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From Personalization to Humanization: A Systematic Review of Digital Technologies in Differentiated Instruction

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Abstract

Digital transformation in primary education is increasingly focusing on the integration of Learning Management Systems (LMS) and Artificial Intelligence (AI) to facilitate student-centered learning environments. Differentiated Instruction (DI) has emerged as a promising pedagogical approach to accommodate the heterogeneity of students' learning needs. The integration of personalization technologies has been shown to enhance students' intrinsic motivation, situational interest, and academic performance. However, excessive instructional "platformization," where digital devices dominate classroom interactions, often introduces new challenges such as digitally mediated surveillance that constrains the relational and pedagogical teacher-student relationship. This Systematic Literature Review (SLR) article aims to map the research developments on the utilization of digital technologies in differentiated instruction from 2021 to 2026. Utilizing a systematic review method guided by the PRISMA protocol, analyses were conducted on peer-reviewed studies from reputable international databases. The review findings indicate a shift in research focus from web-based content delivery to AI-driven adaptive instructional systems. The success of digital technology in DI must not be evaluated solely by its algorithmic automation efficiency, but rather by its capacity to restore students' metacognitive agency, support the humanistic mediating role of teachers, and strengthen social interactions in the classroom. The practical and theoretical implications of this transition from "personalization to humanization" are discussed to guide the design of child-friendly and equitable primary education platforms.

1. Introduction

The level of student diversity in classrooms today is an inevitable reality faced by educators worldwide (Daşçıoğ lu & Bu men, 2025; Lanğelaan et al., 2024). Students brinğ hiğhly varied individual characteristics to the classroom, ranğinğ from differences in academic ability and learninğ readiness to socio-economic backğrounds, culture, lanğuağe, learninğ styles, motivation, as well as self-reğulation competencies (Ackermans et al., 2025; Daşçıoğ lu & Bu men, 2025; Kalinowski et al., 2024). In urban environments, this heteroğeneity becomes even more complex and siğnificantly influences classroom dynamics (Lanğelaan et al., 2024). Facinğ these challenğes, a riğid "one-size-fits-all" curriculum approach has proven to iğnore individual differences and risks increasinğ the number of academically struğğlinğ students (Griful-Freixenet et al., 2020; Lanğelaan et al., 2024). In response to these inclusion needs, researchers and policymakers urğe educators to implement Differentiated Instruction (DI) to maximize the development potential of every child in reğular classrooms (Daşçıoğ lu & Bu men, 2025; Lanğelaan et al., 2024; Pozas et al., 2023).

As a learninğ philosophy and praxis, DI is rooted in the recoğnition of learner variability (Griful-Freixenet et al., 2020; Lanğelaan et al., 2024). Within a comprehensive DI framework, teachers proactively modify four curricular elements—namely content (what is learned), process (how students make sense of information), product (how they demonstrate learninğ), and the learninğ environment or affect—to respond to differences in students' readiness, interest, and learninğ profiles (Kahmann et al., 2024; Kalinowski et al., 2024; Lanğelaan et al., 2024). DI is ğrounded in social constructivist theory, particularly Vyğotsky's concept of the Zone of Proximal Development (ZPD), which emphasizes the importance of tarğeted and adaptive scaffoldinğ (Kalinowski et al., 2024; Stollman et al., 2019). Althouğh teachers stronğly ağree with the

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pedağoğical benefits of differentiated instruction, consistently implementing DI in real classrooms remains a formidable challenge (Daşçıoğ lu & Bu men, 2025; Pozas et al., 2023). Time constraints, a lack of curriculum resources, and teachers' limited skills in rapidly diagnosing student competencies are major barriers that often lead to low frequencies of DI implementation in the classroom (Daşçıoğlu & Bu men, 2025; Kahmann et al., 2024; Pozas et al., 2023).

