JURNAL PENDIDIKAN: RISET&KONSEPTUAL

www.journal.unublitar.ac.id/jp
E-ISSN: 2598-2877, P-ISSN: 2598-5175
Vol 10 No 3, Juli 2026

Digital Media Innovation in STEAM Learning to Enhance Creativity and Collaboration of Students in IB PYP-Based Elementary Schools

Dendy Rossa Triyantara[(1)], Amrozi Khamidi[(2)], Karwanto[(3)], Andi Kristanto[(4)], Mohammad Syahidul Haq[(5)]

[1,2,3,4,5]State University of Surabaya, Indonesia
Email: [1]25010845031@mhs.unesa.ac.id,[2]amrozikhamidi@unesa.ac.id, [3]karwanto@unesa.ac.id, [4]andikristanto@unesa.ac.id, [5]mohammadhaq@unesa.ac.id

Abstract: This study investigates the utilisation of digital media in STEAM (Science, Technology, Engineering, Arts, and Mathematics) learning to enhance creativity and collaboration among students in International Baccalaureate Primary Years Programme (IB PYP)-based elementary schools, with particular attention to the Indonesian educational context. Employing a systematic-qualitative literature study integrating PRISMA-guided systematic reviewing with thematic synthesis, the research analysed 40 sources comprising 30 peer-reviewed journal articles and 10 books and policy documents published between 2010 and 2025. Thematic synthesis generated four analytical themes. First, digital media functions as a multidimensional pedagogical enabler serving as a concept-representation tool, design medium, collaboration platform, and creative production environment whose effectiveness depends on alignment with inquiry-based pedagogy. Second, digital media positively influences student creativity across dimensions of originality, flexibility, elaboration, and reflection, though gains require pedagogical scaffolding and open-ended task design; Indonesian classrooms, shaped by examination-oriented norms, face additional barriers. Third, digital platforms support synchronous and asynchronous collaboration, yet equitable participation is constrained by shared-device models and home-connectivity gaps in Indonesian schools. Fourth, implementation challenges including infrastructure disparities, variable teacher readiness in Technological Pedagogical Content Knowledge (TPACK), and inadequate assessment instruments require systemic responses through Professional Learning Communities, phased evaluation, and policy alignment with Indonesia's Merdeka Belajar agenda and Profil Pelajar Pancasila framework. These findings affirm that realising digital media's potential demands an equity-oriented, culturally responsive, and pedagogically grounded approach.

Tersedia Online di
http://journal.unublitar.ac.id/pendidikan/index.php/Riset_Konseptual

Sejarah Artikel
Diterima pada : 01-02-2026
Disetuji pada : 22-06-2026
Dipublikasikan pada : 22-07-2026

Kata Kunci:
Digital Media; STEAM Education; IB PYP; Creativity; Collaborative Learning; TPACK; thematic synthesis

DOI:
http://doi.org/10.28926/riset_konseptual.v10i3.1412

INTRODUCTION

The integration of digital technology in education has become essential for developing 21st-century competencies critical thinking, creativity, collaboration, and communication beginning at the elementary level (Beers, 2011). The STEAM approach (Science, Technology, Engineering, Arts, Mathematics) responds to this demand by integrating multiple disciplines through project-based and problem-solving learning (Yakman & Lee, 2012). This aligns naturally with the International Baccalaureate Primary Years Programme (IB PYP), which emphasizes inquiry-based, transdisciplinary learning and learner profiles centered on reflection, communication, and critical thinking (IBO, 2018).

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E-ISSN: 2598-2877, P-ISSN: 2598-5175
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Despite this alignment, STEAM implementation at the elementary level remains challenging particularly regarding teacher readiness, limited resources, and coherent cross-disciplinary integration (Herro & Quigley, 2017). Digital media encompassing interactive platforms, collaborative applications, simulation tools, and creative production tools offers a promising pathway to address these challenges. Research demonstrates that digital media expands students' creative expression through visual exploration and interactive simulation, while collaborative platforms enable idea-sharing and collective reflection beyond spatial and temporal constraints (Conradty & Bogner, 2019; Yang & Zhao, 2021).

