



Reconstructing Sustainable Teacher Professional Development in Responding to Algorithmic Dominance in Digital Education

Hasmi Nur Bayhaqi^{1*}, Abdulloh Hamid², Moh. Faizin³

^{1*} Universitas Islam Negeri Sunan Ampel Surabaya, Indonesia

² Universitas Islam Negeri Sunan Ampel Surabaya, Indonesia

³ Universitas Islam Negeri Sunan Ampel Surabaya, Indonesia

Korespondensi*: haqielibbien@gmail.com

Info Artikel

Riwayat artikel:

Submitted: Januari 04, 2026

Revision: Maret 20, 2026

Accepted: April 20, 2026

Publish: April 30, 2026

Abstract

Objective: This study aims to analyze the implications of algorithmic dominance for teachers' professional identity and pedagogical agency while reconstructing Sustainable Teacher Professional Development (TPD) to better respond to the complexities of digital education. **Methodology:** This study employed a qualitative approach using library research and a conceptual-critical design. Data were collected through documentation of academic literature, including international journal articles, scholarly books, research reports, and educational policy documents, and analyzed using qualitative-interpretive content analysis combined with critical-conceptual synthesis. **Findings:** The findings indicate that algorithmic dominance has transformed the epistemological foundations of education through datafication, automation, and platformization, resulting in shifts in knowledge production, distribution, and validation. These transformations affect teachers' epistemic authority, pedagogical agency, and professional identity, increasing the risk of pedagogical atrophy and reducing teacher autonomy within data-driven educational environments. **Implications:** This research implies that teacher professional development programs should move beyond technical digital skills and focus on strengthening algorithmic literacy, critical awareness, pedagogical reflection, and teachers' capacity to maintain humanistic values in digital learning contexts. **Originality:** This study contributes to the literature by reconstructing Sustainable Teacher Professional Development from a critical-humanistic perspective and positioning algorithmic dominance as the primary analytical lens, an approach that remains underexplored in previous studies that predominantly emphasize digital competencies and technology integration

Keywords:

Sustainable teacher professional development; algorithmic dominance; teacher agency; digital education; educational transformation

Abstrak

Tujuan: Penelitian ini bertujuan menganalisis implikasi dominasi algoritma terhadap identitas profesional dan agensi pedagogik guru serta merekonstruksi Sustainable Teacher Professional Development (TPD) agar lebih responsif terhadap kompleksitas pendidikan digital. **Metode:** Penelitian ini menggunakan pendekatan kualitatif melalui studi kepustakaan dengan desain konseptual-kritis. Data diperoleh dari berbagai sumber literatur akademik dan dianalisis menggunakan analisis



	isi interpretatif serta sintesis konseptual-kritis. Temuan: Hasil penelitian menunjukkan bahwa dominasi algoritma telah mengubah fondasi epistemologis pendidikan melalui proses datafikasi, otomatisasi, dan platformisasi yang berdampak pada otoritas epistemik, agensi pedagogik, dan identitas profesional guru. Kondisi ini meningkatkan risiko pedagogical atrophy serta mengurangi otonomi guru dalam lingkungan pendidikan berbasis data. Implikasi: Program pengembangan profesional guru perlu melampaui penguasaan keterampilan digital teknis dengan memperkuat literasi algoritmik, kesadaran kritis, refleksi pedagogik, dan nilai-nilai humanistik. Orisinalitas: Penelitian ini menawarkan rekonstruksi Sustainable Teacher Professional Development dari perspektif kritis-humanistik dengan menempatkan dominasi algoritma sebagai lensa analisis utama yang masih jarang dibahas dalam penelitian sebelumnya.
--	---

How to cite this article (APA 7th Edition):

Bayhaqi, H. N., Hamid, A., & Faizin, M. (2026). Reconstructing Sustainable Teacher Professional Development in Responding to Algorithmic Dominance in Digital Education. *Ashlach : Journal of Islamic Education*, 4(01), 173–186. <https://doi.org/10.55757/ashlach.v4i01.1362>

INTRODUCTIONS

Over the past decade, global education has undergone a transformation that is no longer gradual but disruptive. Digital learning platforms such as Google Classroom, Canvas, and Coursera no longer merely serve as channels for content delivery; they have evolved into pedagogical infrastructures that shape how knowledge is curated, distributed, and evaluated (Jarke & Breiter, 2019). Behind their user-friendly interfaces operate algorithmic systems that actively influence learning experiences by recommending content, predicting performance, adapting learning pathways, and generating automated feedback with minimal direct teacher involvement (Raj & Renumol, 2024). This phenomenon represents more than a technological shift; it signifies an epistemological transformation in the way education functions. Evidence demonstrates a significant acceleration of this trend. The global educational technology (EdTech) market is projected to reach USD 605 billion by 2027, while the integration of artificial intelligence (AI) into learning systems continues to grow rapidly (HoloniQ, 2023). In Indonesia, this acceleration has become increasingly evident in the post-pandemic era, as platforms such as Ruangguru, Zenius, and AI-powered learning management systems have reached millions of learners, while the Merdeka Belajar policy has promoted large-scale digital integration throughout the national education ecosystem (Kemendikbudristek, 2022). More importantly, this acceleration has occurred faster than the capacity of educational systems to critically reflect upon its implications.