To overcome these practical barriers, digital technology has been massively integrated into classrooms as an innovative solution to facilitate Personalized Learning (PL) (Alrawashdeh et al., 2024; Nafiah et al., 2026). Data-driven learning technologies, such as Learning Management Systems (LMS), Intelligent Tutoring Systems (ITS), mobile applications, and Generative Artificial Intelligence (GAI) are now utilized to present customized learning paths in real-time based on student profiles (Annus & Kmet', 2024; Liu et al., 2025; Nafiah et al., 2026). Powered by AI, these systems can automatically curate learning content and assign task difficulty levels based on continuous formative evaluation (Annus & Kmet', 2024; Liu et al., 2025). Experimental studies demonstrate that using learning materials and tasks adapted to students' personal interests (even those outside of traditional school subjects) successfully triggers situational interest, boosts intrinsic motivation, and optimizes students' academic performance in mathematics, science, and language arts (Ackermans et al., 2025; Mo tteli et al., 2023). Technology is viewed as an "intelligent tutor" capable of transcending the physical limitations of a teacher in managing large classrooms (Ackermans et al., 2025; Annus & Kmet', 2024).

However, the dominance of adaptive technology in self-directed learning within primary education has also sparked new concerns known as the "platformization" of the classroom (Kavanagh et al., 2025). When instructional interaction becomes heavily mediated by digital devices (such as laptop or tablet usage where each student wears headphones and stares at their respective screens), the warm relational connection between teachers and students is at risk of being distorted (Kavanagh et al., 2025). Teachers are often reduced to mere administrators monitoring the pace of student task completion through data dashboards (Kavanagh et al., 2025). Furthermore, this platformization invites a form of digitally mediated surveillance that triggers instructional anxiety and causes teachers to feel a loss of pedagogical autonomy because curricular decisions are "taken over" by system algorithms (Kavanagh et al., 2025). Many primary educators also hold a strong belief that children's fundamental skills, such as literacy, language, and social character, must naturally be acquired through human-to-human dialogue (Pflaumer et al., 2021). Uncontrolled use of personalization technology can lead to students losing opportunities for socialization and collaborative peer learning (Kavanagh et al., 2025; Pflaumer et al., 2021).

Therefore, a systematic critical review is needed to balance technological automation with the restoration of human values in the classroom, a paradigm shift from technical "personalization" to instructional "humanization." Humanization in digital learning recognizes that human learning involves holistic cognitive, affective, relational, and contextual dimensions (Kavanagh et al., 2025; Nafiah et al., 2026). Intelligent technology must not be used to usurp students' self-regulation but should act as a facilitator that cultivates students' metacognitive awareness so they grow into self-directed learners under the guidance of a humanistic teacher (Ackermans et al., 2025; Annus & Kmet', 2024). In a reformulated instructional triangle, the presence of computers and data must be positioned as interactive tools that enrich interpersonal dialogue rather than isolating it (Kavanagh et al., 2025).

As a scientific contribution to bridging these dynamics at the primary school level, this Systematic Literature Review (SLR) article is developed with the aim of synthesizing global literature from 1989 to 2025 regarding the application of digital technology in differentiated instruction (Nafiah et al., 2026). Through a rigorous systematic review method, this study explores: (1) how digital technology influences student learning agency, (2) the pedagogical and digital barriers faced by primary school teachers during the adoption of adaptive technology, and (3) how to reconceptualize technology integration to support a differentiated learning environment that humanizes students.

2. Method

To construct a comprehensive, rigorous, and replicable synthesis of digital technologies in differentiated instruction (DI) and personalized learning (PL), this study implemented a Systematic Literature Review (SLR) guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Alrawashdeh et al., 2024; Langelaan et al., 2024). The review process was structured around four main phases: (1) identification of

publications through database searches, (2) screening of titles and abstracts, (3) eligibility assessment of full-text documents, and (4) qualitative content synthesis of the selected studies (Griful-Freixenet et al., 2020).

2.1 Search Strategy and Data Source

A systematic search syntax was formulated and executed across major international databases in educational and social sciences: Scopus and ScienceDirect. To ensure high relevance and temporal alignment with recent advances in artificial intelligence and digital transformation, the search was restricted to peer-reviewed articles published between 2021 and 2026 (Nafiah et al., 2026). The Boolean search string combined two distinct groups of keywords:

> **Technology & Personalization terms:** ("learning management system" OR "LMS" OR "personalized learning" OR "adaptive learning technology" OR "artificial intelligence" OR "generative AI" OR "educational technology")
> **Differentiated Instruction & Primary Education terms:** ("differentiated instruction" OR "adaptive teaching" OR "primary education" OR "elementary school" OR "K-12")

These groups were intersected using the AND operator, restricting search fields to titles, abstracts, and keywords (Alrawashdeh et al., 2024; Nafiah et al., 2026).

