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THE NEW NORM: EVALUATING BLENDED LEARNING IN SCIENCE EDUCATION – A SYSTEMATIC REVIEW

Nurashikin Muzafar[1*], Nur Jahan Ahmad[2]

[1] School of Educational Studies, Universiti Sains Malaysia, Malaysia
Email: auroraike@gmail.com
[2] School of Educational Studies, Universiti Sains Malaysia, Malaysia
Email: jahan@usm.my
[*] Corresponding Author

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Abstract:

In recent years, the educational landscape has transformed significantly, with blended learning emerging as a pivotal approach in science education. This Systematic Literature Review (SLR) examines the incorporation of blended learning, which incorporates traditional in-person teaching with online learning activities, presenting distinctive opportunities to improve student engagement, accessibility, as well as educational outcomes. However, the adoption of blended learning in science education encounters challenges, including digital equity issues, technology access, as well as the necessity for professional development for educators. Utilizing the PRISMA framework, this review systematically identifies, screens, and analyses relevant studies from Web of Science (WoS) as well as Scopus databases, focusing on publications from 2022 to 2024. Out of 1069 initial publications, 22 studies were chosen for in-depth analysis. Here, the findings reveal that blended learning environments foster critical thinking as well as problem-solving skills, which are vital for scientific inquiry, while also addressing limitations of traditional education, such as large class sizes and limited resources. However, challenges like technological access and teacher training persist. The review emphasizes the significance of strategic implementation as well as the need for a balanced approach that incorporates both synchronous and asynchronous learning formats. In conclusion, blended learning represents a paradigm shift in science education, offering a dynamic and flexible approach to Teaching and Learning (TnL). By critically evaluating its effectiveness and tackling the related challenges, educators can fully leverage blended learning to improve science education as well as equip students for future demands. This review provides insights into best practices for successful implementation, emphasizing the transformative potential regarding blended learning in improving educational outcomes.

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Keywords:

Blended Learning, Hybrid Learning, Science Education, Engagement, Challenges

Introduction

In recent years, education has seen a profound transformation spurred by technological progress and the changing demands of students. One of the most prominent changes is the rise of blended learning, an educational method that integrates traditional in-person teaching with online learning components. This hybrid model has gained traction across various educational settings, particularly in science education, where it offers unique opportunities to enhance student engagement, accessibility, and learning outcomes (Finlay et al., 2022; Gaffas, 2023; Taufik et al., 2022; Vallee et al., 2020). As educators and institutions strive to satisfy the needs with regard to the 21st-century learner, understanding the implications and effectiveness with regard to blended learning in science education has become increasingly important. Blended learning in science education is a trend and a response to the challenges and opportunities presented by the digital age. Combining digital resources as well as tools into the science curriculum enables a more customized and adaptable learning experience. Students can explore a vast array of online information and resources, engage in interactive simulations, and participate in virtual labs that complement traditional classroom activities (Gaffas, 2023; Sefriani et al., 2021; Taufik et al., 2022). This approach caters to diverse learning styles and adopts critical thinking as well as problem-solving skills, which are important in scientific inquiry. The shift towards blended learning is also driven by the need to prepare students for a rapidly changing world. Science education involves empowering learners with the knowledge as well as skills needed to understand complex scientific concepts and address real-world challenges. Blended learning environments offer students chances to collaborate with their peers, participate in hands-on experiments, as well as apply theoretical knowledge in practical contexts (Johler, 2022; Mohamed, 2022). This experiential learning approach is essential for fostering a deeper comprehension of scientific principles as well as their applications.

Moreover, blended learning addresses some of the limitations of traditional science education. Large class sizes, limited resources, and time constraints often hinder effective Teaching and Learning (TnL) in conventional settings. By leveraging online platforms, educators can offer supplementary materials, conduct assessments, and provide feedback more efficiently (Halasa et al., 2020; Yu et al., 2022). This not only improves the learning experience but also allows for more effective use of classroom time, where educators can focus on facilitating discussions, conducting experiments, and providing personalized support. Given the potential benefits, the blended learning implementation in science education does not avoid any challenges. Issues, for example, access to technology, digital equity, as well as the requirement for professional development for educators must be addressed to ensure successful integration (Hill & Smith, 2023; Rasheed et al., 2020). Additionally, evaluating the effectiveness of blended learning necessitates a thorough understanding of its effect with regard to student learning outcomes, engagement, and satisfaction.

In conclusion, blended learning represents a paradigm shift in science education, offering a dynamic and flexible approach to TnL. As educational institutions continue to embrace this model, it is imperative to critically evaluate its effectiveness and address the challenges

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associated with its implementation. By doing so, educators can fully leverage blended learning to improve science education and equip students for future challenges. This article seeks to investigate the current landscape with regard to blended learning concerning science education, examine its benefits as well as challenges, and provide insights into best practices for its successful implementation.