Despite its promising benefits, the increasing dominance of algorithms in education has introduced challenges that often remain overlooked. Algorithmic systems operate according to their own logic of efficiency, predictability, and data-driven optimization. Recommendation systems determine relevant learning content based on interaction histories rather than contextual pedagogical considerations. Learning analytics produce performance reports that appear objective but often reduce the complexity of human development into quantifiable metrics. Likewise, adaptive learning systems personalize learning pathways in real time while simultaneously narrowing opportunities for intellectual exploration, creativity, and critical thinking. Turvey and Pachler (Turvey & Pachler, 2026) argue that the convergence between human-mediated pedagogy and algorithm-mediated pedagogy generates structural tensions that cannot be resolved merely through technical adaptation, as

both operate according to fundamentally different rationalities. Within this framework, educational success is increasingly defined by measurable indicators, effectiveness by platform-generated metrics, and relevance by algorithmic recommendations. Consequently, the most human dimensions of education; critical dialogue, productive uncertainty, pedagogical empathy, and moral development, risk becoming invisible because they are difficult to quantify. This development reflects not merely a technical issue but an epistemological shift that redefines education from a process of human formation into a process of performance optimization.

The implications of this shift are particularly evident in the position and role of teachers. On the one hand, teachers are expected to continuously adapt to rapidly evolving digital environments. On the other hand, such adaptation often remains superficial. Teachers learn to operate platforms, manage learning management systems, upload materials, and interpret analytical dashboards, yet they are rarely equipped to critically examine the algorithmic logic underpinning these systems. As a result, many teachers gradually move from being autonomous pedagogical agents to becoming platform operators who execute system-generated instructions. Ambady and K. (Ambady & K. V, 2025) describe this condition as a transformation in which teachers risk becoming data custodians whose responsibilities revolve more around managing algorithmic information than cultivating meaningful pedagogical relationships. This situation is further exacerbated by what Trevisan et al. (Trevisan et al., 2024) identify as pedagogical atrophy, namely the gradual erosion of teachers' relational, contextual, and non-computable pedagogical capacities as educational processes become increasingly dependent on AI-driven systems. Therefore, the challenge is not merely one of technical competence but of professional identity itself.

Teacher Professional Development (TPD) should ideally serve as a response to these challenges. However, existing TPD models often lag behind the realities faced by teachers. Most professional development initiatives designed to address digital transformation remain dominated by technical-instrumental orientations, including platform training, software workshops, and digital competency certifications. Amemasor et al. (Amemasor et al., 2025), through a systematic review, found that although digital TPD positively influences technology integration, most programs focus primarily on technical mastery without adequately fostering critical reflection, pedagogical agency, or contextual responsiveness. Similarly, Eradze et al. (Eradze et al., 2023) argue that the urgent post-pandemic challenge is no longer introducing digital tools but enabling teachers to innovate pedagogically within increasingly complex digital environments. In Indonesia, teacher training initiatives under the Merdeka Mengajar platform frequently emphasize module completion and certification rather than transforming teachers' understanding of their professional roles in the digital age (Bayhaqi & Darmawan, 2025). Consequently, what often occurs is not genuine professional development but repetitive technical updating that fails to address deeper structural issues.

Previous studies have attempted to address this challenge. Moylan and Code (Code et al., 2023) examined Professional Digital Competence frameworks and found that algorithm literacy remains insufficiently integrated despite its growing importance for teachers. Stenberg et al. (2025) further revealed that teacher education programs continue to approach AI through predominantly techno-optimistic perspectives, often overlooking its implications for teacher identity and professional autonomy. Likewise, Gu et al. (Gu et al., 2025) demonstrated that the effectiveness of digital TPD depends largely on its ability to move beyond technical knowledge transfer toward the development of adaptive and reflective professional capacities. Nevertheless, these studies remain fragmented. They address digital competence or reflective professional development separately without

explicitly constructing a framework for Sustainable Teacher Professional Development grounded in the recognition of algorithmic dominance as an epistemological challenge. This gap provides the foundation for the present study.

Based on this context, the study aims to critically analyze the implications of algorithmic dominance for teachers' professional roles and identities while reconstructing a model of Sustainable Teacher Professional Development capable of responding to these challenges at a paradigmatic level. The originality of this study lies in repositioning TPD from a professional training program that merely requires updating into a concept that must be critically, reflectively, and humanistically reconstructed. In doing so, the study extends the discourse on TPD beyond technical competencies toward a critical-humanistic perspective better suited to addressing the complexities of digital education (Amemasor et al., 2025; Trevisan et al., 2024). Specifically, this study seeks to answer two research questions: (1) How does algorithmic dominance transform the pedagogical landscape and teachers' professional identities? and (2) How should Sustainable Teacher Professional Development be reconstructed to equip teachers with critical awareness and pedagogical autonomy in negotiating algorithmic dominance with dignity and professionalism?

METHOD

Research Design

This study employed a qualitative approach using library research and a conceptual critical approach. The study was designed to critically examine the transformation of algorithm driven digital education and its implications for Sustainable Teacher Professional Development (TPD). Rather than testing empirical relationships among variables, the research focused on analyzing and synthesizing theoretical perspectives regarding algorithmic dominance, digital pedagogy, teacher professionalism, and sustainable professional development.

Data Collection

The data were collected through document analysis of academic literature relevant to digital education, artificial intelligence, educational algorithmization, teacher professionalism, and Teacher Professional Development. Sources included peer reviewed international journal articles, scholarly books, research reports, and educational policy documents. Literature selection was based on three criteria: substantive relevance to the research focus, publication credibility within reputable academic databases, and recency of publication to reflect current developments in digital education discourse.