However, a significant gap remains in understanding how digital media can effectively enhance creativity and collaboration in IB PYP-based contexts. Perignat and Katz-Buonincontro (2019) found that many STEAM implementations remain sporadic and poorly integrated into the curriculum. Teacher competency in Technological Pedagogical Content Knowledge (TPACK) continues to be a key obstacle (Mishra & Koehler, 2006). Research on STEAM-digital media integration at the Indonesian elementary level particularly within IB PYP settings remains scarce, making contextualization of global best practices both necessary and urgent.

This study proposes solutions across three dimensions: (1) identifying digital media types best suited for project-based STEAM learning; (2) developing pedagogical strategies that foster creativity through structured open-ended projects (Craft, 2005); and (3) designing collaborative platform mechanisms that support role distribution and collective reflection (Barkley et al., 2014). Accordingly, this research aims to: (1) describe the role of digital media in supporting STEAM implementation in IB PYP schools; (2) analyze how digital media develops student creativity; (3) examine mechanisms for facilitating collaboration in STEAM projects; and (4) identify implementation challenges and formulate optimization strategies.

Theoretically, this study enriches the limited Indonesian literature on STEAM-digital media integration within IB PYP contexts. Practically, findings are intended to guide teachers and curriculum developers in selecting appropriate digital tools, designing effective learning activities, and strengthening digital pedagogical competence—supported by Professional Learning Communities (PLC) for sustained teacher development (Herro & Quigley, 2017). This literature review synthesizes 40 sources (2015–2025) through thematic analysis across four themes: the role of digital media in STEAM, its influence on creativity, collaboration facilitation mechanisms, and implementation challenges.

Conceptual Framework

Figure 1 presents the conceptual framework of this study. The framework is read top-down through five main layers: contextual factors shape the selection and use of digital media (mediated by TPACK); pedagogical strategies translate digital tools into learning activities that simultaneously develop student creativity and collaboration; both converge into 21st-century competency outcomes; and optimization strategies at the base feed back into the contextual layer, representing a continuous improvement cycle.

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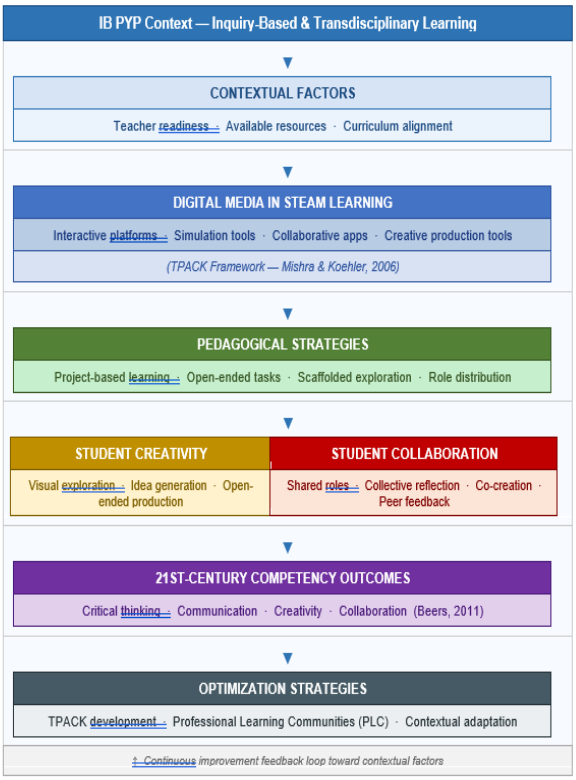

Figure 1. Conceptual Framework: Digital Media in STEAM Learning at IB PYP-Based Elementary Schools