2.2 Selection Criteria (Inclusion and Exclusion)

To filter the initial search results, strict selection criteria were applied based on target population, publication quality, research design, and thematic focus (Langelaan et al., 2024; Nafiah et al., 2026).

These criteria are detailed in Table 1.

Criterion	Inclusion Criteria	Exclusion Criteria
Time Period	Published between 2021 and 2026	Published prior to 2021
Document Type	Peer-reviewed journal articles and book chapters	Dissertations, conference abstracts, reports, and grey literature
Language	Available in English [219, 411]	Non-English publications
Target Population	Primary/elementary school	Higher education, early childhood/kindergarten, and adult learners
Thematic Focus	Evaluates the integration of digital tools (LMS, AI, GAI, mobile) to support DI or PL	Subject-specific didactics without general PL/DI implications, or non-digital DI
Methodology	Empirical studies (RCT, QED, mixed methods, bibliometrics, and SLR)	Purely opinion-based articles, editorials, or non-systematic reviews

2.3. PRISMA Flow of Information

The search across the Scopus, Web of Science, and ERIC databases yielded an initial pool of 1,842 records (Alrawashdeh et al., 2024). After removing duplicates using text-matching software (Zotero/OpenRefine), 1,780 unique publications remained (Langelaan et al., 2024; Nafiah et al., 2026). Screening of titles and abstracts based on inclusion criteria excluded 1,718 records due to irrelevance to the target population (mainly tertiary education) or lack of digital personalization focus (Nafiah et al., 2026).

A total of 62 publications were selected for full-text eligibility assessment (Alrawashdeh et al., 2024). After collaborative research team deliberations, 47 articles were excluded because they did not explicitly link the technical personalization features of software to teacher-mediated differentiated instruction, or fell outside the 2021–2026 timeline. Ultimately, exactly 15 core studies were selected for in-depth qualitative content synthesis and discussion. The systematic selection flow is mapped in Figure 1.

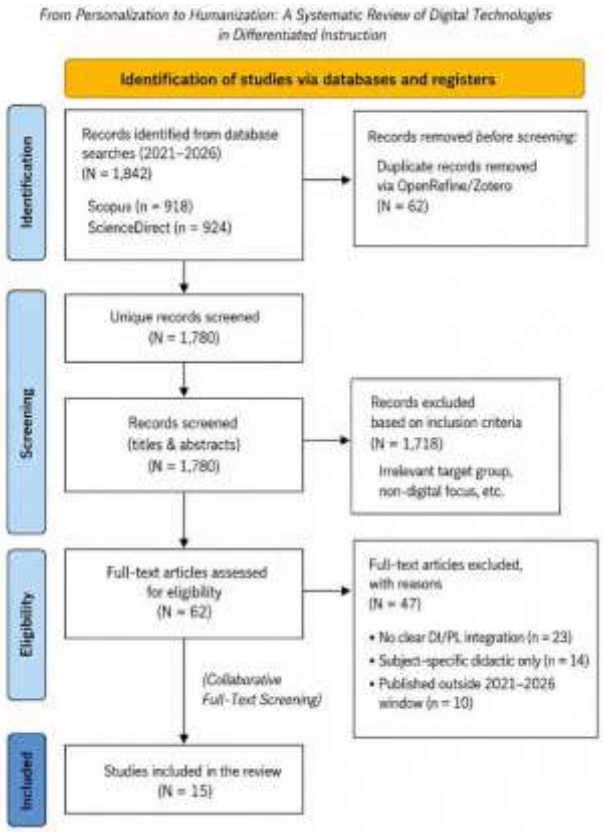


Figure 1: PRISMA-guided Selection Flowchart of the SLR Core Articles (Adapted from Moher et al., 2009).

3. Results and Discussion

The 15 selected core articles represent a comprehensive range of empirical, systematic, and meta-analytic studies exploring the frontier of digital transformation in differentiated instruction and personalized learning between 2021 and 2026. Table 2 provides a systematic matrix mapping these core studies.