Literature Review

The shift towards blended learning in science education, especially with the occurrence of the COVID-19 pandemic, has been a focal point of recent educational research. On the other hand, the study by Fabian et al. (2024) highlights the transition to synchronous hybrid learning, where students participate both in-person and online simultaneously. This approach, while offering flexibility, presents challenges such as technological difficulties and reduced opportunities for collaboration. However, students reported better time management and engagement in hybrid settings. Similarly, Setiawaty et al. (2024) explored the mobile Augmented Reality (AR) integration in science education, finding that AR can enhance learning outcomes and student engagement, although content development remains a challenge. Lunt et al. (2024) examined team-based learning in large cohorts, noting improvements in engagement and performance and emphasizing the need to carefully adapt methodologies to suit hybrid environments.

Integrating digital skills into blended learning environments is crucial for developing transferable skills among students. Dissanayeke et al. (2024) demonstrated how digital group work assignments can foster skills such as teamwork and digital literacy, which are essential for employability. This is in line with the outcomes of Chohan et al. (2024), who investigated online design courses and proposed a hybrid pedagogy combining traditional and virtual instruction. Their research underscores the importance of structuring academic activities to effectively integrate online teaching strategies. McCaw et al. (2024) further explored blended synchronous learning in teacher education, identifying significant challenges related to institutional support and educator well-being but also highlighting the potential for professional development through collaborative learning. The influence with regard to course modality on student satisfaction, as well as academic findings, has been a subject of investigation, as seen in Dong's (2024) research at a liberal arts college. Here, the research found that while online classes resulted in lower satisfaction levels, blended learning offered a viable alternative with potential benefits. Calonge et al. (2024) focused on HyFlex courses, which combine face-to-face and online activities, finding that such courses can achieve equivalent learning outcomes if designed to promote engagement. Zhao et al. (2024) delved into the utilization of Virtual Reality (VR) in blended teaching, demonstrating its effectiveness in enhancing student acceptance and emotional attitudes, particularly in specialized courses like animation.

The application of blended learning in dental education, as discussed by Duś-Ilnicka et al. (2024), further illustrates the benefits of this approach in fostering interprofessional education and collaboration. The Blended Intensive Programme (BIP) organized by Wroclaw Medical University involved participants from multiple countries and incorporated both remote and in-person learning experiences. This program not only facilitated the exchange of knowledge but also strengthened international collaborations, highlighting the importance of hybrid teaching programs in broadening the learning spectrum in dental studies. Carter et al. (2024) examines the perceptions of elementary teacher candidates in a hybrid science methods course, demonstrating the benefits about blending online as well as in-person approaches to improve learning outcomes. Other than that, the research describes hands-on learning, flexibility, as

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well as peer interactions as key affordances of the hybrid model, while also acknowledging challenges such as self-discipline and pacing in online learning. Albeedan et al. (2024) present a Mixed Reality (MR) system designed for crime scene investigation training, showcasing how MR technology can offer interactive and cost-effective training experiences. These studies collectively emphasize the wide-ranging applications of blended learning across different educational settings and the potential to improve learning outcomes via innovative teaching methods.

The investigation of self-directed learning methods and techniques in blended learning courses, as investigated by Villalobos et al. (2024), provides valuable insights into the mechanisms with regard to student learning in these settings. The study employs data-driven methods to analyse the learning tactics and strategies of students across different course designs and learning contexts, revealing significant variations in tactics related to time management and interaction with self-regulated learning support tools. Wang et al. (2024) further investigate the impacts of blended learning utilising an LMS, employing machine learning algorithms to analyse the association between different dimensional factors and English proficiency scores. The research establishes association rules that provide improved student performance, highlighting the potential of LMS platforms in enhancing learning outcomes. Herodotou et al. (2024) propose a blended learning model for biodiversity monitoring within Community and Citizen Science (CCS) programs, highlighting the need to create inclusive, educational, as well as accessible initiatives for a wide range of volunteers. This research generally emphasizes the significance of understanding how students learn in blended environments and the potential for leveraging technology to enhance educational outcomes.

The design and evaluation of learning experiences in blended learning environments, as explored by Wong et al. (2024), emphasize the critical role about situational interest and user experience in enhancing student engagement. Utilizing a structural equation model, the research examines the relationships among user experiences, mind-wandering, situational interest, as well as online engagement, demonstrating substantial direct effects between these factors. The results highlight the necessity of integrating evidence-based pedagogical strategies with human-centred user experience design to boost engagement and minimize mind-wandering in online learning settings. These insights have important implications for the design of blended learning courses, emphasizing the need for a holistic approach that regards both user experience as well as pedagogical factors. These studies collectively emphasize the transformative impact about blended learning concerning science education as well as the importance of leveraging technology to enhance educational outcomes.

