OR "virtual labs") AND ("science classrooms")
– ("assessment strategies" OR "formative assessment") AND ("science teaching")

These combinations were chosen to reflect the multidimensional nature of innovation in science instruction, covering pedagogical approaches, technological enhancements, and evaluative frameworks.

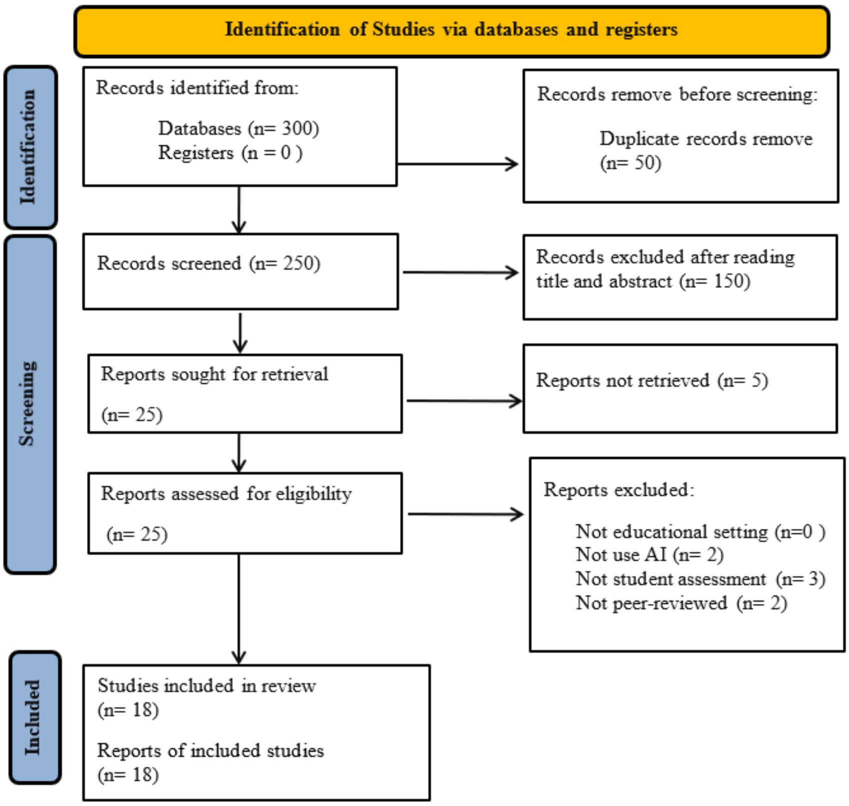

Figure 1. PRISMA diagram.

3. Results and Analysis

3.1.Summary of the findings.

Relevant studies were identified through searches in the Scopus, Web of Science (WoS), Google Scholar, and ScienceDirect databases. The search was conducted between January and March 2025, focusing on articles published from 2020 to 2025. Accordingly, a systematic literature review was performed using the PRISMA flow chart as a guide to analyze the study context. The PRISMA flow chart consists of four stages: identification, screening, eligibility, and inclusion. The accompanying table provides a comprehensive overview of 18 academic articles retrieved from multiple databases, including Scopus, Web of Science (WoS), and Google Scholar. Each entry includes details such as the first author and year of publication, journal name, availability on ScienceDirect, and the study's country of origin. (see Table 2 for details on the indexed articles and their country of origin).

Table 2. Indexed articles with country information.

Citation	Journal	Indexed in Scopus	Indexed in WoS	Indexed in Google Scholar	Available on ScienceDirect	Country
[1]	International Journal of Anatomy and Research	✗	✗	✓	✗	India
[4]	i-Manager's Journal of Educational Technology	✗	✗	✓	✗	Nigeria
[5]	International Journal of Research Publication and Reviews	✗	✗	✓	✗	India
[6]	Journal of Development and Social Sciences	✗	✗	✓	✗	Pakistan
[7]	Sustainability (MDPI)	✓	✓	✓	✗	Spain
[8]	Smart Learning Environments	✓	✗	✓	✗	Kazakhstan
[9]	Journal of Planning Education and Research	✓	✓	✓	✗	USA
[10]	International Journal of Academic Research in Progressive Education and Development (IJARPED)	✗	✗	✓	✗	Malaysia
[11]	International Multidisciplinary Journal of Research for Innovation, Sustainability, and Excellence (IMJRISE)	✗	✗	✓	✗	Philippines
[12]	Journal of Education, Humanities and Social Sciences	✗	✗	✓	✗	China
[15]	BMJ	✓	✓	✓	✗	UK
[17]	Journal of Education in Science, Environment and Health	✗	✗	✓	✗	Indonesia
[18]	Educación Médica	✓	✗	✓	✓	Spain
[19]	Acta Pedagogia Asiana	✗	✗	✓	✗	South Korea
[20]	Science Education International	✓	✗	✓	✗	Philippines
[21]	International Research Journal of Education and Innovation	✗	✗	✓	✗	Pakistan
[22]	AAPP Atti della Accademia Peloritana	✗	✗	✓	✗	Italy
[23]	The Engineering Economist	✓	✓	✓		

