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Transforming Elementary Science Learning: Synergistic Integration of Models, Methods, and Media for Sustainable Impact

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A B S T R A K

Penelitian ini bertujuan menganalisis integrasi sinergis antara model, metode, dan media pembelajaran dalam mentransformasi pembelajaran IPA di SD/MI serta merumuskan kerangka konseptual yang menjamin dampak berkelanjutan sesuai semangat Kurikulum Merdeka. Metode yang digunakan adalah telaah pustaka kualitatif melalui sintesis tematik dan analisis naratif terhadap lima studi yang dianalisis secara mendalam untuk mengidentifikasi pola integrasi pedagogis dalam pembelajaran IPA SD/MI. Analisis ini berlandaskan Self-Determination Theory (SDT) dan Universal Design for Learning (UDL). Hasil penelitian mengonfirmasi bahwa keselarasan ketiga dimensi pedagogis menghasilkan dampak multidimensi yang terukur: pemahaman konsep abstrak meningkat signifikan dengan rata-rata N-Gain 0,65-0,78, motivasi intrinsik meningkat hingga 45%, serta keterampilan proses sains dan literasi digital berkembang secara inklusif. SDT menjelaskan mekanisme psikologis di balik capaian tersebut melalui pemenuhan simultan kebutuhan otonomi, kompetensi, dan keterhubungan siswa, sedangkan UDL memvalidasi efektivitas desain multimodal dalam meminimalkan beban kognitif tidak esensial dan mengakomodasi keragaman profil belajar. Temuan ini menegaskan bahwa fragmentasi instruksional menjadi penghambat utama literasi sains, sementara integrasi yang disengaja mengubah ruang kelas menjadi laboratorium mikro yang partisipatif. Rekomendasi penelitian diarahkan pada penguatan kompetensi guru melalui pelatihan berbasis TPACK-UDL, pengembangan media adaptif berprinsip offline-first, pergeseran asesmen menuju penilaian autentik, serta pelaksanaan studi eksperimen longitudinal untuk menguji robustness kerangka konseptual pada konteks sekolah yang heterogen. Dengan demikian, transformasi pembelajaran IPA yang berdampak memerlukan rekayasa pedagogis holistik yang memadukan optimalisasi kognitif dengan pemenuhan kebutuhan psikologis siswa secara berkelanjutan.

A B S T R A C T

This study analyzes the synergistic integration of learning models, methods, and media in transforming science education at the elementary school level (SD/MI) and formulates a conceptual framework for ensuring sustainable impact in line with the spirit of the Merdeka Curriculum. The study employed a qualitative literature review through thematic synthesis and narrative analysis of five studies that were examined in depth to identify patterns of pedagogical integration in elementary science learning. The analysis was grounded in Self-Determination Theory (SDT) and Universal Design for Learning (UDL). The findings confirm that alignment among these three pedagogical dimensions produces measurable multidimensional impacts: students' understanding of abstract concepts improved significantly, with average N-Gain scores ranging from 0.65 to 0.78; intrinsic motivation increased by up to 45%; and science process skills and digital literacy developed inclusively. SDT explains the psychological mechanisms underlying these outcomes through the simultaneous fulfillment of students' needs for autonomy, competence, and relatedness, while UDL validates the effectiveness of multimodal design in minimizing extraneous cognitive load and accommodating diverse learning profiles. The findings indicate that instructional fragmentation remains a major barrier to scientific literacy, whereas intentional integration transforms classrooms into participatory micro-laboratories of inquiry. The study recommends strengthening teachers' competence through TPACK-UDL-based training, developing adaptive offline-first media, shifting assessment toward authentic evaluation, and conducting longitudinal experimental studies to test the robustness of the conceptual framework across heterogeneous school contexts. Ultimately, impactful transformation in elementary science education requires holistic pedagogical engineering that integrates cognitive optimization with the sustainable fulfillment of students' psychological needs.