Data Sources

The primary data sources consisted of scholarly publications discussing educational technology, artificial intelligence, learning analytics, platformization of education, algorithmic governance, teacher identity, and Sustainable Teacher Professional Development. These sources were systematically identified, reviewed, categorized, and interpreted according to the objectives of the study.

Data Analysis

Data were analyzed using qualitative content analysis combined with critical conceptual analysis. The analysis emphasized in depth interpretation of concepts, arguments, and theoretical propositions contained within the selected literature. The first stage involved identifying epistemological transformations emerging from algorithmic dominance in digital education, particularly those related to pedagogical relations, knowledge authority, and teacher professional identity. The second stage focused on critically synthesizing existing

Teacher Professional Development frameworks. Finally, the study reconstructed a Sustainable Teacher Professional Development framework that is more reflective, humanistic, and responsive to the complexities of algorithm driven digital education.

Trustworthiness of the Study

To ensure the credibility of the findings, the study employed source triangulation through the use of diverse academic references from multiple disciplinary perspectives. The analytical process also emphasized critical comparison, conceptual consistency, and theoretical validation across the reviewed literature. These strategies were applied to enhance the rigor and trustworthiness of the conceptual reconstruction developed in this study.

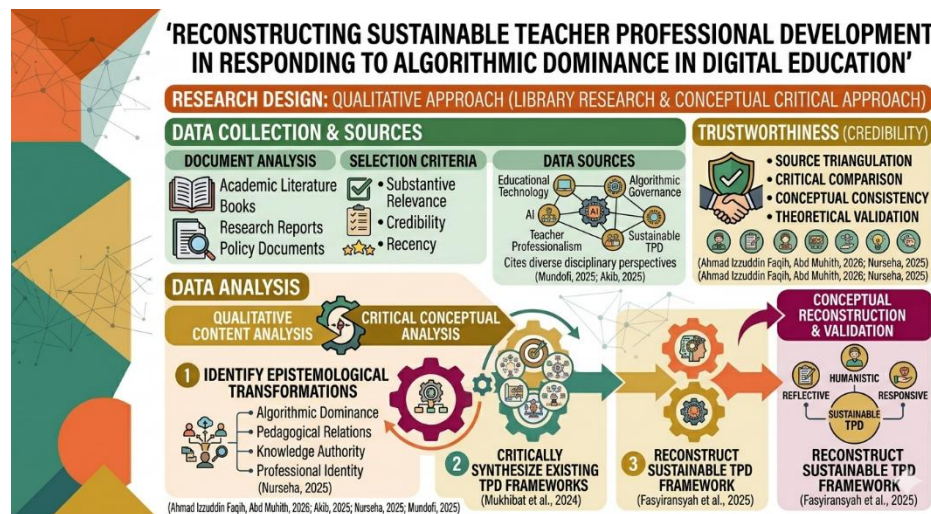


Figure 1 Metode penelitian (gambar elaborasi penulis)

RESEARCH RESULT

This study identifies four major findings through a critical-conceptual analysis of literature on algorithmic domination in digital education and its implications for the reconstruction of Sustainable Teacher Professional Development.

Algorithms Have Evolved into Epistemic Architecture in Digital Education

The first finding confirms that algorithms in digital education no longer function as neutral technical tools. Perrotta et al. (Perrotta et al., 2020) and Williamson et al (Williamson et al., 2023) demonstrate that algorithmic systems have developed into epistemic architecture that actively shapes how knowledge is produced, distributed, and validated within digital education ecosystems. This transformation is driven by three structural factors: the data-driven business model of the EdTech industry, the institutional appeal of pedagogical efficiency through automation, and persistently low algorithm literacy among educational actors (Muhić et al., 2023; Renz & Hilbig, 2020). Across these drivers, AI systems, adaptive learning platforms, learning analytics, and recommender systems collectively reduce learning interactions into digital traces that are continuously collected, analyzed, and used as the basis for pedagogical decision-making (Perrotta et al., 2020; Vetter & McDowell, 2023).

Algorithmic Domination Produces a Threefold Epistemological Shift

The second finding reveals that algorithmic domination has restructured the epistemological foundations of education across three dimensions. In the dimension of

knowledge production, algorithmic logic tends to prioritize viral and emotionally engaging content over pedagogically meaningful material, pushing digital knowledge toward shallow and rapid information consumption (Amin, 2025; Ramiel & Fisher, 2024; Sutrisno, 2025). In the dimension of knowledge distribution, algorithmic personalization creates filter bubbles that limit students' exposure to diverse intellectual perspectives (Lagos-Castillo et al., 2025; Vorobyeva et al., 2025). In the dimension of knowledge validation, epistemic authority has shifted from teachers and institutions toward algorithmic metrics, data scores, and system recommendations, rendering moral, reflective, and dialogical dimensions of education increasingly invisible because they resist quantification (Ramiel & Fisher, 2024; Shulga, 2024). This threefold shift marks the movement of digital education from human-centered pedagogy toward data-driven pedagogy.

Algorithmic Domination Triggers a Crisis of Teacher Identity and Pedagogical Agency

The third finding confirms that algorithmic domination has fundamentally altered the professional position of teachers in digital education ecosystems. Jose et al. (Antony Jose et al., 2025) identify that generative AI increasingly functions as a superior knower in learning spaces, displacing teacher epistemic authority toward machine-made credibility. Trevisan et al. (Trevisan et al., 2024) document the phenomenon of pedagogical atrophy, the gradual erosion of teachers' most humanistic pedagogical capacities as cognitive tasks are progressively delegated to algorithmic systems. Ambady and K. (Ambady & K. V, 2025) confirm that teachers are being transformed into data custodians whose primary work involves managing data flows and validating automated outputs rather than building meaningful pedagogical relationships. Daliri-Ngametua and Hardy (Daliri-Ngametua & Hardy, 2022) describe the cumulative outcome of these pressures as the disappearing teacher, the progressive fading of teachers as authentic agents of educational relationships, leaving schools that are pedagogically eviscerated yet administratively full.