Research Question

Research Questions (RQs) are crucial in a Systematic Literature Review (SLR) because they prepare the foundation and direction for the entire review process. They guide the scope and focus of the SLR, helping to determine which studies to include or exclude, ensuring that the review remains relevant and specific to the topic of interest. A well-defined RQ ensures that the literature search is exhaustive and systematic, covering all relevant studies that address key aspects of the topic. This minimizes the risk of bias and ensures a complete overview of the existing evidence. Additionally, RQs facilitate the categorization and organization of data from included studies, providing a framework for analysing findings and synthesizing results to draw meaningful conclusions. They also enhance clarity and focus, avoiding ambiguity and keeping the review concentrated on specific issues, making the findings more actionable and relevant.

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Defining the RQs is crucial during the planning phase and is also the most significant aspect of any SLR, as it guides the entire review process (Kitchenham, 2007).

1. What are the primary challenges faced by science educators and students in the implementation of blended learning in science education?
2. How do different pedagogical strategies in blended and hybrid learning environments affect student engagement among high school science students?

Material And Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework is a greatly considered standard for conducting SLR, ensuring transparency, thoroughness, and consistency throughout the process. By adhering to PRISMA guidelines, researchers are systematically directed to identify, screen, and include studies in their review, thereby enhancing the accuracy and rigor of the analysis. This approach also underscores the significance of randomized studies, acknowledging their role in minimizing bias and providing robust evidence for the review Page et al., (2020). In this analysis, two primary databases, Web of Science (WoS) as well as Scopus, were chosen for their thorough nature and extensive coverage. However, it is recognized that no database is without flaws; each has limitations, such as coverage gaps or varying levels of detail, which must be considered during the review process.

The PRISMA framework is organized into four key sub-sections, which are identification, screening, eligibility, including data abstraction. Firstly, identification involves searching databases to locate all relevant studies. This is followed by screening, where studies are evaluated against predefined criteria to exclude those that are irrelevant or of low quality. The eligibility phase further assesses the remaining studies to ensure they meet the inclusion criteria. Finally, data abstraction involves extracting and synthesizing data from the included studies, which is essential for drawing meaningful and reliable conclusions. This structured approach ensures that the systematic review is conducted with high rigor, yielding reliable results that can inform further research and practice.

Identification

In this research, key stages of the systematic review process were employed to gather a substantial amount of pertinent literature. The process started with selecting keywords, then expanded to include related terms found through dictionaries, encyclopedias, thesauri, as well as prior studies. All relevant terms were assessed, and search strings were established about the WoS as well as Scopus databases (refer to Table 1). This initial stage regarding the systematic review yielded 1,069 publications related to the study topic from both databases.

Table 1: Search String

Scopus	TITLE-ABS-KEY ((blend* OR hybrid) AND (learning) AND (school) AND (science) AND (educat*)) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2024)) **Date of Access: August 2024**

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Wos	(blend* OR hybrid) AND (learning) AND (school) AND (science) AND (educat*) (Topic) and 2024 or 2023 or 2022 (Publication Years), Article (Document Types), English (Languages), as well as Education Educational Research or Social Sciences Other Topics (Research Areas) **Date of Access: August 2024**

Screening
During the screening phase, potentially relevant research items are assessed to confirm their alignment with the established RQs. This step typically involves choosing research items that focus on blended or hybrid learning in science education. Duplicate papers are removed at this stage. Initially, 934 publications were excluded, leaving 135 papers for further examination referring to specific inclusion as well as exclusion criteria (please refer to Table 2). Here, the primary criterion was literature, comprising key sources of practical recommendations such as meta-syntheses, reviews, books, meta-analyses, chapters, book series, as well as conference proceedings not included in the latest study. Note that the review focused exclusively on English-language publications from 2022 to 2024. Overall, thirty publications were not accepted due to duplication.

Table 2: The Selection Criterion Is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2022 – 2024	< 2022
Literature type	Journal (Article)	Review, Book, Conference
Publication Stage	Final	In Press
Subject	Social science	Besides Social science

Eligibility
In the third step, referred to as the eligibility phase, 105 articles were selected for review. During this process, the titles as well as key content of each article were thoroughly evaluated to ensure that they aligned with the research objectives and met the inclusion criteria. As a result, 83 articles were excluded because they did not qualify, either due to being outside the scope, having irrelevant titles, abstracts not aligned with the study's objectives, or lacking full-text access supported by empirical evidence. This left 22 articles for the subsequent review.

Data Abstraction as well as Analysis
In this research, an integrative analysis was utilised as among the assessment methods to review and combine various quantitative research designs. The primary objective was to examine pertinent topics as well as subtopics. Note that the initial phase of data collection was crucial for developing the overarching themes. As illustrated in Figure 2, the authors carefully assessed a collection of 22 publications to extract statements or information pertinence to the study's focus areas. They then assessed the crucial current research associated with blended learning in science education. Additionally, the methodologies and research findings of all the reviewed studies were thoroughly investigated. Subsequently, the author worked with co-authors to identify themes grounded in the evidence from this study. Correspondingly, throughout the data analysis, they maintained a log to document analyses, perspectives, questions, as well as other reflections pertinent to interpreting the data. Lastly, the authors contrasted their findings

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to check for inconsistencies in the theme development process. Consequently, if any differences in concepts arose, they were discussed collaboratively among the authors.