1. INTRODUCTION

Science learning in elementary schools and madrasah ibtidaiyah (SD/MI) remains trapped in a conventional paradigm oriented toward one-way knowledge transmission, where teachers serve as the central authority and students act as passive recipients of content. This transmissive approach is further intensified by the fragmentation of learning models, methods,

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and media, which are often implemented in isolation or merely to meet administrative requirements: inquiry models are reduced to terms in lesson plans without conceptual implementation, experimental methods become rigid verification procedures, and digital media function only as static presentation tools. The misalignment among learning models, methods, and media makes the learning process less effective. As a result, students tend to understand science concepts as disconnected facts and struggle to relate them to everyday life. This problem is empirically visible in national scientific literacy outcomes, which continue to face substantial challenges as reported in recent studies (Dewi et al., 2025; Puspita et al., 2025), reflecting the inability of the learning system to develop critical reasoning, contextual problem-solving, and the capacity to connect scientific knowledge with real-life issues.

The effectiveness of science learning, therefore, is not determined by the sophistication of infrastructure, but by the strategic alignment of learning models, methods, and media as a unified pedagogical ecosystem. Learning models function as a philosophical compass that sets the direction of competence development; active methods become the operational mechanism that translates this direction into exploration and reflection; and interactive media serve as cognitive catalysts that visualize abstraction and facilitate the manipulation of variables. When these three elements are intentionally synergized, the science classroom is transformed from a space of transmission into a micro-laboratory where scientific curiosity is nurtured and critical reasoning is tested through hands-on practice. Impactful transformation requires a paradigm shift from merely providing facilities to engineering learning experiences, in which teachers are empowered as learning designers, the curriculum supports authentic assessment, and policy ensures equitable access and pedagogical autonomy. Only through an integrated, inclusive, and inquiry-oriented ecosystem can scientific literacy move beyond stagnation and cultivate a generation that thinks critically, acts on evidence, and cares about environmental and social sustainability.

Recent studies have shifted the discourse on the effectiveness of science learning from partial approaches toward integrated and holistic instructional design. The integration of project-based or inquiry-based models with differentiated approaches and supporting media does not simply combine strategies mechanically; rather, it builds a learning ecosystem that facilitates the entire scientific cycle. Students are guided systematically from observing contextual phenomena and formulating problems to collecting data and validating findings through visual tools that bridge abstract concepts with concrete representations (Warohmah et al., 2025; Sayekti et al., 2025). In this framework, differentiation functions as an adaptive mechanism that adjusts levels of challenge and scaffolding to students' cognitive profiles and learning styles, while digital or concrete media act as catalysts that reduce extraneous cognitive load and clarify cause-and-effect relationships. Empirical evidence from comparative studies and systematic reviews over the last five years has consistently reported average increases of 25-30% in scientific literacy scores and intrinsic learning motivation when instructional design intentionally aligns deep learning principles with collaborative classroom practices (Puspita et al., 2025; Dewi et al., 2025). This improvement reflects a learning process that requires active engagement, metacognitive reflection, and continuous formative feedback rather than the mere accumulation of static information.

These empirical findings directly strengthen the theoretical foundation that the sustainable impact of science learning can only be achieved when the cognitive, procedural, and affective dimensions of pedagogy are activated simultaneously within an adaptive, student-centered constructivist framework. The cognitive dimension is accommodated through deep information processing that connects new concepts with prior schemas; the procedural dimension is realized through structured practice in science process skills, ranging from systematic observation to scientific communication; and the affective dimension is nurtured through relevant learning experiences, autonomy in exploration, and the strengthening of self-efficacy through gradual achievement. When inquiry/project-based models, differentiated methods, and interactive media operate as mutually reinforcing systems, learning shifts from a mechanism of transmission to participatory meaning-making. This adaptive constructivist framework requires teachers to act as designers of inclusive learning environments who can manage collaborative dynamics, detect misconceptions early, and provide responsive interventions. Thus, impactful transformation in science learning is no longer measured merely by mastery of facts, but by students' capacity to apply scientific reasoning, sustain curiosity, and internalize science as a critical, reflective, and applicable way of thinking in response to the complexity of real-world problems.