Conventional TPD Models Fail to Address the Epistemological Crisis

The fourth finding reveals that existing Teacher Professional Development models, including those specifically designed for the digital era, remain trapped within a technical-instrumental paradigm that fundamentally misreads the nature of the crisis teachers face. Abedi (Abedi et al., 2023) and Montero-Mesa et al. (Montero-Mesa et al., 2023) show that most TPD programs focus almost exclusively on basic technical skills for operating devices and platforms, leaving pedagogical transformation entirely unaddressed. Ahadi et al. (Ahadi et al., 2024) find that workshop-based programs tend to be ceremonial and episodic, producing no measurable change in teachers' beliefs, practices, or student outcomes. Aagaard et al. (Aagaard et al., 2025) demonstrate that the epistemic dimension of technology, specifically how technology transforms knowledge, practice, and professional identity, is almost entirely absent from current TPD frameworks. Moylan and Code (Code et al., 2023) confirm that algorithm literacy has not been explicitly integrated into most digital competence frameworks for teachers, leaving educators without the critical tools needed to read, question, and negotiate with the algorithmic systems governing their professional work.

DISCUSSION

This study set out to answer two research questions: how algorithmic domination transforms the pedagogical landscape and the professional identity of teachers, and how Sustainable Teacher Professional Development needs to be reconstructed to equip teachers with the critical awareness and pedagogical agency required to negotiate algorithmic domination with dignity. The four findings presented above converge into a single coherent argument: the crisis facing teachers in the age of algorithms is not a crisis of technical competence but a crisis of epistemological and professional identity that demands a paradigmatic response, not merely a programmatic one.

Algorithmic Domination as an Epistemological Crisis, Not a Technical Challenge

The finding that algorithms have evolved into epistemic architecture confirms what critical scholars of digital education have long argued: technology in education is never neutral. Williamson et al. (Williamson et al., 2023) and Perrotta et al. (Perrotta et al., 2020) demonstrate that algorithmic systems carry embedded logics of efficiency, optimization, and datafication that actively reshape what counts as knowledge, who counts as a knower, and what counts as valid learning. This finding aligns with Lagos-Castillo et al. (Lagos-Castillo et al., 2025) and Jandrić and Knox (Jandrić & Knox, 2022), who argue that in the postdigital era, knowledge has become a networked substance whose authenticity increasingly depends on algorithmic construction rather than human negotiation. The implication is significant: if algorithms function as epistemic agents rather than neutral tools, then responding to their domination requires epistemological reorientation, not merely technical adaptation.

The threefold epistemological shift identified in this study, across the dimensions of knowledge production, distribution, and validation, provides empirical grounding for this claim. The finding that algorithmic logic prioritizes viral and emotionally engaging content over pedagogically meaningful material (Amin, 2025; Sutrisno, 2025) reflects what Vetter and McDowell (Vetter & McDowell, 2023) describe as epistemic inequality, a condition in which access to meaningful learning opportunities is determined not by equitable pedagogical relationships but by commercial mechanisms and private data infrastructures. The emergence of filter bubbles in knowledge distribution (Vorobyeva et al., 2025) further undermines one of education's most fundamental purposes: opening intellectual horizons rather than narrowing them. And the displacement of epistemic authority from teachers to algorithmic metrics (Shulga, 2024) represents what Popow (Popow, 2026) identifies as a form of epistemic colonization, where neoliberal data logic and technocratic rationality determine what is considered worth knowing. Together, these three dimensions confirm that the shift from human-centered to data-driven pedagogy is not a neutral evolution but a deeply contested transformation with profound consequences for the meaning of education itself.

Teacher Identity Crisis as the Human Face of Algorithmic Domination

The third finding, that algorithmic domination has triggered a crisis of teacher identity and pedagogical agency, represents what this study identifies as the most consequential dimension of the broader epistemological crisis. The phenomenon of pedagogical atrophy documented by Trevisan et al. (Trevisan et al., 2024) and the professional atrophy risk identified by Turvey and Pachler (Turvey & Pachler, 2026) reveal that the erosion of teacher agency is not a dramatic rupture but a gradual and cumulative process that unfolds silently within the normalcy of digital routines. Every time a pedagogical decision is delegated to an algorithmic system, the capacity to make similar decisions independently is slightly diminished. This cumulative dependency is not easily reversed and tends to deepen the longer teachers operate under algorithmic governance.

The transformation of teachers into data custodians described by Ambady and K. (Ambady & K. V, 2025) and the new forms of labor bondage identified by Andrade and Barbosa (Andrade & Barbosa, 2025) reveal the material dimension of this crisis: teaching as a profession is being redefined not by pedagogical logic but by platform logic. Kerssens and Van Dijck (Kerssens & Van Dijck, 2022) confirm that pedagogical autonomy in platform societies

is no longer a protected right but a configurable variable subject to the interests of technology markets. The concept of the disappearing teacher (Daliri-Ngametua & Hardy, 2022) captures the existential endpoint of this trajectory: schools that are administratively full but pedagogically hollow, and a profession that has been stripped of the relational, ethical, and humanistic substance that gives it meaning. This finding calls for urgent attention not merely to teacher competence but to teacher dignity, understood as the right to remain a thinking, feeling, and meaning-making agent in the educational relationship.