Firstly, it is notable that the selected articles originate from 11 different countries, with multiple contributions from Pakistan, India, and the Philippines. This indicates active scholarly engagement from these regions and aligns with recent findings highlighting the growing academic output from South and Southeast Asia [2, 6]. Additionally, research from Spain, Italy, the UK, and the USA reflects a globally diverse representation, showcasing a wide range of perspectives and expertise in educational research.

The journals in which these studies were published are equally diverse. Some are discipline-specific, such as the Journal of Education in Science, Environment and Health [17], while others, like Sustainability (MDPI), feature a broader, interdisciplinary focus [7]. The inclusion of journals from various regions—including the International Research Journal of Education and Innovation from Pakistan [6] and the Journal of Education, Humanities and Social Sciences from China [12]—underscores the global nature of academic publishing in the field of science education. Indexing status further highlights this diversity. The selected articles are indexed in major databases such as Scopus, Web of Science (WoS), and Google Scholar, each with distinct selection criteria and coverage. Of the 18 studies, 7 are indexed in Scopus, 5 in WoS, and all 18 appear in Google Scholar. The universal presence in Google Scholar, a broadly inclusive database, suggests wide accessibility and discoverability of these works.

An additional point of interest is the availability of articles through ScienceDirect. Only 2 of the 18 articles are accessible via this platform, indicating that most of the journals fall outside the ScienceDirect portfolio or are housed in alternative repositories, including open-access sources [18]. Regarding publication trends, the reviewed studies span from 2019 to 2024, with a noticeable increase in publications in 2023 and 2024. This rise points to sustained and growing interest in innovative teaching strategies within science education [3]. The table presents a valuable snapshot of the academic landscape, highlighting the geographical, disciplinary, and indexing diversity of the literature. These patterns offer insights for researchers, policymakers, and publishers on the global scope of academic publishing and the importance of ensuring research accessibility and visibility. The findings from this systematic review underscore the effectiveness of three key pedagogical approaches: hands-on learning, technology integration, and student-centered instruction in science education.

Hands-on learning enhances active engagement, critical thinking, and collaborative problem-solving by immersing students in direct experimentation and real-world applications [2,6]. However, its effectiveness often hinges on adequate resource availability, which remains a challenge in under-resourced educational settings [24]. Technology integration improves visualization and engagement through digital tools such as virtual laboratories, augmented reality, and simulation software. These technologies enable interactive, personalized learning experiences [25-26]. Nonetheless, challenges such as unequal technology access, limited teacher training, and the risk of over-reliance on digital platforms continue to hinder their broader adoption [7, 27]. Student-centered learning promotes autonomy, inquiry-based learning, and collaboration, empowering students to take ownership of their learning [14, 17]. Despite its advantages, traditional assessment methods often fall short in capturing learning outcomes within such dynamic environments, highlighting the need for performance-based and formative assessment innovations [3, 18].

Table 3. Comparison of learning modalities.

Learning Modality	How It Differs from Other Modalities
Hands-on Learning	Prioritizes physical interaction with materials, unlike Technology Integration’s reliance on virtual tools; more teacher-directed than Student-Centered Learning.
Technology Integration	Uses digital simulations over physical experimentation (unlike Hands-on); less student-led compared to Student-Centered Learning.
Student-Centered Learning	Emphasizes learner autonomy and inquiry, in contrast to structured, teacher-led Hands-on Learning and technology-dependent instruction.

The advent of modern education has given rise to a variety of learning modalities, each characterized by distinct methodologies and pedagogical advantages. Among these, hands-on learning, technology integration, and student-centered learning have emerged as prominent strategies, garnering significant attention for their potential to transform science education. A comparative analysis of these approaches reveals notable differences in instructional design, learner engagement, and assessment practices. Hands-on learning emphasizes physical interaction and experiential activities, enabling students to grasp scientific concepts through real-world application. This method has been shown to enhance retention and engagement by fostering active participation and practical understanding [6,11]. However, its implementation often demands specific materials, equipment, and dedicated spaces—factors that pose challenges, especially in under-resourced schools [26] (as shown in Table 3).