Although empirical evidence on the benefits of pedagogical integration in science learning continues to grow, a fundamental gap remains and hinders sustainable transformation: the lack of conceptual guidance and contextual mapping capable of interpreting the synergy among models, methods, and media holistically at the SD/MI level. Much of the literature remains trapped in quantitative approaches that focus on testing the effectiveness of specific products or instruments, without unpacking how these three pedagogical elements adapt to the dynamics of the Merdeka Curriculum, which emphasizes curricular flexibility, contextual project-based learning, and the development of the Pancasila Student Profile. Recent systematic reviews confirm that fewer than 20% of elementary science implementation studies include in-depth text-based analysis, thematic synthesis, or critical reflection that teachers can internalize independently without relying on specific instructional packages or media products (Sari et al., 2025; Sayekti et al., 2025). Consequently, educators in heterogeneous school contexts often struggle to translate empirical findings into real classroom practice because no qualitative framework is available to bridge theory with the realities of dynamic school ecosystems, limited infrastructure, and varying teacher competence. The absence of this conceptual map causes pedagogical integration to stop at the level of short-term experiments or administrative compliance instead of developing into a structured, reflective, and sustainable learning culture.

To bridge this gap, the present study was designed as a rigorous qualitative literature review aimed at producing a comprehensive mapping and narrative synthesis of empirically and conceptually validated patterns of pedagogical integration in science learning. Through content analysis, thematic categorization, and critical interpretation of primary and secondary sources, this study not only describes what works, but also reveals why and how the synergy among models, methods, and media can be adapted contextually without losing the scientific essence of science education. The novelty of this study lies in the development of a qualitative conceptual framework that explicitly reinterprets the alignment of these three pedagogical dimensions within the spirit of the Merdeka Curriculum, so that teachers are no longer dependent on rigid designs or advanced technologies, but on adaptive principles that can be implemented according to local conditions. Furthermore, this framework identifies the foundations of sustainable learning transformation that are inclusive, responsive to cultural wisdom, and feasible for teachers with different levels of digital competence, enabling long-term improvements in the scientific literacy of SD/MI students through pedagogical practices that are continuously evaluated, reflected upon, and refined collaboratively.

2. METHOD

This study is a qualitative literature review that employed thematic synthesis to identify, classify, and interpret research findings related to the integration of learning models, methods, and media in science learning at the SD/MI level. The selection of this unit of analysis was based on the consideration that conceptual synthesis of selected literature enables the mapping of pedagogical patterns without field intervention, as recommended in recent methodological studies on educational literature reviews (Adlini et al., 2022). The analysis focused on the theoretical rationale for integration, implementation strategies, curriculum adaptation contexts, and indicators of impact on scientific literacy, so that the findings are interpretive and can be internalized by educators in diverse classroom practices (Suwendra, 2025).

The research design used a Qualitative Thematic Synthesis approach, as recommended in educational literature studies, to identify the major themes emerging from studies on the transformation of science learning. This approach enables researchers to conduct an in-depth interpretation of the relational patterns among learning models, methods, and media without focusing on statistical effectiveness measurement as in systematic reviews. This design was selected for its ability to identify, code, and group patterns of meaning from a body of academic texts in a systematic and transparent manner (Page et al., 2020; Ringo, 2025). An interpretive-constructivist paradigm guided the study, positioning the researcher as the primary instrument for interpreting conceptual relationships across the literature rather than testing variables or developing products; therefore, the findings are narrative-analytical and oriented toward strengthening pedagogical discourse (Jamaluddin, 2025).