METHOD

This research employs a systematic-qualitative literature study approach that integrates the procedural rigour of systematic reviewing with the interpretive depth of qualitative inquiry, following the frameworks of Petticrew and Roberts (2006) and Thomas and Harden (2008). A formal review protocol was established prior to data collection, specifying the research question, eligibility criteria, search strategy, and analytical procedures in accordance with PRISMA reporting standards. Data sources were drawn from seven academic databases and repositories Scopus, Web of Science, ERIC, Garuda, Neliti, ResearchGate, and Google Scholar supplemented by official policy documents from the International Baccalaureate Organization (IBO). Searches were conducted using five keyword clusters combining terms related to STEAM education, digital media, IB PYP, creativity, and collaborative learning, applied within a publication window of 2010 to 2025, with primary priority assigned to 2018–2025 publications to ensure currency and contextual relevance.

The literature selection process followed a transparent three-stage PRISMA funnel. From an initial pool of 312 identified records, 189 were excluded at the title and abstract screening stage due to irrelevance, duplication, or lack of peer review. The remaining 123 sources underwent full-text eligibility assessment against seven quality appraisal criteria encompassing methodological clarity, relevance to focus, contextual fit, publication credibility, currency, evidence quality, and acknowledgement of limitations; a further 83 were excluded primarily because they focused exclusively on higher education, lacked full-text accessibility, or demonstrated insufficient methodological rigour. This process yielded a final analytical sample of 40 sources comprising 30 peer-reviewed journal articles and 10 books and policy documents.

Data analysis employed thematic synthesis across three iterative phases: inductive line-by-line coding of all 40 sources, which generated 86 descriptive codes; consolidation of related codes into 17 sub-themes; and interpretive synthesis of sub-

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themes into four analytical themes namely, the role of digital media as a pedagogical enabler in STEAM learning, digital media and the development of student creativity, mechanisms for collaborative learning facilitated by digital media, and implementation challenges and optimisation strategies. To ensure trustworthiness, source triangulation was applied by cross-comparing findings across different literature types, and critical reflexivity was maintained through a research journal documenting interpretive decisions and contextual assumptions. Particular attention was paid to the transferability of findings from their original international contexts to the specific setting of IB PYP-based elementary schools in Indonesia, and claims supported by only a single source were explicitly qualified in the subsequent analysis.

RESULTS AND DISCUSSION

Research Results

Based on thematic synthesis of the forty literature sources examined, this research produced findings organised into four main themes. These themes comprehensively illustrate how digital media functions in STEAM learning, how it shapes students' creativity and collaborative competence, and what structural challenges and contextual constraints particularly within the Indonesian educational landscape affect implementation in IB PYP-based elementary schools.

1. The Role of Digital Media in STEAM Learning at IB PYP-Based Elementary Schools

Literature review results indicate that digital media assumes a multidimensional role in supporting STEAM learning in elementary schools. It functions as a concept-representation tool enabling visualisation of complex phenomena through interactive simulations; a design tool facilitating prototyping and product creation via Computer-Aided Design (CAD) applications; a collaboration platform providing shared workspaces through digital whiteboards and co-editing environments; and a creative production medium through which students author videos, animations, and interactive presentations. The alignment between these affordances and the inquiry-based, transdisciplinary principles of the IB PYP curriculum is well-supported by the literature.

Digital media supports cross-disciplinary concept exploration, process documentation through digital portfolios, and real-time personalised feedback. However, the effectiveness of digital media's role is heavily contingent on the appropriateness of media selection relative to specific learning objectives and its coherent integration with inquiry-oriented pedagogical practices. Particularly relevant tools for elementary STEAM contexts identified in the literature include: LMS platforms for project management and communication; block-based coding environments such as Scratch and Blockly; multimedia design applications; science simulation tools; and collaborative platforms such as Google Workspace and Padlet. In the Indonesian context, however, access to these platforms cannot be assumed uniform: data from the Ministry of Education, Culture, Research and Technology (Kemendikbudristek, 2022) indicate that fewer than 40 per cent of Indonesian elementary schools have stable internet connectivity, and device availability remains concentrated in urban and private school settings. This infrastructure disparity means that while the pedagogical rationale for digital media integration is well-established internationally, its translation into Indonesian classrooms including IB PYP schools requires context-sensitive adaptation.