The Paradigmatic Gap in Conventional TPD

The fourth finding, that conventional TPD models fail to address the epistemological crisis, exposes a structural irony at the heart of current educational policy: the systems designed to support teachers are themselves reproducing the very logic that undermines teacher agency. The dominance of technical-instrumental TPD documented by Abedi (Abedi et al., 2023) Montero-Mesa et al. (Montero-Mesa et al., 2023), and Vanegas et al. (Osorio Vanegas et al., 2025) reflects what Aagaard et al. (Aagaard et al., 2025) identify as the persistent instrumentalism of teacher preparation for the digital age, a condition in which the how of using technology consistently overshadows the why and the what does it mean. The ceremonial and episodic character of most TPD workshops (Ahadi et al., 2024; Fernández-Batanero et al., 2020) ensures that whatever technical skills are transmitted in training rooms never translate into the deeper transformations of belief, practice, and professional identity that constitute genuine professional development.

The absence of algorithm literacy from most digital competence frameworks (Code et al., 2023) is particularly consequential. Without the capacity to read, question, and critically negotiate with algorithmic systems, teachers cannot protect their pedagogical autonomy, cannot identify the bias and power dynamics embedded in the platforms they use, and cannot guide their students toward critical engagement with the digital environments shaping their lives. Stenberg et al. (Stenberg et al., 2025) confirm that teacher education continues to be dominated by techno-optimistic narratives that ignore the critical implications of algorithmization for teacher identity and autonomy. This finding establishes that what is needed is not an update to TPD content but a reconstruction of the conceptual framework underlying TPD itself.

Reconstructing Sustainable TPD: Five Interconnected Components

The reconstruction of Sustainable TPD proposed in this study responds directly to the gaps identified across the four findings. It is built on five interconnected components that together constitute a paradigmatic reorientation of teacher professional development. The first component, critical algorithm literacy, addresses the most fundamental gap in current TPD frameworks. Drawing on Zhai (Zhao & Zhai, 2024), Sperling et al. (Sperling et al., 2024), and Moylan and Code (Code et al., 2023), this component positions algorithm literacy not as an optional module but as the foundational competence of professional development in the algorithmic age. Teachers need to understand not only how algorithms work technically but how they govern decisions, embed biases, reproduce inequalities, and shape the epistemological conditions of learning (Baker & Hawn, 2022; SEJDIU et al., 2026). Without this foundation, all other components of TPD remain vulnerable to algorithmic capture.

The second component, humanistic digital pedagogy, responds to the dehumanizing tendencies of data-driven education identified in the second and third findings. Maulidi et al. (Maulidi et al., 2025) demonstrate that techno-humanistic learning frameworks can integrate cognitive, affective, and psychomotor dimensions with digital ethics and humanistic values in

ways that position technology as an instrument serving humanistic educational purposes rather than defining them. Kong and Yang (Kong & Yang, 2024) offer a human-centered generative AI framework that repositions teachers as humanistic storytellers and empathic facilitators rather than platform operators. This component insists that empathy, dialogue, and authentic interpersonal relationships are not soft additions to digital pedagogy but its irreducible core.

The third component, reflective pedagogical agency, directly addresses the pedagogical atrophy identified in the third finding. Turvey and Pachler (Turvey & Pachler, 2026) and Mouta et al. (Mouta et al., 2025) demonstrate that preventing pedagogical atrophy requires TPD programs that explicitly develop teachers' capacity to understand the limitations and risks of AI in education, not only its possibilities. Kim (Kim, 2025) adds that teachers with strong pedagogical agency are capable of leading collaboration with AI from a position of equality, positioning AI as a partner serving their pedagogical purposes rather than an authority determining their professional direction. Zhai (Zhai, 2025) confirms that the transformation of the teacher's role in the era of generative AI demands a shift from teacher as knowledge transmitter to teacher as orchestrator of critical and reflective learning experiences.

The fourth component, ethical AI awareness, responds to the absence of ethical dimensions in conventional TPD identified in the fourth finding. Alzahrani (Alzahrani, 2024) identifies privacy, security, algorithmic bias, transparency, and the erosion of human connection as the shadows of AI that must be made explicit in every program of teacher professional development. Daher (Daher, 2025) through the EQUIP framework positions ethical governance as inseparable from qualified professional learning, enabling teachers to evaluate AI tools critically, read data with considerations that go beyond numbers, and lead responsible AI initiatives in their communities. Without this ethical dimension, technically capable teachers remain blind to the social and moral consequences of the technologies they deploy.

The fifth component, sustainable adaptive learning communities, provides the organizational form that makes the other four components durable and self-renewing. Mouta et al. (Mouta et al., 2025) and Brandão et al. (Brandão et al., 2024) demonstrate that meaningful continuing professional development creates spaces in which teachers collectively construct alternative narratives to corporate platformization, negotiate the educational values they hold, and sustain their professional agency against mounting institutional pressures. Zhai (Zhai, 2025) and Sperling et al. (Sperling et al., 2024) introduce the concept of digital Bildung as the ultimate horizon of professional learning communities: the formation of a reflective, ethical, and socially oriented digital self that cannot be completed in a single training session but requires a collective journey of continuous renewal.