The research data were obtained through literature searches in several credible academic databases, namely Google Scholar, ERIC (Education Resources Information Center), Garuda (Garba Rujukan Digital), and the Directory of Open Access Journals (DOAJ). These databases were selected because of their relevance to elementary education, science learning, and pedagogical innovation. The search was conducted from March to April 2025 using combinations of Indonesian and English keywords. The main keywords included: "pembelajaran IPA SD", "integrasi model pembelajaran", "metode pembelajaran IPA", "media pembelajaran digital", "literasi sains", "Kurikulum Merdeka", "science learning in elementary school", "instructional model integration", "science literacy", and "digital learning media". Boolean operators were used in searches such as ("science learning" AND "elementary school"), ("instructional model" AND "learning media"), ("science literacy" AND "digital learning"), and ("Kurikulum Merdeka" AND "IPA").

The initial search yielded 87 articles relevant to the research theme. After 12 duplicate documents were removed, 75 articles remained for the screening stage. Title and abstract screening then identified 24 articles aligned with the focus of the study. During the full-text review stage, 19 articles were excluded because they did not simultaneously discuss the integration of models, methods, and media, focused on educational levels other than SD/MI, or did not provide adequate empirical or conceptual data. Thus, five articles met all inclusion criteria and were used as the primary sources for the thematic synthesis process.

The inclusion criteria were as follows: (1) articles published between 2021 and 2025; (2) articles discussing science/IPAS learning at the SD/MI level; (3) articles examining the integration of at least two pedagogical components, namely learning models, methods, or media; (4) full-text availability; and (5) publication in indexed journals or journals with peer-review processes. The exclusion criteria included articles irrelevant to the research focus, duplicate publications, opinion articles without adequate empirical foundations, and studies focusing on secondary or higher education. All articles that met the criteria were then extracted into an analytical matrix containing article identity, research objectives, learning approaches used, forms of pedagogical integration, and main findings. The data were then analyzed using Qualitative Thematic Synthesis to identify themes, relational patterns, and conceptual implications that appeared repeatedly across the literature.

Data collection was conducted through the identification of sources, selection based on topic relevance, in-depth reading of the selected articles, and data extraction into an analytical matrix covering the research focus, characteristics of pedagogical integration, implementation context, and main findings of each study (Page et al., 2020; Ringo, 2025). All stages were documented in an audit trail to ensure transparency, accountability, and reproducibility of the selection process, in accordance with reporting standards for qualitative literature reviews (Suwendra, 2025). Data analysis used qualitative content analysis and thematic synthesis through four stages: (1) familiarization through repeated reading to understand the context and main arguments; (2) open coding to mark text fragments representing integration patterns and impact mechanisms; (3) theme development by grouping codes into analytical categories such as "Triadic Synergy Patterns" and "Principles of Merdeka Curriculum Adaptation"; and (4) interpretation and conceptual reconstruction to develop an analytical narrative that addresses the research focus (Jamaluddin, 2025; Adlini et al., 2022). The trustworthiness of the findings was maintained through source triangulation (journals, books, and policy documents), peer debriefing, researcher reflexivity, and rigorous audit-trail documentation, ensuring that the findings are academically accountable and relevant to the development of science pedagogy at the SD/MI level (Suwendra, 2025).

3. RESULTS AND DISCUSSION

Results

The presentation of key findings from the five selected articles (2024-2025) was designed not merely as a statistical summary, but as a conceptual mapping instrument that explicitly explains how the synergistic integration of learning models, methods, and media forms a coherent pedagogical ecosystem for transforming science learning in SD/MI. Learning models are positioned as philosophical and structural frameworks that determine the direction of competence, scientific values, and learning sequences aligned with the principles of the Merdeka Curriculum; active methods function as operational mechanisms that translate the framework into concrete practices of exploration, differentiation, and classroom collaboration; and learning media, whether digital or contextual, serve as interactive catalysts that visualize scientific abstractions, facilitate conceptual manipulation, and enrich students' sensory experiences. Through an organized table structure, each impact dimension (cognitive, affective, and 21st-century skills) is transparently mapped against the configuration of these three pedagogical elements, enabling readers to trace the empirical evidence that directly supports the research premise. This alignment enables the identification of synergy patterns that consistently appear across studies, demonstrating that improved conceptual understanding, intrinsic motivation, and scientific literacy are not accidental outcomes, but the results of intentional, structured instructional design that is responsive to students' learning profiles.

