

Embodied-Technological Epistemology of Learning: Reinterpreting Learning through Merleau-Ponty in the Digital and AI Era

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ABSTRACT

This study reconceptualizes learning in the digital and AI era as an embodied, relational, and technologically mediated process. Grounded in Merleau-Ponty's phenomenology of perception, it develops an Embodied-Technological Epistemology of Learning through a philosophical-conceptual interpretive literature review. The analysis synthesizes embodied cognition, post-phenomenology, and contemporary AI-in-education scholarship. Findings identify three interconnected dimensions of learning: embodied perception, technological mediation, and human meaning-making, with human epistemic agency emerging as a critical condition of meaningful learning. Generative AI can extend learners' access, reflection, and cognitive capacities, but excessive reliance may displace questioning, interpretation, evaluation, and judgment. The study therefore argues that technology should function as an extension rather than a substitute for embodied human agency, offering a philosophical foundation for human-centered learning in the AI era.

INTRODUCTION

Learning has traditionally been understood as a process of knowledge transmission in which teachers communicate information and students receive, interpret, and reproduce it. Although this model has contributed significantly to modern education, its emphasis on cognition and information processing tends to marginalize the embodied dimension of learning. Learners do not encounter knowledge as detached minds but as embodied subjects who perceive, move, act, feel, and interact with others within a meaningful world.

The transformation of education through digital technologies further challenges this conventional understanding. Learning now takes place through learning management systems, virtual classrooms, mobile devices, simulations, and increasingly, artificial intelligence (AI). These technologies expand access, interaction, and personalization, but they also transform the conditions under which learners encounter and construct knowledge. The question is therefore no longer simply how technology can improve the delivery of knowledge, but how technological mediation changes the learner's relationship with knowledge, others, and the world. This question becomes particularly important with generative AI, which increasingly participates not only in accessing information but also in generating explanations, arguments, feedback, and other forms of knowledge-like content (Yan et al., 2024).

Maurice Merleau-Ponty's phenomenology of perception provides an important philosophical foundation for addressing this problem. Merleau-Ponty (2012) rejects the Cartesian separation between mind and body and understands perception as fundamentally grounded in the lived body. Human beings are not detached consciousnesses observing an external world; they are embodied subjects already situated within meaningful relationships with their environment. From this perspective, learning is not merely the acquisition of information but an embodied process of perceiving, interpreting, and acting. The classroom is therefore not simply a space for information exchange but a lived environment in which bodies, gestures, voices, attention, movement, and intersubjective relations participate in the constitution of meaning.

This phenomenological perspective resonates with contemporary embodied cognition, which emphasizes the relationship among brain, body, and environment in learning (Castro-Alonso et al., 2024). It also connects with post phenomenology, particularly Don Ihde's account of technological mediation, which argues that technologies do not merely function as neutral instruments but shape human perception and relations with the world (Ihde, 1990, 1995). Recent scholarship on AI-mediated learning further demonstrates the need to reconsider human agency, cognition, and learning in technologically mediated environments (Miao & Cukurova, 2024; Yan et al., 2024).

Despite these developments, the literature remains theoretically fragmented. Phenomenology emphasizes the embodied learner, embodied cognition examines body-cognition-environment relations, post phenomenology explains human-technology mediation, while AI-in-education research increasingly addresses AI-mediated knowledge and human agency. What remains insufficiently developed is an integrated epistemological account

connecting these perspectives to explain how learning is transformed when embodied human experience becomes increasingly mediated by digital and AI technologies.

This article addresses this gap by developing an Embodied-Technological Epistemology of Learning. Its novelty lies in bringing Merleau-Ponty's phenomenology of the lived body into dialogue with embodied cognition, post-phenomenology, and contemporary AI-mediated learning. The article argues that technology should not be understood merely as a tool for delivering knowledge but as a mediating environment that can extend, reorganize, or constrain embodied perception, interaction, and meaning-making. Accordingly, this study asks: How does Merleau-Ponty's phenomenology of perception reconceptualize learning, and what are its implications for learning mediated by digital technologies and AI?