Implications for the Future of Education

If these five components are implemented seriously and systematically, the implications for education extend far beyond teacher competence. Teachers become relevant again not because they are faster than AI but because they do what AI cannot: interpret meaning, exercise ethical judgment, respond with empathy, and guide human growth in contextually sensitive ways (Kim, 2025; Kong & Yang, 2024; Mouta et al., 2025). Education remains humanistic not as nostalgic resistance to technology but as an active commitment to using technology as an instrument for strengthening empathy, collaboration, and character development that resists computation (Alzahrani, 2024; Maulidi et al., 2025). AI becomes

genuinely a tool rather than a controller, positioned as a partner within a human-centered pedagogical framework rather than an authority replacing human judgment (Kim, 2025; Turvey & Pachler, 2026). And the moral dimension of education is preserved: when critical algorithm literacy, ethical AI awareness, and digital Bildung become the core of teacher professional competence, questions of justice, dignity, and collective well-being will never be absent from educational technology decisions (Baker & Hawn, 2022; Sperling et al., 2024; Zhai, 2025).

Ultimately, the reconstruction of Sustainable TPD proposed in this study returns teachers to the center of education, not as information centers already displaced by search engines and generative AI, but as centers of meaning that cannot be replaced by anything. The future of education is not determined by the sophistication of algorithms but by the collective capacity of human beings, above all teachers, to preserve

the meaning, values, and humanity of education amid deepening technological domination. Teachers who have undergone genuine TPD reconstruction will not ask whether AI will replace them. They will ask something far more important: what kind of education do we want to leave to a generation growing up in a world increasingly governed by machines, and what role must they play to ensure that education remains worthy of being called human.

CONCLUSION AND SUGGESTION

Algorithmic domination in digital education demonstrates that contemporary educational transformation is no longer merely concerned with the use of technology in learning but has moved toward an epistemological shift that fundamentally alters how knowledge is produced, distributed, and validated. Artificial intelligence, learning analytics, adaptive learning, and digital platforms no longer function solely as instructional instruments but actively shape the logic of pedagogical decision-making through mechanisms of datafication, automation, and efficiency optimization. This condition has given rise to the paradigm of data-driven pedagogy, which gradually displaces humanistic pedagogical relationships in favor of algorithmically governed learning mechanisms, placing education at risk of losing the reflective, dialogical, and contextual dimensions that constitute the core of the human formation process. These transformations carry serious implications for the professional position and identity of teachers: algorithmic domination affects not only how teachers work but also their epistemic authority, pedagogical agency, and the meaning of the teaching profession itself, accelerating the emergence of pedagogical atrophy and the progressive disappearance of teachers as authentic agents of educational relationships. Sustainable Teacher Professional Development must therefore be reconstructed in ways that are more critical, reflective, and humanistic, strengthening algorithm literacy, critical awareness, pedagogical reflection, and the capacity to preserve pedagogical autonomy and humanistic values within data-driven learning environments.

The findings of this study extend the discourse on Sustainable Teacher Professional Development by positioning algorithmic domination as an epistemological and humanistic concern rather than merely a matter of technological adaptation. The novelty of this study lies in its reconstruction of Sustainable TPD from a critical-humanistic perspective built on five interconnected components, namely critical algorithm literacy, humanistic digital pedagogy, reflective pedagogical agency, ethical AI awareness, and sustainable adaptive learning communities, taking algorithmic domination as the analytical point of departure rather than digital technical competence as most previous studies have done. Practically, this study demonstrates that educational institutions and teacher training providers need to reorient TPD design away from its overemphasis on digital application mastery toward

professional development models that are reflective and critically oriented toward the work of algorithms in education. Nevertheless, this study remains limited to a critical-conceptual approach grounded in library research and therefore does not directly capture the empirical experiences of teachers navigating algorithmic domination in the field.

Based on these conclusions, several suggestions are directed to relevant stakeholders. Educational institutions and policymakers need to fundamentally reorient TPD programs from a technical-instrumental orientation toward a critical-humanistic framework, integrating critical algorithm literacy, ethical AI awareness, and reflective pedagogical agency as core professional competencies rather than supplementary additions. Teacher educators and curriculum developers should explicitly incorporate algorithm literacy into professional digital competence frameworks and replace episodic workshop formats with sustained, collaborative, and community-based professional learning models that enable genuine reflective transformation. Future researchers are encouraged to pursue empirical investigations into teachers' lived experiences of algorithmic domination, including their strategies of adaptation, negotiation, and pedagogical resistance within AI-driven and platformized education ecosystems, as well as comparative studies across diverse institutional settings to examine how reconstructed TPD models can be practically

Pernyataan Etika & Peran Penulis (CRediT Statement)

Penulis Satu (Hasmi Nur Bayhaqi): Konseptualisasi, Metodologi, Investigasi, Analisis Data, Penulisan – Draf Asli.

Penulis Dua (Abdulloh Hamid): Kurasi Data, Validasi, Penulisan – Tinjauan dan Penyuntingan.

Penulis Tiga (Moh. Faizin): Supervisi, Validasi, Penulisan – Tinjauan dan Penyuntingan, serta Pengawasan Akademik.

Kebijakan Data

Data yang mendukung temuan penelitian ini tersedia dari penulis korespondensi berdasarkan permintaan yang wajar.

Persetujuan Etik

Penelitian ini telah disetujui dan mematuhi standar etika penelitian pada manusia.

implemented.