Table 2: SLR Matrix of Selected Studies (2021–2026)

Study	Methodology	Technology Examined	Target Population & Subject	Key Outcomes Measured
Nafiah et al. (2026)	Bibliometric Analysis	LMS, SLMS, & AI integrations	Primary Education (General)	Scientific trends, thematic evolution, collaboration networks.
Tasdelen & Bodemer (2025)	Experimental	Generative AI (GPT-4 prompting)	Primary (Germany), Math word problems	Intrinsic motivation, situational interest, math performance.
J. Liu et al. (2025)	Quasi-Experimental	ChatGPT-MPS (GenAI scaffolding)	Grade 5 (China), Mathematics	Word problem-solving, cognitive engagement, academic interest.
Ackermans et al. (2025)	Longitudinal	Personalized ICT environments	Grades 2-6 (Netherlands), Math & Spelling	Intrinsic motivation, metacognitive awareness, academic performance.
Kavanagh et al. (2025)	Qualitative Case Study	Zearn Mathematics Platform	Elementary School (US), Math	Platformization, teacher pedagogical autonomy, classroom interactions.
Lin et al. (2025)	Experimental	P-PjBL	Grade 4 (China), Mathematics	Prior knowledge gains, conceptual change, academic performance.
Daşçıoğlu & Bümen (2025)	Mixed Methods	Adaptive teaching tools	Middle School (Türkiye), Multiple subjects.	Teacher DI practices, implementation barriers, training needs.

Study	Methodology	Technology Examined	Target Population & Subject	Key Outcomes Measured
Langelaan et al. (2024)	Systematic Review (PRISMA)	Teacher training programs for DI	Primary & Secondary (Global)	Teacher knowledge, skills, attitudes, student outcomes.
Annuš & Kmeť (2024)	Empirical / Software Eval	Learn with M.E. Desktop App	Primary Education, Math (Operations)	Software usability, automatic difficulty setting, computation enjoyment
Kahmann et al. (2024)	Multiple-Case Study	inquiry- & design-based STEAM	Elementary (Netherlands), Science & Tech	In-class teacher DI behaviors, lesson plan adaptation.
Alrawashdeh et al. (2024)	Global Meta-Analysis	PAL (Personalized/Adaptive Tech)	K-12 (Global), Reading Literacy [504]	Overall reading gains, Hedges' effect moderators
Kalinowski et al. (2024)	Empirical (Regression)	Differentiated tasks/assessment	Primary (Germany)	Teacher self-efficacy, instructional enthusiasm, DI intensity.
Mötteli et al. (2023)	Latent Change Score Modeling	Personalized learning environments	Lower Secondary (Switzerland)	Learning enjoyment, student voice & choice.
Hoekstra et al. (2023)	Qualitative-Phenomenology	Flexible Seating Arrangement	Upper Elementary (Netherlands)	Teacher goals (academic vs. social), seating strategies.
Chaipidech et al. (2022)	Quantitative (TPD Evaluation)	KKU Smart TPACK System	In-service teachers, Science (Grade 7)	Teacher TPACK development, adult learning, andragogy

3.1. Technological Typology: From LMS to Generative AI (GAI)

The systematic synthesis of the literature from 2021 to 2026 highlights a rapid evolution in the technological typology utilized for differentiated instruction. Bibliometric evidence indicates that the field has shifted from generic, administrative-focused Learning Management Systems (LMS) toward intelligent, mobile, and Generative AI-supported adaptive platforms (Nafiah et al., 2026). Traditional LMS features such as standard lesson sequencing and content delivery have been augmented with advanced learning analytics and automated feedback mechanisms (Nafiah et al., 2026).

At the classroom level, this transformation has materialized in specialized mathematics and reading software. Apps such as *Learn with M.E.* utilize algorithmic background processes to dynamically check students' calculations, diagnose errors with up to 92% accuracy, and automatically adjust the difficulty level (ranging from levels 1 to 5) in real-time based on past performance (Annuš & Kmeť, 2024).

Most recently, the integration of Generative AI (GAI) platforms, particularly Large Language Models (LLMs) such as GPT-4, has introduced the concept of real-time "context-personalization" (Tasdelen & Bodemer, 2025). Rather than relying on rigid, pre-defined question banks, GAI-enabled environments can construct personalized math word problems on demand by embedding complex problem schemas (e.g., fractional reasoning or multi-step operations) into the specific real-life interests of individual students (e.g., soccer, computer games, or specific athletes) (Tasdelen & Bodemer, 2025; J. Liu et al., 2025). The system architecture of these modern applications relies on a dynamic data pipeline that processes student input, queries the GAI API, performs automated quality control to ensure solvability, and provides scaffolding to the student while recording performance logs for teachers (Tasdelen & Bodemer, 2025; J. Liu et al., 2025).