By addressing this question, the article seeks to contribute a philosophical foundation for understanding twenty-first-century learning as an embodied, relational, and technologically mediated process, while maintaining human agency, critical judgment, and meaningful engagement at the center of education.

LITERATURE REVIEW

Embodiment and Learning

Recent scholarship increasingly challenges the view of learning as primarily the cognitive processing and acquisition of information by emphasizing the learner's embodied and situated engagement with the world. Embodied cognition conceptualizes cognition as emerging from the dynamic relationship among brain, body, action, and environment, suggesting that learning is shaped by bodily activity and perceptual engagement rather than occurring independently of them (Castro-Alonso et al., 2024). This perspective is philosophically grounded in Merleau-Ponty's phenomenology, which rejects the Cartesian separation between mind and body and positions the lived body as the primary medium through which the world is perceived and becomes meaningful (Merleau-Ponty, 2012). Accordingly, embodiment shifts the epistemological understanding of learning from the reception of information toward situated perception and engagement.

Technological Mediation of Learning

The increasing digitalization of education introduces another dimension to this embodied account. Learning management systems, virtual environments, simulations, and digital interfaces do not simply provide alternative channels for information delivery; they mediate learners' relationships with knowledge, others, and their environments. Postphenomenology, particularly Ihde's account of technological mediation, explains this relationship by emphasizing that technologies shape how human beings perceive and act upon the world (Ihde, 1990, 1995). Thus, educational technologies should be understood neither as completely neutral instruments nor as autonomous determinants of learning, but as mediating structures that can reshape the conditions of perception, interaction, and participation.

AI-Mediated Learning and the Emerging Gap

Generative AI further intensifies this transformation because it increasingly participates in producing explanations, feedback, arguments, and other knowledge-like outputs. Recent AI-in-education scholarship highlights its potential for personalization, cognitive support, and new forms of human-AI interaction while simultaneously raising questions about human agency and the changing role of learners and educators (Miao & Cukurova, 2024; Yan et al., 2024). The emerging issue is therefore not simply whether AI improves learning outcomes, but how AI-mediated environments reshape the learner's relationship with knowledge and epistemic agency.

The literature nevertheless remains conceptually fragmented. Embodied cognition explains the relationship between body, cognition, and environment; Merleau-Ponty provides a phenomenological account of embodied perception; postphenomenology explains technological mediation; and AI-in-education research examines changing patterns of cognition, interaction, and agency. What remains insufficiently developed is an integrated epistemological account of how embodied learning is transformed when technological and AI mediation becomes part of the learner's environment of knowing. The conceptual framework of embodied-technological epistemology of learning is shown in Figure 1.

This gap provides the conceptual basis for the present study. Rather than treating embodiment, technology, and AI as separate domains, the study brings them into dialogue to examine learning through the interconnected dimensions of embodied perception, technological mediation, and human meaning-making. This synthesis provides the foundation for the proposed Embodied-Technological Epistemology of Learning, which is further developed and examined through the results and discussion of this study.