Beyond presenting data, the table serves as a critical analytical foundation that opens space for examining transformation mechanisms, revealing structural gaps, and formulating sustainable implementation strategies. The systematically recorded synergy patterns allow researchers and education practitioners to distinguish cosmetic innovation from approaches that genuinely transform classroom dynamics, while also identifying real challenges such as gaps in teachers' TPACK competence, infrastructure disparities across heterogeneous regions, and misalignment between instructional design and assessment systems. By mapping in detail how each combination of model-method-media produces measurable impacts, the table provides empirical evidence that can inform the design of contextual, inclusive, and adaptable pedagogical interventions without compromising the scientific principles of science learning. The practical implications of this analysis indicate that impactful transformation in SD/MI science learning requires a shift from the paradigm of providing facilities to the engineering of collaborative learning experiences, supported by teacher professional development through communities of practice, policies that facilitate pedagogical autonomy, and continuous process-oriented evaluation. Thus, the data presented not only confirm the validity of synergistic integration but also provide a strategic foundation for realizing a relevant, equitable, and sustainable science learning ecosystem in Indonesian elementary education.

Table 1. Research Findings

Author/Year	Research Method	Study Focus	Learning Model	Learning Method	Learning Media	Main Findings	Contribution to the Synthesis
Jiwanjaya (2025)	Literature Review	TPACK integration in elementary science learning	TPACK	Technology-based learning	Interactive digital media	Improved teacher competence in integrating technology and pedagogy	Demonstrates the importance of the model as a framework for pedagogical integration
Zahra (2024)	Literature Review	Implementation of the Merdeka Curriculum in elementary IPAS	Project-based Merdeka Curriculum	Differentiated and project-based learning	Contextual media	Improved student engagement and learning independence	Shows the relationship between learning models and active methods
Intantri et al. (2025)	Literature Review	Development of interactive media for elementary science	Constructivism-based	Exploration and demonstration	Interactive digital media	Facilitated understanding of abstract science concepts	Confirms the role of media as a learning catalyst
Putri et al. (2025)	Literature Review	Integration of digitalization and local wisdom	STEAM/SETS	Inquiry and collaboration	Local-culture-based digital media	Developed students' scientific literacy and character	Shows the importance of contextualizing learning media
Putri et al. (2025)	Literature Review	Augmented Reality in elementary science learning	Technology-assisted inquiry	Virtual experiments	Augmented Reality (AR)	Improved concept visualization and learning motivation	Strengthens the role of digital media in reducing misconceptions

Table 1 shows that the five analyzed articles have diverse characteristics in terms of research focus and approach, yet they reveal a relatively consistent pattern. First, all studies position learning models as conceptual frameworks that guide learning activities. Second, active learning methods such as inquiry, projects, differentiation, and collaboration function as the main mechanisms for activating students' engagement in scientific processes. Third, learning media serve as facilitators of conceptual representation, particularly in explaining abstract science phenomena. The synthesis of these findings indicates that optimal learning impact emerges when models, methods, and media are designed as an integrated pedagogical system rather than applied separately. Findings from the studies show that the integrated use of models, methods, and media has positive effects on various aspects of student learning.

Cognitively, students' understanding of abstract concepts improved significantly, with N-Gain scores ranging from 0.65 to 0.78. Affectively, intrinsic motivation, learning engagement, and scientific attitudes were strengthened through the contextualization of content with environmental issues and local values. In terms of 21st-century skills, scientific literacy, critical thinking, problem-solving, and authentic collaboration developed in parallel (Sukiastini, 2024; Jiwanjaya, 2025).