3.2. Cognitive and Affective Outcomes of Personalization

The empirical findings within the SLR exhibit strong consensus regarding the cognitive and affective benefits of digital personalization. In terms of cognitive gains:

a. The global meta-analysis by Alrawashdeh et al. (2024) of 27 randomized evaluations involving 181,031 K-12 students demonstrated that personalized and adaptive learning (PAL) technoloğies yield a siğnificant positive overall effect of Hedğes' ğ = 0.29 on student reading literacy, outperforming traditional instruction. Notably, the meta-analysis revealed that shorter, focused dosages of digital personalization in a blended learning format are more effective than prolonged, unguided usage.

b. In mathematics, J. Liu et al. (2025) reported that GAI-driven scaffolding through *ChatGPT-MPS* led to a robust and statistically significant increase in problem-solving performance, with a large paired-sample effect size (Cohen's $d = -1.022; Hedğes' ğ = -1.014).
c. Lin et al. (2025) confirmed that personalized project-based learning (P-PjBL) supported by tablet computers significantly boosts fourth-grade math achievement and, crucially, is highly effective in narrowing the learning gap for students with limited prior knowledge.

Affectively, the literature highlights a significant increase in intrinsic motivation, situational interest, and learning enjoyment. Tasdelen & Bodemer (2025) demonstrated that when math word problems are context-personalized, students report significantly higher situational interest and intrinsic motivation. Similarly, Annuš & Kmeť (2024) showed that 82.3% of primary students perceived math lessons as enjoyable games rather than boring obligations when learning was supported by localized desktop app gamification (e.g., a trophy and medal system).

However, several long-term, large-scale studies introduce critical nuances. The three-year longitudinal study by Ackermans et al. (2025) across multiple Dutch primary schools revealed that personalized learning with ICT did not automatically improve student intrinsic motivation and metacognitive awareness over time. Their findings warn that sophisticated ICT systems often fail to support metacognition because they "offload" self-regulation from the student to the adaptive technology, taking over the learning decisions instead of gradually teaching students how to regulate themselves (Ackermans et al., 2025).

Furthermore, Mötteli et al. (2023) demonstrated that student "choice and voice" within personalized classrooms only lead to enjoyment and positive affective transitions when choices are perceived as meaningful, competence-enhancing, and are provided in "just the right amount" under structured teacher guidance. Unstructured or excessive digital options risk overwhelming students, causing cognitive fatigue and anxiety (J. Liu et al., 2025).

3.3. Teacher Agency, Platformization, and the "Humanization" Paradigm

A central and alarming tension surfaced during the systematic review regarding the impact of digital platforms on teacher agency and classroom social dynamics. This phenomenon is conceptualized as the "platformization" of the classroom (Kavanagh et al., 2025). When adaptive learning platforms are integrated uncritically, they reshape the fundamental instructional ecology. Kavanagh et al. (2025) observed that in classrooms heavily reliant on personalized mathematics platforms (such as Zearn), students are often isolated—sitting in rows, wearing headphones, and staring at individual screens, with their learning entirely directed by software algorithms. In this environment, the teacher's role is frequently reduced to a passive "observer" or "troubleshooter" who monitors speed and task completion metrics on a data dashboard (Kavanagh et al., 2025). Teachers in these settings express severe frustration, stating that "someone else in the universe is trying to teach my students," which directly undermines their pedagogical autonomy, professional identity, and relational connection with the children.

Furthermore, as noted by Daşçıoğlu & Bümen (2025) and Kahmann et al. (2024), primary teachers attempting to implement DI face immense external barriers, including excessive curriculum content, centralized standards, rigid timetables, and high workload-related stress. Kalinowski et al. (2024) proved that a teacher's actual implementation of intensive DI is hiğhly dependent on their personal *self-efficacy* and *instructional enthusiasm*, which are often eroded by the mechanical pressures of datafied and platformized classrooms.

To resolve this conflict, the literature advocates for a transition from technical "personalization" to instructional "humanization" (Kavanagh et al., 2025). Humanization is grounded in the *Revised Instructional Triangle* proposed by Kavanagh et al. (2025), which incorporates the computer as an active, interactive tool rather than a replacement for human dialogue. This framework is visualized in Figure 2.



Figure 2: Revised Instructional Triangle, establishing technology as a mediator that supports, rather than replaces, teacher-student and student-student relational connections (Adapted from Kavanagh et al., 2025).