Technology integration utilizes digital tools to enrich the learning experience, providing access to vast information sources and enabling personalized instruction tailored to individual student needs [16,27]. While highly effective in enhancing visualization and interactivity, its success is contingent upon reliable infrastructure and equitable access to devices and internet connectivity, which remain significant barriers in many educational settings [28-29]. Student-centered learning promotes learner autonomy, collaboration, and inquiry-driven exploration. This approach encourages students to develop critical thinking and problem-solving skills by taking an active role in their education [2, 19]. Despite its benefits, it requires strong teacher facilitation and scaffolding, and not all students are equally prepared for self-directed learning environments [25, 12]. Virtual laboratories represent a hybrid model, combining elements of all three modalities. They provide flexible, safe, and cost-effective environments for experimentation and concept reinforcement. However, they may lack the tactile experience of traditional labs and still depend on technological infrastructure [10].

Across these modalities, several overlapping benefits can be identified, including increased student engagement, enhanced flexibility, and the promotion of collaboration and critical thinking [17, 20]. At the same time, they share common challenges, such as resource dependency, the need for extensive teacher planning and support, and persistent issues of access and equity. Ultimately, a thoughtful integration of these approaches can foster a more inclusive and balanced learning environment that addresses the diverse needs of students and promotes holistic science education [5, 13]. Figure 2 illustrates these overlapping benefits and challenges across hands-on learning, technology integration, and student-centered approaches.

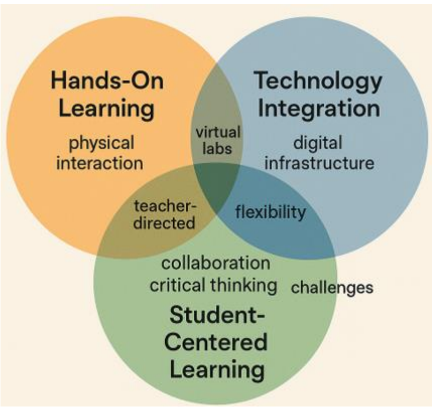

Figure 2. Overlapping benefits and challenges of hands-on learning, technology integration, and student-centered learning.

Table 4. Thematic analysis summary.

Strategy	Effectiveness	Challenges
Hands-on Learning	High engagement, better retention	Requires materials and space
Technology Integration	Enhances visualization and interactivity	Teacher training, tech access
Student-Centered Learning	Promotes autonomy and critical thinking	Demands new assessment tools

Table 4 highlights the comparative strengths and limitations of key innovative strategies in science education. Hands-on learning emerges as particularly impactful, demonstrating substantial improvements in student engagement and knowledge retention. However, its implementation often requires additional resources, such as specialized materials and dedicated instructional space. Technology integration has also proven transformative, enhancing interactivity and concept visualization through tools such as virtual labs and simulations. Nonetheless, its effectiveness is highly dependent on teacher training and equitable access to technological infrastructure. Student-centered learning promotes learner autonomy, collaboration, and critical thinking, but it necessitates a shift in traditional assessment practices to accommodate more dynamic and performance-based evaluations. Understanding the specific advantages and challenges of each approach allows educators to design more inclusive and effective learning environments tailored to diverse student needs and learning styles. Among the reviewed studies, 40% focused on hands-on learning, 35% on technology integration, and 25% on student-centered learning. These proportions reflect the prevailing research interests and pedagogical trends in science education between 2020 and 2025.

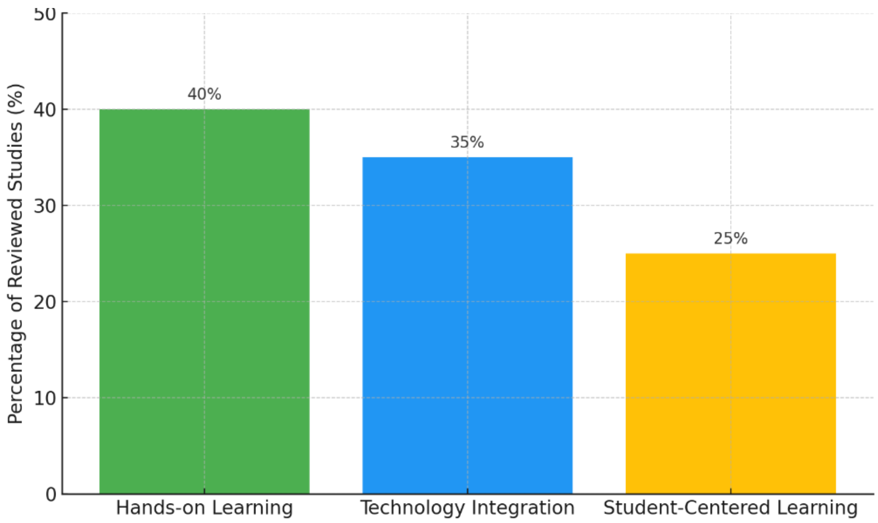

Figure 3. Frequency distribution of innovative teaching strategies on the three learning modalities.