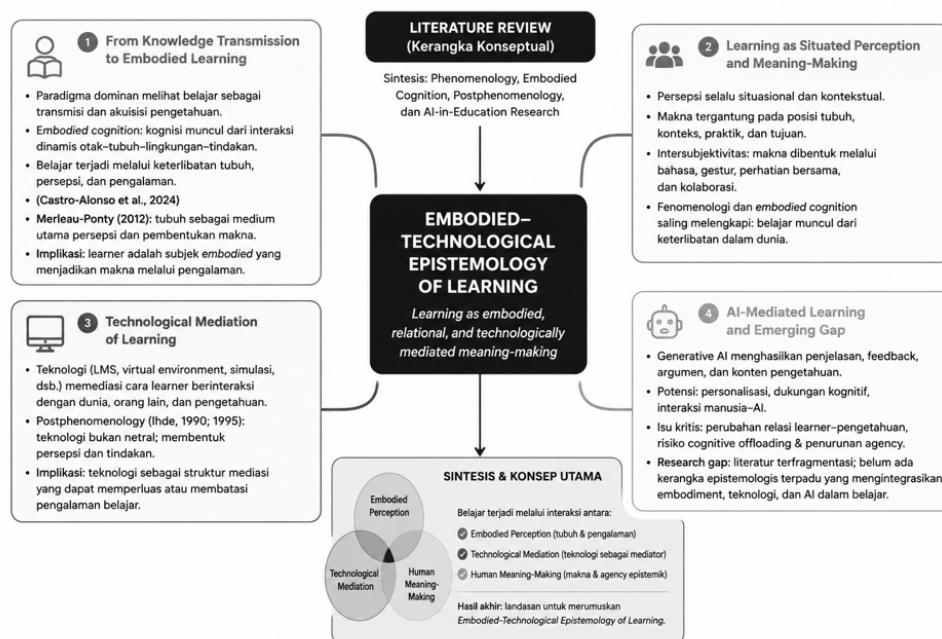


Figure 1. Conceptual Framework (Embodied-Technological Epistemology of Learning)

METHODOLOGY

This study employs a philosophical-conceptual research design using an interpretive literature review to develop an Embodied-Technological Epistemology of Learning. Rather than collecting empirical data from human participants, the study critically examines philosophical and interdisciplinary literature concerning embodied perception, cognition, technological mediation, and AI-mediated learning. This methodological orientation is appropriate because the primary objective of the study is not to measure the effectiveness of a particular educational technology but to clarify and synthesize the epistemological assumptions underlying learning in technologically mediated environments.

Sources and Selection of Literature

The literature analyzed in this study consists of two interconnected bodies of scholarship. The first comprises foundational theoretical works, particularly Maurice Merleau-Ponty's phenomenology of perception and Don Ihde's postphenomenological account of technological mediation. The second comprises contemporary scholarship on embodied cognition, digital learning, and artificial intelligence in education. Recent literature was prioritized to capture current transformations in learning associated with digital technologies and generative AI, while foundational philosophical works were retained because of their conceptual significance.

Literature was selected purposively based on its relevance to four analytical dimensions: (1) embodiment and perception in learning, (2) the relationship between cognition, body, and environment, (3) technological mediation of human experience, and (4) AI-mediated learning and human agency. Studies were included when they contributed directly to understanding one or more of these dimensions. Literature that addressed educational technology primarily from a technical or performance-oriented perspective without substantive relevance to learning, agency, perception, or epistemology was given less analytical priority.

Analytical Procedure

The analysis followed an interpretive and synthetic procedure consisting of four stages. First, the study identifies the central epistemological assumptions underlying conventional and contemporary accounts of learning. This stage establishes the conceptual problem of treating learning primarily as information acquisition and cognitive processing.

Second, the study conducts a critical reading of Merleau-Ponty's phenomenology to identify the concepts of lived body, perception, situatedness, and embodied engagement that are relevant to learning. These concepts are then placed in dialogue with embodied cognition to examine how phenomenological and cognitive perspectives converge in challenging a disembodied conception of learning.

Third, the analysis introduces postphenomenology to examine how technological artifacts and interfaces mediate the learner's relationship with the world. This perspective is subsequently connected with contemporary scholarship on AI-mediated learning to identify how generative AI potentially

transforms perception, interaction, knowledge construction, and epistemic agency.

Fourth, the findings from these conceptual strands are synthesized rather than presented as separate theoretical accounts. The synthesis examines their points of convergence, conceptual tensions, and explanatory limitations to formulate an Embodied-Technological Epistemology of Learning. The resulting framework conceptualizes learning through the reciprocal relationship among embodied perception, technological mediation, and human meaning-making.