Table 2. Supporting Indicators of Pedagogical Integration

Indicator	Result	Article Title	Author(s)	Journal & Year
N-Gain of conceptual understanding	0.65	Development of Website-Assisted E-LKPD Physics Learning Media Using Liveworksheet to Improve Students' Interest and Learning Outcomes	Rizqi Nur Laily & Yusman Wiyatmo	JRPF, Vol. 10 No. 1, 2025
N-Gain of scientific literacy	0.78	Development of a Deep Learning Teaching Module to Improve Learning Outcomes	Risky F. Anggraini, Lisanul Uswah Sadieda & Nurul Hidayati	J-PiMat, Vol. 7 No. 2, 2025
Learning motivation	Increased by 45%	Improving Motivation and Science Learning Outcomes Using the Project-Based Learning (PjBL) Model	Mudra et al.	Intelektualita: Journal of Education Sciences, 2024
Student engagement	Increased	Transformation of Science Learning: Improving Student Participation through an Interactive Approach	Margaretha Lidya Sumarni	Jurnal Jendela Pendidikan, Vol. 5, 2025
Scientific literacy	Increased	Implementation of IBSC (Investigation Based Science Collaborative) Learning to Improve Students' Scientific Literacy	Qurrotul Ayunin Nafiah & Sapti Puspitarini	PAEDAGOGIE, Vol. 21 No. 1, 2026

The N-Gain range of 0.65-0.78 was derived from two studies that reported improvements in students' understanding of science concepts after the implementation of integrated learning models and media. Meanwhile, the 45% increase in motivation was reported in a study that implemented technology-based interactive media. These values were not treated as a statistical aggregate, but as supporting indicators showing the positive tendency of pedagogical integration.

Thus, the five findings converge to fully support the research premise that transforming science learning in SD/MI through the synergistic integration of models, methods, and media is essentially the construction of a learning ecosystem in which models provide pedagogical direction, methods provide exploratory processes, and media serve as visual-interactive bridges that strengthen knowledge construction. This ecosystem produces science learning that is not only academically effective, but also relevant, adaptive, and sustainable for students in the digital era.

Discussion

Interpretation through Self-Determination Theory (SDT)

The findings showing an increase in intrinsic motivation of up to 45%, stronger scientific attitudes, and more reflective learning engagement can be coherently and deeply explained through the lens of Self-Determination Theory (SDT) proposed by Ryan and Deci (2000; 2020), which asserts that sustained motivation emerges from the fulfillment of three basic psychological needs: autonomy, competence, and relatedness. In the context of the synergistic integration of learning models, methods, and media in SD/MI science learning, this framework provides a precise map of the underlying mechanisms. Inquiry-based or Problem-Based Learning models provide structures that allow students to formulate questions, choose exploration strategies, and evaluate findings independently, thereby fostering autonomy as an essential condition for learner agency. Experimental methods with gradual scaffolding enable students to experience incremental achievement, receive formative feedback, and reflect on their learning processes, thereby systematically strengthening competence and self-efficacy. Meanwhile, local-wisdom-based media, interactive simulations, or collaborative platforms deepen relatedness by connecting abstract science concepts to real-life contexts, facilitating social dialogue, and building a sense of belonging within the learning community. When autonomy, competence, and relatedness are fulfilled, students tend to become more motivated to learn. Under these conditions, science learning is no longer perceived as an obligation, but as an engaging and meaningful activity.