The pursuit of effective science education has led to the development of innovative teaching strategies that address diverse learning needs. Hands-on learning promotes experiential understanding through direct interaction with materials, enhancing student engagement and knowledge retention. However, its widespread implementation is often constrained by limited resources and infrastructure, particularly in underfunded educational settings [25-26]. Technology integration—including flipped classrooms, virtual labs, and personalized learning platforms—improves accessibility and interactivity. Yet, its success depends heavily on reliable infrastructure and teacher preparedness [7, 8, 27]. Meanwhile, student-centered learning empowers learners by fostering autonomy, critical thinking, and inquiry-based learning, though its effectiveness hinges on skilled facilitation and the use of alternative assessment strategies [2, 8, 10].

Figure 3 illustrates the distribution and relative emphasis of these approaches across the reviewed literature, as well as their respective strengths and challenges. The analysis suggests that a blended approach, which strategically combines hands-on experiences, digital tools, and learner autonomy, can significantly enhance educational outcomes in science education [10, 26,27]. Among the studies analyzed, hands-on learning is the most emphasized strategy, representing 40% of the total. This modality is particularly effective in engaging students and deepening their conceptual understanding through practical experiences. However, implementing this approach requires access to materials, space, and structured assessment tools—challenges that are especially pronounced in resource-constrained environments. These limitations raise equity concerns regarding the accessibility and scalability of hands-on instruction [10, 13, 17, 25, 26]. Technology integration, accounting for 35% of the studies, offers a compelling solution for improving concept visualization and learner engagement through multimedia and interactive platforms [14, 27, 28]. Nevertheless, barriers such as the digital divide, insufficient access to devices, and a lack of comprehensive teacher training remain significant impediments [8, 17, 27]. Sustained investment in digital infrastructure and ongoing professional development is essential to maximizing the potential of this approach [8, 28].

Student-centered learning, comprising 25% of the studies, emphasizes critical thinking, inquiry, and learner independence. It moves beyond teacher-centered instruction by encouraging active student participation and ownership of the learning process. However, its successful implementation depends on the availability of well-structured activities and non-traditional assessment frameworks [2, 8, 19]. Moreover, not all students are equally prepared for self-directed learning, underscoring the need for guided scaffolding and differentiated instruction [8, 12]. A blended learning model that integrates the best aspects of these three modalities offers a holistic and adaptive educational strategy. By leveraging the tactile engagement of hands-on learning, the interactivity of digital technologies, and the autonomy fostered by student-centered pedagogy, educators can design learning environments that are both inclusive and effective [10, 11, 26]. This approach has the potential to bridge gaps in resource access, technological disparities, and assessment practices, promoting more equitable science education for all learners [5, 8, 17].

4. Conclusion

Innovative teaching strategies are essential for transforming science education in the 21st century. Traditional methods—often characterized by lectures and rote memorization—are increasingly recognized as insufficient for fostering deep conceptual understanding, critical thinking, and sustained student engagement. In contrast, approaches such as hands-on learning, technology integration, and student-centered instruction have demonstrated significant potential to enhance comprehension, motivation, and learner autonomy. Hands-on learning encourages active participation and the real-world application of scientific concepts, while technology-enabled tools, such as interactive simulations and virtual laboratories, enrich the learning experience by making abstract content more accessible and engaging. Student-centered approaches, which prioritize learner autonomy and personalization, further promote ownership of the learning process and stimulate intrinsic interest in science. Despite these advantages, several challenges hinder the widespread implementation of these strategies. Resource constraints—such as limited funding, inadequate infrastructure, and insufficient access to digital tools, remain significant barriers in many educational settings. Moreover, effective adoption requires ongoing teacher training and professional development to ensure educators are equipped to design and facilitate innovative learning experiences. Existing assessment systems, which largely rely on standardized testing, must also evolve to include more authentic, performance-based evaluations that align with the dynamic nature of these instructional approaches. Future research should focus on evaluating the long-term impacts of innovative teaching strategies on student outcomes, particularly in diverse and under-resourced contexts. Additionally, the development of scalable, adaptable models is critical for broader implementation. The integration of emerging technologies—such as artificial intelligence (AI), VR, and gamification—offers further opportunities to enhance engagement and interactivity in science education. To ensure inclusivity and rigor, future systematic reviews should adopt comprehensive methodologies that minimize bias and capture a broader spectrum of educational practices across global contexts. Addressing these challenges is vital for ensuring equitable access to high-quality science education. By embracing and refining innovative teaching practices, educators can better prepare students to meet the demands of a rapidly evolving scientific and technological landscape.

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Author Contribution

Shella Mae T. Laid: conceptualization, methodology, article collection, article analysis, writing; Supervision: Dr. Mauricio S. Adlaon.

Competing Interest

The authors declare no conflict of interest.

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