Data Analysis

Because this is a conceptual-philosophical study, data analysis does not employ statistical software or quantitative procedures. The primary analytical tools are conceptual analysis, interpretive analysis, critical comparison, and theoretical synthesis. Conceptual analysis is used to clarify the meaning and epistemological implications of key concepts such as embodiment, perception, mediation, agency, and meaning-making. Interpretive analysis is employed to examine these concepts within their philosophical contexts, particularly in Merleau-Ponty and postphenomenological scholarship. Critical comparison is then used to identify convergences and limitations across phenomenology, embodied cognition, postphenomenology, and AI-in-education research.

The final stage involves theoretical synthesis, through which the study integrates the insights of these perspectives into a coherent epistemological framework. The validity of the resulting framework is therefore assessed through conceptual coherence, philosophical consistency, explanatory adequacy, and its capacity to account for the transformation of learning under digital and AI mediation. The methodology ultimately enables the study to move beyond a cataloguing of theories toward an integrated philosophical explanation of how technological mediation transforms the embodied conditions of knowing and learning.

RESULTS AND DISCUSSION

The analysis generated four interconnected findings that provide the conceptual basis for the proposed Embodied-Technological Epistemology of Learning. The findings were derived by synthesizing recent scholarship on embodied cognition, technological mediation, and AI-mediated learning, while using Merleau-Ponty's phenomenology as the philosophical foundation for interpreting the relationship between body, perception, technology, and knowledge. Rather than treating these perspectives as independent theoretical categories, the analysis identified their points of convergence and tension and integrated them into a framework consisting of embodied perception, technological mediation, and human meaning-making. The analytical stages, principal sources, and resulting findings are summarized in Table 1.

Table 1. Analytical Synthesis of the Research Findings

	Analytical Stage	Sources	Key Finding	Epistemological Implication
1	Embodied Learning	Merleau-Ponty (2012); Castro-Alonso et	Learning is fundamentally connected to bodily	Learning cannot be reduced to the reception and

	Analytical Stage	Sources	Key Finding	Epistemological Implication
		al. (2024); <i>Effectiveness of Embodied Learning on Learning Performance</i> (2024)	perception, action, experience, and interaction with the environment. Recent research indicates that embodied learning can improve learning performance and reduce cognitive load.	processing of information; bodily experience is part of the condition through which knowledge becomes meaningful.
2	Technological Mediation	Ihde (1990, 1995); Smith (2023); Sweeney (2024)	Technology does not merely deliver learning content but mediates how learners perceive, interact with, and experience the learning environment.	Technology should be understood as a constitutive mediator that can extend, reorganize, or constrain learners' experience and engagement with knowledge.
3	AI-Mediated Learning	Miao and Cukurova (2024); Yan et al. (2024); Deng et al. (2024); Yusuf et al. (2024)	Generative AI increasingly participates in explanation, feedback, content generation, and knowledge construction, while also offering opportunities for personalization and cognitive support.	AI represents a new form of epistemic mediation that changes not only access to knowledge but also the processes through which learners encounter and construct knowledge.
4	Human Epistemic Agency	Roe and Perkins (2024); Wang et al. (2026); Viberg et al. (2026)	AI can support learner autonomy, reflection, and self-regulation, but excessive reliance may encourage cognitive offloading and weaken independent judgment.	The educational value of AI depends on whether it strengthens or substitutes for learners' capacity to question, interpret, evaluate, and make judgments.
5	Embodied-Technological Epistemology	Synthesis of the sources above	Embodied perception, technological mediation, and human meaning-making are mutually interconnected dimensions of learning in technologically mediated environments.	Learning in the AI era should be understood as an embodied, relational, and technologically mediated process in which technology extends rather than replaces human epistemic agency.

Summary of Results

The synthesis in Table 1 constitutes the principal result of the study. It demonstrates that the central issue in technologically mediated learning is not merely the effectiveness of technology but the transformation of the conditions of knowing. Embodied cognition establishes the importance of bodily and environmental engagement; postphenomenology explains how technologies mediate this engagement; and contemporary AI research demonstrates that generative AI increasingly participates in cognitive and knowledge-producing activities.