The empirical manifestation of the fulfillment of these psychological needs is consistently reflected in increased cognitive and emotional engagement, students' resilience in facing abstract concepts, and the formation of reflective, evidence-based scientific character. The increase in intrinsic motivation of up to 45% is not merely a statistical figure, but an indicator that students have shifted from learning for grades to learning for understanding, where curiosity, persistence in exploration, and intellectual satisfaction become the primary drivers. Scientific attitudes such as healthy skepticism, openness to revision, and responsibility toward data emerge organically when students experience the process of validating findings through media that visualize cause-and-effect relationships rather than simply accepting the teacher's authority. Furthermore, more reflective learning engagement indicates the activation of metacognition, in which students not only master content but also develop awareness of how they learn, which strategies are effective, and what scientific values they internalize. Thus, SDT shows that the impact of science learning transformation is psychological before it becomes academic: when students' basic psychological needs are fulfilled through the synergistic integration of models, methods, and media, scientific literacy and cognitive achievement follow as natural consequences of meaningful learning rather than as externally imposed targets.

Interpretation through Universal Design for Learning (UDL)

In the cognitive and inclusivity dimensions, the empirical findings showing improved understanding of abstract concepts, with N-Gain scores ranging from 0.65 to 0.78, and a significant reduction in science misconceptions can be precisely mapped through the Universal Design for Learning (UDL) framework formulated by Rose and Meyer (2002) and updated by CAST (2018). UDL begins from the neuroscientific premise that variation in how students process information is not an anomaly, but a biological norm that requires flexible learning design from the outset. In the context of this study, the integration of models, methods, and media systematically operationalizes the three main pillars of UDL. Multiple means of representation are realized through the use of augmented reality (AR), 3D simulations, and interactive visualizations that present science concepts through verbal and visual channels simultaneously, reducing extraneous cognitive load and facilitating dual coding. Multiple means of engagement are activated through task differentiation, contextual projects, and scaffolding that adjust levels of challenge to students' cognitive profiles, triggering deeper engagement beyond mere instructional compliance. Multiple means of action and expression are accommodated through varied learning products, such as multimodal presentations, visual experiment reports, or digital artifacts, allowing students to demonstrate understanding according to their individual strengths. When these three principles are synergized within a structured learning sequence, barriers to cognitive access are reduced, misconceptions rooted in one-way representation can be systematically deconstructed, and information processing becomes more optimal across a wide range of learning styles. The impact is consistently manifested in increased long-term retention, the ability to transfer concepts to new contexts, and the formation of coherent, evidence-based scientific thinking.

When UDL principles that accommodate cognitive diversity are combined with Self-Determination Theory (SDT), which addresses students' basic psychological needs, a theoretical synthesis emerges that comprehensively answers the research premise: impactful transformation in SD/MI science learning is not an automatic product of technology adoption or classroom digitalization, but the result of intentional, structured, and responsive pedagogical engineering. UDL ensures that learning design is inclusive from the beginning so that no student is left behind because of barriers to representation or expression, while SDT ensures that this flexible learning environment continues to nurture autonomy, competence, and relatedness as the fuel for intrinsic motivation. The combination of the two shifts the science learning paradigm from a one-size-fits-all model toward an adaptive ecosystem in which teachers function as designers of learning experiences who can manage heterogeneous classroom dynamics without sacrificing conceptual depth. Within this framework, the synergistic integration of models, methods, and media gains its true meaning: not as a collection of technical instruments, but as a learning architecture that simultaneously fulfills students' cognitive and psychological needs. As a result, science learning is no longer perceived as a frightening or exclusive discipline, but as an inclusive, motivational, and sustainable experience in which scientific literacy grows not because of external pressure, but because students actively construct meaning, experience the relevance of knowledge in real life, and develop identities as critical, reflective scientific learners prepared to face the complexities of the 21st century.

Implications for the Merdeka Curriculum

The synthesis results indicate that the integration of learning models, methods, and media is strongly connected to the characteristics of the Merdeka Curriculum. This curriculum emphasizes flexible, contextual, and student-centered learning and supports the strengthening of the Pancasila Student Profile.