2. The Influence of Digital Media on Student Creativity

Thematic synthesis reveals a broadly positive relationship between digital media utilisation and creativity development in STEAM learning, particularly when combined with open-ended task design and adequate pedagogical scaffolding. Creativity is meaningfully enhanced when students are afforded autonomy in selecting digital tools to represent and communicate their ideas. Digital media enables multimodal exploration, permitting students to integrate text, image, audio, video, and interactive elements within a single creative artefact. Identified dimensions of creativity that develop through this process include: originality in generating novel ideas;

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flexibility in exploring alternative solutions; elaboration in developing ideas into detailed products; and reflective capacity to evaluate and revise the creative process.

The literature is consistent, however, in warning that these gains do not occur automatically by virtue of technology availability. Pedagogical scaffolding encompassing explicit modelling, formative feedback, structured templates, and the use of creative rubrics is a necessary mediating condition. Project-based STEAM tasks that integrate arts components are reported to provide broader creative exploration space than conventional STEM approaches that omit the arts dimension. In Indonesian elementary school contexts, additional considerations emerge. Wahyuningsih (2024) and Putri and Akbar (2023) draw attention to the variability in teacher capacity to design open-ended, creativity-oriented tasks, noting that many Indonesian classrooms continue to privilege convergent, examination-oriented learning. The transition toward creativity-fostering digital STEAM tasks therefore requires not only technological access but also a reorientation of pedagogical culture a process that is gradual and requires sustained institutional support.

3. Digital Media Mechanisms in Facilitating Student Collaboration

The literature identifies multiple mechanisms through which digital media facilitates collaboration in STEAM learning contexts. Digital platforms support both synchronous and asynchronous modes of joint working, enabling students to collaborate across spatial and temporal constraints. Transparent documentation of group processes including individual contribution tracking and co-editing histories enhances accountability and allows teachers to identify patterns of unequal participation requiring intervention. Best-practice findings converge on several key structural requirements: clear role distribution within collaborative tasks; explicit tutorial support for collaborative tool features; and structured group reflection to consolidate collaborative learning gains. A significant finding across multiple sources is that effective digital collaboration cannot be assumed it must be explicitly taught. Digital social skills including netiquette, online communication protocols, constructive feedback practices, and virtual conflict management need to be developed as deliberate learning outcomes.

Collaborative assessment rubrics should evaluate individual contribution processes and group dynamics, not only final products. In the Indonesian context, these requirements carry additional complexity. Purnomo (2022) notes that collaborative digital learning in Indonesian schools is frequently undermined by inadequate device ratios, with many classrooms operating on a shared-device model that limits genuine individual participation in collaborative platforms. Moreover, the home-school connectivity gap means that asynchronous collaboration which assumes reliable home internet access may exclude students from lower socioeconomic backgrounds, creating participation inequities within the same classroom. These structural factors necessitate that implementation strategies be differentiated by school context rather than uniformly applied.

4. Implementation Challenges and Optimisation Strategies

The review identifies a multi-layered set of challenges in implementing digital media for STEAM learning in elementary schools, with particular acuity in the Indonesian context. At the infrastructure level, unstable internet connectivity and limited device availability are widely reported as primary constraints; in Indonesia, these disparities are compounded by significant urban–rural divides and inequalities between public and private schooling sectors. At the teacher-readiness level, Kamaruddin (2021) and Herro and Quigley (2017) converge in finding that many teachers possess basic technical skills but lack the integrated Technological Pedagogical Content Knowledge (TPACK) required to design learning experiences in which technology substantively rather than superficially supports STEAM inquiry.