Quality of Appraisal

Referring to the guidelines suggested by Kitchenham and Charters (Kitchenham, 2007), after selecting the Primary Studies (PSs), it is necessary to evaluate the quality of the research they present and perform a quantitative comparison. In this study, we apply Quality Assessment (QA) from Anas Abouzahra et al, (2020), comprising six QAs for our SLR. The scoring procedure for evaluating each criterion involves three possible ratings: "Yes" (Y), having a score of 1 provided that the criterion is completely satisfied; "Partly" (P), having a score of 0.5 provided that the criterion is somewhat satisfied but contains some shortcomings or gaps, as well as "No" (N) having a score of 0 provided that the criterion is not satisfied at all.

Table 3: Outlines of QA process for Quality Assessment

Quality Assessment	Expert 1	Expert 2	Expert 3	Total Mark
Is the purpose of the study clearly stated?	Y	Y	Y	3
Is the interest and the usefulness of the work clearly presented?	Y	Y	Y	3
Is the study methodology clearly established?	Y	Y	Y	3
Are the concepts of the approach clearly defined?	Y	Y	Y	3
Is the work compared and measured with other similar work?	Y	Y	Y	3

The table outlines a QA process used to evaluate a study based on specific criteria. Three experts assess the study using the criteria listed, and each criterion is scored as "Yes" (Y), "Partly" (P), or "No" (N). Here is a detailed explanation:

1. **Is the purpose of the study clearly stated?**
   - This criterion checks whether the study's objectives are clearly defined and articulated. A clear purpose helps set the direction and scope of the research.
2. **Is the interest and usefulness of the work clearly presented?**
   - This criterion evaluates whether the study's significance and potential contributions are well-explained. It measures the relevance and impact of the research.
3. **Is the study methodology clearly established?**
   - This assesses whether the research methodology is well-defined and appropriate for achieving the study's objectives. Clarity in methodology is crucial for the study's validity and reproducibility.
4. **Are the concepts of the approach clearly defined?**
   - This criterion looks at whether the theoretical framework and key concepts are clearly articulated. Clear definitions are essential for understanding the study's approach.

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5. **Is the work compared and measured with other similar work?**
    - This evaluates whether the study has been benchmarked against existing research. Comparing with other studies helps position the work within the broader academic context and highlights its contributions.

Each expert independently assesses the study according to these criteria, and the scores are then totalled across all experts to determine the overall mark. For a study to be accepted for the next process, the total mark, derived from summing the scores from all three experts, must exceed 3.0. This threshold ensures that only studies meeting a certain quality standard proceed further.