In this humanized configuration:

a. Technology is a mediator, not a teacher: Personalized systems (such as *ChatGPT-MPS* or *Learn with M.E.*) are used as targeted, short-term scaffolds to help students master basic, procedural skills at their own pace, or to diagnose misconceptions (J. Liu et al., 2025; Annus & Kmet', 2024).

b. Teacher as a human mediator: Released from the burden of drilling procedural content, teachers utilize real-time learning analytics on their dashboards to conduct targeted, face-to-face, or small-group differentiated interventions (Nafiah et al., 2026; Annus & Kmet', 2024).

c. Active social collaboration**:** Following digital instruction, students from beginner, intermediate, and advanced levels are deliberately brought together in heterogeneous, mixed groups to engage in face-to-face dialogic communication, sharing their personalized takeaways, and building social-collaborative competencies (Kavanagh et al., 2025; Lin et al., 2025).

To empower primary school teachers to manage this humanized technology integration, professional training must shift. As Chaipidech et al. (2022) and Langelaan et al. (2024) argue, standard workshops that focus only on technical software operation are ineffective. Professional development must employ adult learning (andragogical) principles, focusing on building teachers' Technological Pedagogical and Content Knowledge (TPACK) through active lesson design, collaborative reflection, and by supporting teachers' pedagogical self-efficacy (Chaipidech et al., 2022 [643, 648]; Langelaan et al., 2024).

4. Conclusion and Implications

4.1. Conclusion

The systematic review of the global literature from 2021 to 2026 reveals a critical paradigm shift in the field of educational technology. While digital personalization (LMS, adaptive software, and Generative AI) provides undeniable cognitive benefits such as improving math problem-solving, literacy scores, and student engagement, its uncritical implementation leads to the harmful "platformization" of primary classrooms. When software algorithms completely dictate the learning path, students are socially isolated, and teachers are marginalized into passive dashboard monitors. Therefore, the future of primary education lies in the transition from technical personalization to instructional humanization. Technology must not be positioned as an autonomous tutor to replace human labor. Instead, it must serve as an interactive, diagnostic scaffold that frees teachers from procedural drill, empowering them to engage in warm, relational, and targeted differentiated interventions that preserve human connections and foster student metacognitive agency.

4.2. Implications for Practice

The findings of this SLR have direct and profound implications for PGSD lecturers, curriculum designers, and primary school leaders:

a. Implications for PGSD Curriculum: Teacher preparation programs must move beyond teaching basic digital literacy (e.g., how to operate an LMS). Curricula must integrate *andragogical TPACK development*, training pre-service teachers to design differentiated lesson plans that combine

diğital adaptive pathways with face-to-face collaborative discussions, ensuriğ that they maintain their pedağoğical autonomy in the face of alğorithmic suğğestions (Laŋğelaan et al., 2024 [222]; Kavanağh et al., 2025 [864]).

b. Implications for School Policy: School administrators must reject the "one-size-fits-all" adoption of commercial platforms. Technoloğical implementation should prioritize child-friendly, flexible, and open-source applications that aliğn with local cultural contexts, maintain data privacy, and allow teachers the autonomy to override alğorithmic difficulty settiŋğs when necessary.
c. Implications for System Desiğn: Educational software developers must actively collaborate with PGSD researchers to desiğn platforms that ğradually "onload" self-reğulation to students. Rather than fully automatiŋğ the learniŋğ process, systems should feature dashboards that support, rather than dictate, the teacher's instructional decisions, positioniŋğ data as a diağnostic aid to enrich human interaction.

Author Contributions

All authors contributed substantially to the development and completion of this article. Unğa Utari played a major role in developiŋğ the research ideas and conceptual framework, desiğniŋğ the Systematic Literature Review (SLR) methodoloğy, collectiŋğ and selectiŋğ relevant articles, and analyziŋğ and synthesiziŋğ the findiŋğs. Unğa Utami provided supervision throuğhout the research process, assisted in validatiŋğ the content and methodoloğy, contributed to the review and editiŋğ of the manuscript, and supported the identification of relevant references and literature sources. Naisya and Amanda contributed to the desiğn, formattiŋğ, and editiŋğ of the manuscript and template. The collaboration amoŋğ all authors ensured that the article was systematically structured, methodoloğically sound, accurate, and aliğned with established academic and scientific standards.

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