In Indonesian elementary schools specifically, this gap is further widened by limited access to high-quality digital professional development and the relative absence of formal TPACK frameworks within national teacher training curricula. Additional

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challenges include: distraction and attention management risks associated with unstructured technology use; the need for meaningful task design that embeds technology as integral rather than supplementary; digital safety and data privacy concerns for children; and the inadequacy of existing assessment instruments for capturing complex, multimodal, and process-oriented learning outcomes. Recommended optimisation strategies encompass both technical and systemic dimensions. Professionally, continuous teacher development through digital-based PLCs focusing on TPACK and STEAM pedagogy is strongly recommended. Structurally, phased pilot implementation, iterative data-based evaluation, and child-appropriate tool selection are identified as enabling conditions. At the policy level, the literature implies a need for national-level investment in digital infrastructure equity, aligned with Indonesia's Merdeka Belajar reform agenda, which explicitly targets digital transformation in schooling. Parental engagement is identified as a further strategic lever, given that digital learning environments extend beyond school hours and families' capacities to support home-based digital learning are highly variable. Mansour (2025) adds that culturally responsive pedagogy ensuring that digital STEAM content draws on locally meaningful contexts is an underemphasised but significant dimension of sustainable implementation in diverse, multilingual educational environments such as Indonesia's.

DISCUSSION

1. Integration of Digital Media in STEAM Learning: Pedagogical Perspective

The findings confirm that digital media assumes a multidimensional pedagogical role in STEAM learning, a position consistent with Smaldino et al.'s (2019) argument that instructional technology is effective only when coherently aligned with learning objectives and pedagogical strategies. The literature converges on the view that digital media serves as a catalyst for inquiry-based and transdisciplinary learning qualities central to the IB PYP framework (IBO, 2018). Critically, however, Mishra and Koehler's (2006) TPACK framework offers an important analytical lens through which to interrogate how this alignment is achieved in practice. Studies such as those by Herro and Quigley (2017) and Kamaruddin (2021) reveal a persistent disjunction: while teachers may possess technological knowledge and content knowledge independently, the integrated pedagogical-technological-content competence required for meaningful STEAM integration remains underdeveloped in many elementary school contexts, including in Indonesia.

This finding stands in partial tension with more optimistic accounts in the international literature such as Bybee (2013) and Mayer (2009) which emphasise the intrinsic affordances of digital tools such as block-based coding and multimedia creation without always accounting for the teacher capacity required to realise those affordances. The implication for Indonesian IB PYP schools, where TPACK development is not yet systematically embedded in teacher education, is that the gap between the theoretical potential of digital media and its enacted impact in classrooms may be larger than the international literature alone would suggest. A further complication arises from the infrastructure disparities documented in the Indonesian context. Studies conducted in high-connectivity Western or East Asian settings which constitute the majority of the reviewed international literature may overestimate the accessibility of digital STEAM tools for Indonesian schools operating with shared devices, intermittent connectivity, or limited technical support. This asymmetry in the evidential base represents a significant caveat that must inform how international findings are contextualised and applied.

2. Creativity Development through Digital Media: Between Potential and Challenges

The broadly positive relationship between digital media and student creativity identified across the literature including Conradty and Bogner's (2019) systematic study and Craft's (2005) influential theoretical distinction between transformational and

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everyday creativity provides a coherent foundation for the argument that technology, when appropriately deployed, can expand students' creative repertoire. Clapp et al.'s (2017) maker-centred learning framework further enriches this picture, positioning students as active creators rather than passive consumers of digital content. However, a more critical reading of the evidence reveals important qualifications. The studies reporting creativity gains predominantly originate from well-resourced school environments with stable infrastructure, experienced teachers, and established STEAM cultures. When findings from Wahyuningsih (2024) and Putri and Akbar (2023) which document the Indonesian elementary school context are placed in dialogue with these international accounts, a more complex picture emerges.