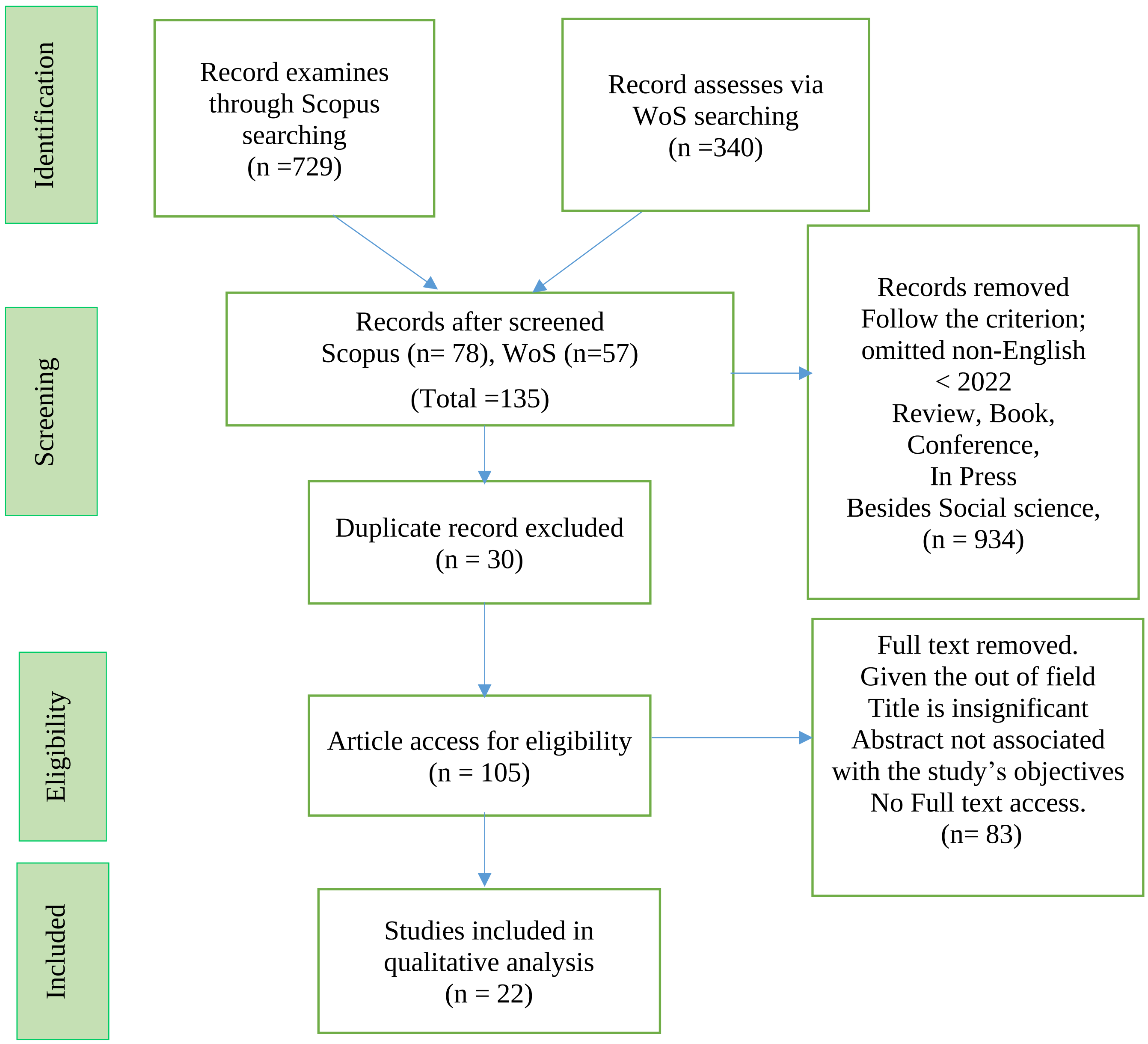

Figure 1. Flow Diagram About The Proposed Search Study

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Result and Finding
Background of selected study:

Table 4: Studies Included In Qualitative Analysis

No	Authors	Title	Year	Journal	Scopus	WoS
1	Silseth K.; Arnseth H.C. (Silseth & Arnseth, 2022)	Weaving together the past, present and future in whole class conversations: analyzing the emergence of a hybrid educational chronotope connecting everyday experiences and school science	2022	Mind, Culture, and Activity	/	
2	Nkanyani T.E.; Mudau A.V.; Sikhosana L. (Nkanyani et al., 2024)	Teaching and learning of physical sciences grade 11 in rural schools through a rural blended learning strategy	2024	Eurasia Journal of Mathematics, Science and Technology Education	/	
3	Peng Y.; Wang Y.; Hu J.(Peng et al., 2023)	Examining ICT attitudes, use and support in blended learning settings for students' reading performance: Approaches of artificial intelligence and multilevel model	2023	Computers and Education	/	/
4	Sun J.C.-Y.; Ye S.-L.; Yu S.-J.; Chiu T.K.F.(Sun et al., 2023)	Effects of Wearable Hybrid AR/VR Learning Material on High School Students' Situational Interest, Engagement, and Learning Performance: the Case of a Physics Laboratory Learning Environment	2023	Journal of Science Education and Technology	/	/
5	Lin M.-C.; Chen H.-C.; Liu H.-H.; Chang C.-Y.(Lin et al., 2022)	Implementation of E-Learning in New Taipei City During COVID-19	2022	Eurasia Journal of Mathematics, Science and Technology Education	/	
6	Barannikov K.; Ananin D.; Strikun N.; Alkanova O.; Bayzarov A.(Barannikov et al., 2023)	Hybrid Learning: Russian and International Practice	2023	Voprosy Obrazovaniya / Educational Studies Moscow	/	

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7	Mutya R.C.; Masuhay A.-R.L.(Mutya & Masuhay, 2023)	The extent of implementation of blended learning in senior high school science education vis-a-vis students' academic achievement	2023	Turkish Online Journal of Distance Education	/	/
8	Sundaram S.; Ramesh R.(Sundaram & Ramesh, 2022)	Effectiveness of joyful game-based blended learning method in learning chemistry during COVID-19	2022	International Journal of Evaluation and Research in Education	/	
9	Yusnidar; Fuldiaratman; Chaw E.P.(Chaw, 2024)	A study of mixed-method: science process skills, interests and learning outcomes of natural science in junior high school	2024	Jurnal Ilmiah Ilmu Terapan Universitas Jambi	/	
10	Salloum S.; Zgheib G.; Ghaffar M.A.; Nader M.(Salloum et al., 2022)	Flipping the Classroom Using the 5E Instructional Model to Promote Inquiry Learning in Online & Hybrid Settings	2022	American Biology Teacher	/	
11	Hermita N.; Erlisnawati; Alim J.A.; Putra Z.H.; Mahartika I.; Sulistiyo U.(Shamsul Hoque et al., 2023)	Hybrid learning, blended learning or face-to-face learning: which one is more effective in remediating misconception?	2024	Quality Assurance in Education	/	
12	Nuhoğlu H.; Şahin Sarkin D.B.; Aşiroğlu S.(Nuhoğlu et al., 2024)	Digital Transformation in Science Education: Teachers' Self-Efficacy of Distance Learning and Blended Learning Experiences	2024	Participatory Educational Research	/	
13	Bulut Ates C.; Aktamis H.(Bulut Ates & Aktamis, 2024)	Investigating the effects of creative educational modules blended with Cognitive Research Trust (CoRT) techniques and Problem-Based Learning (PBL) on students' scientific creativity skills and perceptions in science education	2024	Thinking Skills and Creativity	/	
14	Chekour M.; Seghroucheni Y.Z.; Tadlaoui M.A.; Hafid M.M.(Chekour et al., 2022)	Blended Learning and Simulation for Teaching Electrical Concepts to High School Pupils	2022	Journal of Turkish Science Education	/	