REFERENCE

- Aagaard, T., Amdam, S. H., Nagel, I., Vika, K. S., Andreassen, J. K., Pedersen, C., & Røkenes, F. M. (2025). Teacher preparation for the digital age: Is it still an instrumental endeavor? *Scandinavian Journal of Educational Research*, 69(3), 651–665.
- Abedi, M., Alshybani, I., Shahadat, M. R. Bin, & Murillo, M. (2023). Beyond traditional teaching: The potential of large language models and chatbots in graduate engineering education. *ArXiv Preprint ArXiv:2309.13059*.
- Ahadi, A., Bower, M., Lai, J., Singh, A., & Garrett, M. (2024). Evaluation of teacher professional learning workshops on the use of technology-a systematic review. *Professional Development in Education*, 50(1), 221–237.
- Alzahrani, A. (2024). Unveiling the shadows: Beyond the hype of AI in education. *Heliyon*, 10. <https://doi.org/10.1016/j.heliyon.2024.e30696>
- Ambady, A., & K. V, T. (2025). Persona pedagogica in crisis: are educators becoming data custodians in the age of AI? *Frontiers in Artificial Intelligence*, 8, 1743016.
- Amemasor, S. K., Oppong, S. O., Ghansah, B., Benuwa, B.-B., & Essel, D. D. (2025). A systematic

- review on the impact of teacher professional development on digital instructional integration and teaching practices. *Frontiers in Education*, 10, 1541031.
- Amin, M. S. (2025). Pengaruh algoritma media sosial terhadap narasi keislaman di ruang digital. *El-Wasathy: Journal of Islamic Studies*, 3(1), 148–158.
- Andrade, F. V., & Barbosa, C. S. (2025). DA INOVAÇÃO À CAPTURA: A PLATAFORMIZAÇÃO DA EDUCAÇÃO, O AVANÇO DAS EDTECHS E OS NOVOS GRILHÕES AO TRABALHO DOCENTE. *Colloquium Humanarum. ISSN: 1809-8207*, 22(1), 1--e255210.
- Antony Jose, S., Cowan, N., Davidson, M., Godina, G., Smith, I., Xin, J., & Menezes, P. L. (2025). A comprehensive review on cellulose nanofibers, nanomaterials, and composites: manufacturing, properties, and applications. *Nanomaterials*, 15(5), 356.
- Baker, R. S., & Hawn, A. (2022). Algorithmic bias in education. *International Journal of Artificial Intelligence in Education*, 32(4), 1052–1092.
- Bayhaqi, H. N., & Darmawan, D. (2025). DO TEACHER COMPETENCE, LEARNING ENVIRONMENT, AND ACADEMIC STRESS SIGNIFICANTLY INFLUENCE STUDENT LEARNING OUTCOMES IN ISLAMIC JUNIOR HIGH SCHOOLS? *Prima Magistra: Jurnal Ilmiah Kependidikan*, 6(3), 396–412.
- Brandão, A., Pedro, L., & Zagalo, N. (2024). Teacher professional development for a future with generative artificial intelligence--an integrative literature review. *Digital Education Review*, 45, 151–157.
- Code, J., Moylan, R., Forde, K., & Ralph, R. (2023). Teachers' Sense of Efficacy During a Time of Crisis. *Canadian Journal of Science, Mathematics and Technology Education*, 23(3), 538–558.
- Daher, R. (2025). Integrating AI literacy into teacher education: a critical perspective paper. *Discover Artificial Intelligence*, 5(1), 217.
- Daliri-Ngametua, R., & Hardy, I. (2022). The devalued, demoralized and disappearing teacher: The nature and effects of datafication and performativity in schools. *Education Policy Analysis Archives*, 30, 102.
- Eradze, M., De Martino, D., Tinterri, A., Albó, L., Bardone, E., Sunar, A. S., & Dipace, A. (2023). After the pandemic: Teacher professional development for the digital educational innovation. *Education Sciences*, 13(5), 432.
- Fernández-Batanero, J. M., Montenegro-Rueda, M., Fernández-Cerero, J., & Tadeu, P. (2020). Formación del profesorado y TIC para el alumnado con discapacidad: Una revisión sistemática. *Revista Brasileira de Educação Especial*, 26, 711–732.
- Gu, J., Lai, Y., Shou, H., & Wang, L. (2025). Time since last birth and the risk of endometrial cancer: A meta-analysis of observational studies. *Plos One*, 20(7), e0325907.
- HolonIQ. (2023). Global education technology market outlook 2027. <https://www.holoniq.com>.
- Jandrić, P., & Knox, J. (2022). The postdigital turn: Philosophy, education, research. *Policy Futures in Education*, 20(7), 780–795.
- Jarke, J., & Breiter, A. (2019). The datafication of education. *Learning, Media and Technology*, 44(1), 1–6.
- Kemendikbudristek. (2022). Peraturan Menteri Pendidikan, Kebudayaan, Riset dan Teknologi Republik Indonesia Nomor 22 Tahun 2022. *Kemdikbudristek*, 9(22), 1–87.
- Kerssens, N., & Van Dijck, J. (2022). Governed by edtech? Valuing pedagogical autonomy in a platform society. *Harvard Educational Review*, 92(2), 284–303.