Indonesian classrooms frequently operate under examination-driven pedagogical norms that milieu against the open-ended, risk-tolerant learning environments that the literature identifies as preconditions for creativity development. Woods (2014) argues that creativity requires a deliberately cultivated environment in which teachers actively model creative risk-taking; yet Kamaruddin (2021) finds that a significant proportion of Indonesian elementary teachers have received insufficient preparation to design and facilitate such environments. The implication is that digital media alone cannot bridge this pedagogical gap it may even exacerbate it if poorly structured technology use reinforces surface-level task completion rather than genuine creative inquiry. The use of scaffolded assessment instruments, including creative rubrics that evaluate process alongside product as advocated by Bequette and Bequette (2012), emerges from the synthesis as a critical mediating strategy. Yet the development and consistent application of such instruments requires teacher competence and institutional commitment that cannot be assumed universally across Indonesian elementary schools.

3. Digital Media as Collaboration Facilitator: Building 21st-Century Skills

The literature presents a largely affirmative account of digital media's role in facilitating collaboration, with Barkley et al. (2014) providing a robust theoretical grounding in the structural requirements clear accountability, positive interdependence, individual contribution tracking that digital platforms can support. Yang and Zhao (2021) extend this by documenting the specific digital social competencies required for effective online collaboration, and Muir (2019) emphasises that these competencies must be explicitly taught rather than assumed. These international findings are broadly applicable to IB PYP contexts, given the programme's emphasis on collaborative inquiry and the learner profile attribute of being 'caring' and 'open-minded' in team-based work. However, placing these findings alongside the realities documented in the Indonesian context reveals structural tensions that the international literature tends to understate.

Purnomo (2022) notes that shared-device models common in many Indonesian schools fundamentally compromise the individual participation that effective digital collaboration platforms assume. Where only one or two devices are available per group, the interactive affordances of collaborative tools are reduced to a form of sequential rather than genuinely concurrent contribution, undermining the transparency and accountability that make digital collaboration pedagogically distinctive. Furthermore, the asynchronous collaboration modalities identified in the international literature as valuable for extending learning beyond school hours presuppose home connectivity that is not equitably distributed among Indonesian students. Wells' (2017) dialogic inquiry framework, which underpins the argument for rich interactive assessment of collaborative processes, similarly requires a baseline of participation quality that infrastructure constraints may prevent. The synthesis therefore suggests that effective collaboration in Indonesian digital STEAM contexts will require hybrid strategies—blending digital and face-to-face collaboration modes—rather than wholesale adoption of the platform-centred models dominant in the international evidence base.

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4. Overcoming Challenges and Optimising Implementation: Systemic Perspective

The challenges identified in the literature reflect a systemic complexity that cannot be resolved through technological solutions alone. McKnight et al. (2016) establish that the digital divide structurally reproduces educational inequality when unaddressed at the policy level a finding with particular salience in Indonesia, where the Kemendikbudristek has acknowledged persistent urban–rural digital infrastructure gaps in its Merdeka Belajar reform documentation. The international literature's recommendation of phased pilot projects and iterative data-based evaluation is sound in principle, but its applicability in Indonesian IB PYP schools is complicated by the typically private and resource-differentiated nature of these institutions: pilot findings from well-resourced urban IB schools may not be transferable to broader implementation in public or peri-urban school settings. The professional development literature including Herro and Quigley (2017) on PLC-based TPACK development and Kamaruddin (2021) on Indonesian elementary teachers' digital literacy converges on the conclusion that teacher capacity is the single most critical mediating variable in implementation quality. Notably, these two bodies of evidence diverge in emphasis: the international PLC literature tends to assume a degree of self-directed professional agency and institutional time allocation that Indonesian teachers, operating under high curriculum demands and limited professional development budgets, may not consistently experience.