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15	Acut D.(Acut, 2022)	Developing SIPCaR projects utilizing modern technologies: Its impact on students' engagement, R&D skills, and learning outcomes	2022	LUMAT	/
16	Bedebayeva M.; Grinshkun V.; Kadirbayeva R.; Zhamalova K.; Suleimenova L.(Bedebayeva et al., 2022)	A blended learning approach for teaching computer science in high schools	2022	Cypriot Journal of Educational Sciences	/
17	Amponsah E.B.; Ayim M.; Forkuor J.B.(Amponsah et al., 2024)	From block placement to blended model: the way forward for social work practicum in Ghana	2024	Social Work Education	/
18	Sothayapetch P.; Lavonen J.(Sothayapetch & Lavonen, 2022)	Technological pedagogical content knowledge of primary school science teachers during the COVID-19 in Thailand and Finland	2022	Eurasia Journal of Mathematics, Science and Technology Education	/
19	Xu T.; Xu J.; Xu X.; Lu J. (Xu et al., 2023)	Blended learning on WeChat platform-based spot in lower-secondary school science teaching	2023	Journal of Baltic Science Education	/
20	Mulaudzi M.A.; Du Toit A.; Golightly A.(Mulaudzi et al., 2023)	Hybrid problem-based learning in Technology teacher preparation: Giving students a voice in their learning process	2023	Journal of Education (South Africa)	/
21	Samaila K.; Al-Samarraie H.(Samaila & Al-Samarraie, 2024)	Reinventing teaching pedagogy: the benefits of quiz-enhanced flipped classroom model on students' learning outcomes and engagement	2024	Journal of Applied Research in Higher Education	/
22	Udu D.A.; Nmadu J.; Uwaleke C.C.; Anudu A.P.; Okechineke B.C.; Attamah P.C.; Chukwuemeka C.O.; Nwalo C.N.; Ogonna O.C.(Udu et al., 2022)	Innovative Pedagogy and Improvement of Students' Knowledge Retention in Science Education: Learning Activity Package Instructional Approach	2022	Pertanika Journal of Social Sciences and Humanities	/

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The generated themes were later adjusted to maintain consistency. Three experts reviewed the analysis selection to evaluate and confirm the validity about the issues. During the expert review phase, the significance, clarity, as well as significance about each subtheme were affirmed by developing domain validity. Consequently, the authors also contrasted their outcomes to solve any differences that emerged during the theme development process. Any inconsistencies in the themes were discussed as well as addressed by the authors. Finally, the established themes were refined to maintain consistency. Hence, to confirm the validity regarding the issues, three experts conducted assessments. During the expert review stage, domain validity was established, ensuring that each sub-theme was clear, important, as well as adequate. Revisions were made according to the author's discretion, based on the feedback as well as comments given by the experts.

Theme 1: Blended and Hybrid Learning Approaches

The integration of hybrid as well as blended learning approaches in science education has been extensively studied, revealing both opportunities and challenges. Nkanyani et al. (2024) highlight the persistent issues in rural areas, such as the digital divide and insufficient teacher training, which prolonged the effective implementation of blended learning strategies. Despite these challenges, the study found that learners showed increased motivation and self-directed learning when engaged with Rural Blended Learning Strategies (RBLS). Similarly, Barannikov et al. (2023) emphasize the importance of learner agency in hybrid learning models, noting that while these models offer flexibility and individualized learning opportunities, they are not a one-size-fits-all solution. The study underscores the need for a balanced approach that considers both synchronous and asynchronous learning formats to cater to diverse educational goals. In the context of high school science education, Mutya & Masuhay (2023) report that implementing blended learning has led to outstanding academic achievements among students. The study found a significant relationship between content delivery and assessment methods, suggesting that well-structured blended learning environments can enhance student performance. This is in line with the outcomes of Hermita et al. (2024), who demonstrated that hybrid learning is particularly effective in addressing misconceptions in science education. The study advocates for the use of conceptual change models across various learning modes to maximize teaching strategies as well as enhance educational outcomes.