- Kim, J. (2025). Exploring students' perspectives on Generative AI-assisted academic writing. *Education and Information Technologies*, 30(1), 1265–1300. <https://doi.org/10.1007/s10639-024-12878-7>
- Kong, S.-C., & Yang, Y. (2024). A human-centered learning and teaching framework using generative artificial intelligence for self-regulated learning development through domain knowledge learning in K--12 settings. *IEEE Transactions on Learning Technologies*, 17, 1562–1573.
- Lagos-Castillo, A., Chiappe, A., Ramirez-Montoya, M.-S., & Rodr\''iguez, D. F. B. (2025). Mapping the intelligent classroom: Examining the emergence of personalized learning solutions in the digital age. *Contemporary Educational Technology*, 17(1), ep543.
- Maulidi, A., Alanshori, M. Z., Hidayati, Z., Maknin, N. A. K., Rahmah, W., Zuhri, A. M., & Zaini, A. (2025). Techno-Humanistic Learning: A New Paradigm for Human-Centered Digital Pedagogy on Islamic Education. *EDUKASIA Jurnal Pendidikan Dan Pembelajaran*, 6(2), 831–852.
- Montero-Mesa, L., Fraga-Varela, F., Vila-Couñago, E., & Rodr\''iguez-Groba, A. (2023). Digital technology and teacher professional development: Challenges and contradictions in compulsory education. *Education Sciences*, 13(10), 1029.
- Mouta, A., Torrecilla-Sánchez, E. M., & Pinto-Llorente, A. M. (2025). Comprehensive professional learning for teacher agency in addressing ethical challenges of AIED: Insights from educational design research. *Education and Information Technologies*, 30(3), 3343–3387.
- Muhić, S., Goran, N., & Begović, A. (2023). Proposal of a model for smart waste management system using IoT camera and AI for real-time QR code objects recognition. *2023 31st Telecommunications Forum (TELFOR)*, 1–4.
- Osorio Vanegas, H. D., Segovia Cifuentes, Y. de M., & Sobrino Morrás, A. (2025). Educational technology in teacher training: A systematic review of competencies, skills, models, and methods. *Education Sciences*, 15(8), 1036.
- Perrotta, F., Corbi, G., Mazzeo, G., Boccia, M., Aronne, L., D'Agnano, V., Komici, K., Mazzarella, G., Parrella, R., & Bianco, A. (2020). COVID-19 and the elderly: insights into pathogenesis and clinical decision-making. *Aging Clinical and Experimental Research*, 32(8), 1599–1608.
- Popow, M. (2026). Decolonizing knowledge in the postdigital era: Pedagogical strategies for navigating AI-driven epistemic transformations. *Educational Philosophy and Theory*, 58(1–2), 44–56.
- Raj, N. S., & Renumol, V. G. (2024). An improved adaptive learning path recommendation model driven by real-time learning analytics. *Journal of Computers in Education*, 11(1), 121–148.
- Ramiel, H., & Fisher, E. (2024). The epistemic machinery of educational platforms. *Learning, Media and Technology*, 49(4), 623–638.
- Renz, A., & Hilbig, R. (2020). Prerequisites for artificial intelligence in further education: Identification of drivers, barriers, and business models of educational technology companies. *International Journal of Educational Technology in Higher Education*, 17(1), 14.
- SEJDIU, N. P., Ramadani, R., & Sejdiu, S. (2026). Countering the code: Emancipatory teaching and critical digital literacy in platformized schools. *Open Research Europe*, 6(28), 28.
- Shulga, V. I. (2024). Simulation of ion beam sputtering with OKSANA and SRIM: A

- comparative study. *Vacuum*, 230, 113644.
- Sperling, K., Stenberg, C.-J., McGrath, C., Åkerfeldt, A., Heintz, F., & Stenliden, L. (2024). In search of artificial intelligence (AI) literacy in teacher education: A scoping review. *Computers and Education Open*, 6, 100169.
- Stenberg, C.-J., Åkerfeldt, A., Stenliden, L., & McGrath, C. (2025). Teaching with the algorithm: anticipations of AI in teacher education. *European Journal of Teacher Education*, 48(5), 1056–1076.
- Sutrisno, R. D. (2025). Ketika Algoritma Mengajar: Pendekatan Psikologi Pendidikan Agama Kristen Dalam Membentuk Karakter Anak Di Era Media Digital.". *EDUCATIONAL: Jurnal Inovasi Pendidikan & Pengajaran*, 5.
- Trevisan, L. V., Eustachio, J. H. P. P., Dias, B. G., Filho, W. L., & Pedrozo, E. Á. (2024). Digital transformation towards sustainability in higher education: state-of-the-art and future research insights: LV Trevisan et al. *Environment, Development and Sustainability*, 26(2), 2789–2810.
- Turvey, K., & Pachler, N. (2026). A topological exploration of convergence/divergence of human-mediated and algorithmically mediated pedagogy. *British Journal of Educational Technology*, 57(3), 619–638.
- Vetter, M. A., & McDowell, Z. J. (2023). A spectrum of surveillance: Charting functions of epistemic inequality across EdTech platforms in the post-COVID-19 era. *Journal of University Teaching and Learning Practice*, 20(2), 1–17.
- Vorobyeva, K. I., Belous, S., Savchenko, N. V., Smirnova, L. M., Nikitina, S. A., & Zhdanov, S. P. (2025). Personalized Learning through AI: Pedagogical Approaches and Critical Insights. *Contemporary Educational Technology*, 17(2).
- Williamson, B., Macgilchrist, F., & Potter, J. (2023). Re-examining AI, automation and datafication in education. In *Learning, media and technology* (Vol. 48, Issue 1, pp. 1–5). Taylor & Francis.
- Zhai, X. (2025). Transforming teachers' roles and agencies in the era of generative AI: Perceptions, acceptance, knowledge, and practices. *Journal of Science Education and Technology*, 34(6), 1323–1333.
- Zhao, Q., & Zhai, Y. (2024). Two Simple Methods of Drawing Perspective Drawing by Measuring Point Method. *International Conference on Geometry and Graphics*, 46–52.