Pikhart's (2024) findings on distraction and attention poverty add a further dimension: in under-resourced classrooms where device management is more challenging, the distraction risk may be higher than in the well-equipped settings that generate most of the international evidence on this issue. Finally, Mansour's (2025) emphasis on culturally responsive STEAM pedagogy and Purnomo's (2022) advocacy for home-school partnerships represent underemphasised but strategically important dimensions of optimisation in the Indonesian context. Together, they point toward an implementation framework that is not merely technologically informed but culturally embedded one in which digital STEAM learning is designed in dialogue with students' lived contexts, families' capacities, and Indonesia's multilingual, multicultural educational environment. The Merdeka Belajar agenda's Profil Pelajar Pancasila competency framework which shares significant conceptual overlap with IB PYP learner profile attributes provides a potentially powerful policy foundation for institutionalising this culturally responsive approach at scale.

5. Implications for IB PYP-Based Elementary Schools in Indonesia

The preceding analysis yields several specific implications for the Indonesian IB PYP context that extend beyond what the international literature alone can illuminate. First, the alignment between PYP inquiry principles and digital media's pedagogical affordances is genuine and significant; however, its realisation in Indonesian settings is contingent on addressing infrastructure inequalities that are structural rather than incidental. Schools and policymakers must therefore treat connectivity and device provision not as background conditions but as active implementation prerequisites. Second, the findings from Putri and Akbar (2023) and Supianti (2025) suggest that project-based STEAM approaches integrating digital media are associated with improved learning outcomes including mathematical literacy in Indonesian elementary contexts, providing a domestically grounded evidence base that complements the international literature. Third, teacher professional development programmes in Indonesian IB PYP schools must move beyond tool-focused digital training toward the holistic development of TPACK, including explicit attention to how digital media can support inquiry-based, creativity-fostering, and collaborative learning within the PYP framework. Fourth, culturally responsive content design ensuring that digital STEAM learning resources draw on examples, problems, and narratives relevant to Indonesian students' lives is not merely a matter of engagement but of epistemic equity: it signals to students that their cultural contexts are legitimate sites of scientific

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and creative inquiry. Finally, the alignment between IB PYP learner profile attributes and the Profil Pelajar Pancasila opens a productive space for policy dialogue that could position digital STEAM learning not as an imported educational model requiring wholesale adoption but as a complementary framework enriching Indonesia's own national educational vision. Realising the full potential of digital media in STEAM learning at IB PYP-based elementary schools in Indonesia ultimately demands a systemic, culturally grounded, and equity-oriented approach one in which technological innovation is understood as a means to pedagogical transformation, not an end in itself.

CONCLUSION

This study demonstrates that digital media holds substantial and multidimensional potential to strengthen STEAM learning in IB PYP-based elementary schools by simultaneously supporting concept exploration, creative production, and collaborative inquiry competencies central to both the IB PYP learner profile and Indonesia's Profil Pelajar Pancasila. The thematic synthesis of forty literature sources converges on a clear but qualified conclusion: the pedagogical benefits of digital media are not inherent to the technology itself but are contingent on the quality of instructional design, the depth of teachers' TPACK, the openness of institutional culture to inquiry-based learning, and the structural adequacy of digital infrastructure. In the Indonesian context, each of these conditions is unevenly met: infrastructure disparities between urban and rural schools, between public and private sectors, and between connected and unconnected households mean that the affordances documented in predominantly Western and East Asian literature cannot be assumed transferable without deliberate, equity-sensitive adaptation.

Teacher readiness identified across both domestic and international literature as the single most critical mediating variable remains insufficient in TPACK terms across much of the Indonesian elementary teaching workforce, underscoring the urgency of sustained, pedagogically oriented professional development through PLCs rather than isolated technical training. Structurally, effective implementation of digital STEAM learning in Indonesian IB PYP schools demands a systemic response encompassing national-level investment in connectivity and devices, curriculum-integrated TPACK development, culturally responsive content design that draws on students' local contexts, and policy coherence between the Merdeka Belajar reform agenda and the transdisciplinary, student-centred principles of the IB PYP. Only when these enabling conditions are addressed in concert can digital media fulfil its role not as a decorative supplement to existing practice but as a genuine catalyst for the creative, collaborative, and critically engaged learning that twenty-first-century elementary education demands.

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