The role of technology in blended learning environments is further explored by Chekour et al. (2022), who examined the utilization of simulation tools in teaching electrical concepts. Their research indicates that integrating simulation into blended learning significantly improves conceptual understanding, with a notable difference in performance between students exposed to blended learning and those taught through traditional methods. This is supported by Xu et al. (2023), who found that using platforms like WeChat for pre-class knowledge transmission enhances student participation and performance, particularly among lower-performing groups. The study highlights the capability of digital platforms to assist resource sharing as well as independent learning. In teacher education, Mulaudzi et al. (2023) explore the benefits of hybrid Problem-Based Learning (hPBL) in the training of technology teachers. The study reveals that hPBL gives students a say in their learning process and actively involves them in constructing their knowledge. This approach is echoed by Bedebayeva et al. (2022), who emphasize the need for in-service training to enhance teachers' competencies in blended learning. Note that the research proposes that female teachers have greater competencies in blended learning, indicating potential areas for targeted professional development. Blended and hybrid learning approaches offer significant benefits in science education. Their success

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depends on addressing existing challenges such as technological access, teacher training, and the need for flexible learning models. The studies collectively advocate for strategic implementation of these approaches to maximize educational outcomes and support diverse learning needs.

Theme 2: Technology Integration in Education

Technology integration in education, primarily via blended learning, has been a focal point of recent studies, highlighting its effect on student performance and engagement. Peng et al. (2023) examined the influence of ICT-related factors regarding students' reading performance concerning a blended learning environment. Other than that, the study found that students' perceived autonomy as well as competence in ICT, along with the quality of school Information and Communication Technology (ICT) resources, positively influenced reading performance. However, excessive focus on ICT skills and teacher support negatively correlated with reading scores. This suggests a nuanced relationship between ICT integration and educational outcomes, emphasizing the need for balanced and well-structured ICT policies in schools. Similarly, Sun et al. (2023) demonstrated that the integration of wearable hybrid AR/VR technologies in physics education notably improved students' situational engagement, interest, as well as learning outcomes, demonstrating the capability of immersive technologies to transform science education.

The opportunities as well as challenges of e-learning amid the COVID-19 pandemic have been extensively documented. Lin et al. (2022) discovered the state of e-learning in New Taipei City, revealing significant challenges such as unfamiliarity with e-learning platforms, insufficient home equipment, and difficulties in assessing online learning progress. These outcomes highlight the need to overcome infrastructural as well as pedagogical challenges to optimize e-learning experiences. Similarly, Nuhoğlu et al. (2024) assessed science teachers' self-efficacy in blended learning environments, finding that gender, seniority, and school type influenced teachers' confidence in using digital tools. The study highlighted both positive and negative experiences with blended learning, suggesting that while digital transformation offers significant benefits, it also requires careful management to address teachers' concerns and enhance their teaching efficacy.

The role of Technological Pedagogical Content Knowledge (TPACK) in blended learning environments has been a critical area of study. Sothayapetch and Lavonen (2022) investigated the TPACK of primary school science teachers in Thailand as well as Finland in times of the COVID-19 pandemic. Correspondingly, the study determined that teachers effectively utilized educational technology to deliver lesson content and facilitate learning activities, with tools like Zoom and MS Teams integral to their teaching strategies. The research highlighted the importance of direct and technology-mediated interactions in enhancing students' learning experiences, emphasizing the need for teachers to develop robust TPACK to integrate technology successfully into their teaching practices.

Theme 3: Pedagogical Strategies and Student Engagement

Inquiry-based and Problem-Based Learning (PBL) approaches have been identified as effective strategies for fostering student engagement and creativity in science education. Salloum et al. (2022) demonstrated the effectiveness of combining the flipped classroom model with the 5E instructional model to support inquiry learning in online as well as hybrid settings. This approach encouraged students to engage in asynchronous online activities that accelerated

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curiosity as well as critical thinking before synchronous class sessions. Bulut Ates and Aktamis (2024) further supported the efficacy of PBL by integrating it with Cognitive Research Trust (CoRT) techniques to enhance students' scientific creativity. Their study showed that students exhibited improved creativity skills and positive perceptions of the educational modules, highlighting the importance of student-centered approaches in nurturing creativity. Udu et al. (2022) also emphasized the role of innovative pedagogies, for example, the Learning Activity Package (LAP), in enhancing active participation as well as knowledge retention in science education. These studies collectively underscore the value of inquiry-based and problem-based learning in engaging students and fostering critical thinking and creativity.