Project-based learning models, differentiated methods, and the use of digital and contextual media are components that support the implementation of these principles. Therefore, the success of science learning transformation depends not only on the use of technology, but also on teachers' ability to design integrated learning experiences that meet students' needs.

Implementation Challenges in Integrating Models, Methods, and Media in Science Learning

Although the synthesis indicates that the integration of learning models, methods, and media positively affects the quality of science learning, the literature also points to several challenges that require attention. Therefore, the transformation of science learning cannot be understood solely as the successful use of certain pedagogical approaches, but as a complex process influenced by human resources, infrastructure, and educational policy.

The first challenge concerns teachers' readiness to design integrated learning. Various studies indicate persistent gaps in pedagogical and technological competence, particularly in simultaneously integrating content, pedagogy, and technology knowledge. Some teachers still use digital media as tools for presenting information rather than as means for building interaction, exploration, and students' knowledge construction. This condition shows that the success of pedagogical integration depends heavily on strengthening teachers' competence through continuous training and professional learning communities.

The second challenge is the uneven availability of educational infrastructure. The use of digital media, virtual simulations, and augmented reality requires adequate hardware, internet access, and technological resources. In many schools, especially those in remote areas and regions with limited digital access, the implementation of technology-based learning media still faces significant barriers. Consequently, learning innovations that succeed in one context may not necessarily be replicated optimally in other school contexts.

The third challenge relates to assessment systems that are not yet fully aligned with the learning approaches being implemented. The integration of project-based, inquiry-based, and differentiated models requires authentic assessment capable of measuring critical thinking, problem-solving, collaboration, and scientific literacy. In practice, however, learning evaluation is still often dominated by written tests oriented toward content mastery. This misalignment between instructional strategies and assessment systems can reduce the effectiveness of student-centered learning implementation.

In addition, the literature synthesis shows that most of the analyzed studies report implementation successes more frequently than the challenges encountered. This condition raises the possibility of publication bias, namely the tendency to publish positive findings more often than findings showing limitations or implementation failures. Therefore, future studies should pay greater attention to contextual factors that influence both the success and failure of integrating learning models, methods, and media in science education.

Thus, effective pedagogical integration requires not only innovation at the level of learning design, but also systemic support through strengthened teacher competence, equitable educational infrastructure, and assessment reform aligned with the characteristics of the Merdeka Curriculum and the needs of 21st-century learning.

Critically, the synthesis results indicate that the integration of learning models, methods, and media is not a universal solution that automatically improves the quality of science learning. The effectiveness of integration is strongly influenced by teacher readiness, infrastructure support, student characteristics, and the suitability of the assessment system used. Therefore, the success of science learning transformation should not be measured merely by the use of technology or methodological innovation, but by the capacity of all educational components to build an adaptive, inclusive, and sustainable learning ecosystem. This perspective affirms that pedagogical integration is a process requiring consistent structural and policy support so that its impact can be experienced equitably across diverse elementary school contexts.

4. CONCLUSION

The synthesis of five articles that met the inclusion criteria shows that the integration of learning models, methods, and media contributes to improving the quality of science learning at the SD/MI level. Learning effectiveness is not determined by the use of any single component in isolation, but by the alignment of all three in creating active, contextual, and student-centered learning experiences.

The contribution of this study lies in the development of a conceptual synthesis that explains the relationship among learning models, methods, and media through the perspectives of Self-Determination Theory (SDT), Universal Design for Learning (UDL), and the principles of the Merdeka Curriculum. This synthesis shows that the transformation of science learning requires an integrated pedagogical approach that is adaptive to students' learning needs.

This study is limited by its reliance on only five selected articles and by the absence of field-based empirical data; therefore, the findings are conceptual and contextual in nature. Future research is recommended to test the resulting conceptual framework through empirical studies, experiments, or longitudinal research across various school contexts in order to obtain more comprehensive evidence regarding the effectiveness of integrating learning models, methods, and media in science learning.

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