The integration of game-based learning methods has presented significant promise in improving student engagement as well as learning outcomes in science education. Sundaram and Ramesh (2022) explored the impact of a joyful game-based blended learning method on teaching chemistry to tenth-grade students. Their study revealed that educational games significantly improved learning performance and fostered positive attitudes toward science learning. Educational card games as well as digital media, promoted reflective thinking and self-regulated learning in students. Similarly, Acut (2022) found that Science Investigatory Projects and Robotics (SIPCaR) projects significantly increased student engagement and research skills, demonstrating the potential of interactive and technology-driven pedagogies in maintaining high levels of social engagement, behavioral, as well as cognitive. These findings align with the work of Samaila and Al-Samarraie (2024), who emphasized the benefits of embedding quizzes in flipped classroom models to improve learning achievement as well as student engagement. The interactive elements integration in learning activities appears to be a key factor in promoting student engagement and improving educational outcomes.

Discussion and Conclusion
The integration of blended and hybrid learning approaches in science education presents both opportunities and challenges. Persistent issues such as the digital divide and inadequate teacher training, particularly in rural areas, hinder the effective implementation of these strategies. Despite these challenges, learners often exhibit increased motivation and self-directed learning when engaged with RBLS. Hybrid learning models offer flexibility and individualized learning opportunities. However, they require a balanced approach incorporating synchronous and asynchronous formats to meet diverse educational goals. In high school science education, the blended learning implementation has been associated with significant academic achievements. A strong relationship between content delivery and assessment methods suggests that well-structured blended learning environments can enhance student performance. Hybrid learning is particularly effective in addressing misconceptions in science education, advocating for using conceptual change models across various learning modes to optimize teaching strategies. The role about technology in blended learning environments is crucial. The use of simulation tools in teaching electrical concepts improves conceptual understanding significantly, with students in blended learning environments outperforming those in traditional settings. Digital platforms, such as WeChat, enhance student participation and performance, especially among lower-performing groups, by facilitating resource sharing and independent learning. In teacher education, hPBL empowers students by involving them actively in the knowledge construction process. This approach highlights the importance of in-service training to enhance teachers' competencies in blended learning, with female teachers often demonstrating higher competencies. While blended and hybrid learning approaches offer significant benefits in science education, their success depends on addressing challenges such as technological access,

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teacher training, and flexible learning models. Strategic implementation of these approaches is essential to maximize educational outcomes and support diverse learning needs.

Recent studies have focused on incorporating technology into education, especially via blended learning, and its effects on student performance as well as engagement. Findings indicate that students' perceived autonomy as well as proficiency in ICT, including the quality of school ICT resources, positively influence reading performance. However, an excessive focus on ICT skills and support for teachers can negatively affect reading scores, indicating a complex relationship between ICT integration and educational outcomes. This underscores the necessity for balanced and well-structured ICT policies in schools. Additionally, integrating wearable hybrid AR as well as VR tools in physics education has proven to greatly boost students' situational engagement, interest, as well as learning outcomes, showcasing the transformative impact of immersive technologies in science education. The COVID-19 pandemic has underscored both the challenges as well as opportunities in e-learning. Studies have identified significant obstacles such as unfamiliarity with e-learning platforms, insufficient home equipment, and difficulties in assessing online learning progress. These challenges emphasize the need to address infrastructural and pedagogical barriers to optimize e-learning experiences. Furthermore, factors such as gender, seniority, and school type have been found to influence science teachers' self-efficacy in blended learning environments. While digital transformation offers substantial benefits, it requires careful management to address teachers' concerns and enhance their teaching efficacy. The role of TPACK in blended learning environments has been a critical area of study. Research has shown that primary school science teachers effectively utilize educational technology to deliver lesson content and facilitate learning activities, with tools like Zoom and MS Teams playing a vital role in their teaching strategies. Here, the significance of direct as well as technology-mediated interactions in enhancing students' learning experiences is emphasized, highlighting the need for teachers to develop robust TPACK to successfully incorporate technology into their teaching practices.

Inquiry-based and PBL strategies have proven effective in enhancing student engagement and creativity within science education. Integrating the flipped classroom model with the 5E instructional framework has proven effective in fostering inquiry-based learning in hybrid and online environments. This method encourages students to participate in asynchronous online tasks that spark curiosity as well as critical thinking prior to synchronous class sessions. Additionally, integrating PBL with CoRT techniques have been found to significantly enhance students' scientific creativity, demonstrating the importance of student-centered approaches in fostering creativity. Innovative pedagogies, for example, the LAP, have also been highlighted for their role in improving knowledge retention and active participation in science education. Collectively, these approaches underscore the value of inquiry-based and problem-based learning in engaging students and fostering critical thinking and creativity. The incorporation of game-based learning methods has demonstrated ample promise in elevating student engagement as well as learning outcomes in science education. A joyful game-based blended learning approach is indeed impactful in teaching chemistry to tenth-grade students, significantly improving learning performance and fostering positive attitudes towards science learning. Educational card games and digital media have promoted reflective thinking as well as self-regulated learning in students.

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