The resulting framework therefore positions embodied perception, technological mediation, and human meaning-making as interconnected dimensions through which learning should be understood in the digital and AI era. Recent scholarship further supports the need to preserve human agency and critical oversight when AI becomes increasingly integrated into educational processes.

The findings of this study indicate that learning in technologically mediated environments cannot be adequately understood through a conventional knowledge-transmission model. The synthesis of phenomenology, embodied cognition, postphenomenology, and AI-in-education research demonstrates that learning is constituted through the interaction of an embodied learner, a technologically mediated environment, and processes of human meaning-making. This finding supports the broader shift from viewing learning as primarily cognitive information processing toward understanding learning as situated, embodied, relational, and mediated.

Embodiment as the Epistemological Foundation of Learning

The first finding reinforces the significance of embodiment in understanding how learning occurs. Merleau-Ponty's phenomenology challenges the Cartesian assumption that knowledge originates from a detached consciousness observing an external world. The lived body is instead the subject's primary means of engaging with and making sense of the world (Merleau-Ponty, 2012). This philosophical position is increasingly supported by embodied cognition research, which emphasizes the reciprocal relationship among bodily activity, cognition, and environmental conditions (Castro-Alonso et al., 2024).

The significance of this finding extends beyond arguing that physical activity can make learning more effective. The deeper implication is epistemological: the body is not merely an instrument for learning but part of the condition that makes knowing possible. Learning therefore involves perception, attention, movement, affect, and situated interaction. This interpretation is consistent with recent evidence indicating that embodied learning can positively influence learning performance and cognitive processing. However, the present study extends this literature by shifting the emphasis from the effectiveness of embodied techniques to the philosophical status of embodiment itself. Embodiment is understood not simply as a pedagogical strategy but as a fundamental dimension of the learner's relationship with knowledge.

This distinction is important in the context of digital education. If learning is fundamentally embodied, then the increasing movement of educational

activity into digital environments should not be evaluated only in terms of accessibility, flexibility, or efficiency. It should also be examined in terms of what happens to perception, bodily presence, social interaction, and experiential engagement when learning is mediated through screens, interfaces, and algorithmic systems.

Technology as a Constitutive Mediator

The second finding demonstrates that technology should not be conceptualized merely as an external tool added to an otherwise unchanged learning process. This finding is consistent with postphenomenological approaches, particularly Ihde's argument that technologies mediate human relations with the world (Ihde, 1990, 1995). From this perspective, a technological artifact does not simply transmit information between an already independent learner and an already existing object of knowledge. Instead, it participates in shaping how the learner encounters that object.

This insight is particularly relevant to contemporary digital learning. A learning management system, virtual classroom, mobile device, simulation, or AI interface establishes particular possibilities for seeing, interacting, communicating, and acting. Some technological environments extend human capacities by making previously inaccessible information or experiences available. Others reorganize attention or reduce forms of embodied and interpersonal interaction. Technology therefore possesses a constitutive rather than merely instrumental role in learning.

The finding also helps resolve a limitation in technology-centered educational research. Much research evaluates technology according to outcomes such as achievement, engagement, efficiency, or satisfaction. These measures are important but do not fully capture the epistemological consequences of technological mediation. Two technologies may produce similar learning outcomes while creating substantially different relationships between learners, knowledge, and others. An embodied-technological perspective therefore asks a prior question: What kind of learner-world relationship does a technology produce?

Generative AI and the Transformation of Epistemic Agency

The third finding becomes particularly significant with the emergence of generative AI. Unlike earlier educational technologies that primarily facilitated access, communication, or representation, generative AI can actively produce explanations, summaries, arguments, feedback, and other forms of knowledge-like content. Contemporary AI-in-education research consequently identifies substantial opportunities for personalized learning, feedback, cognitive support, and human-AI collaboration (Miao & Cukurova, 2024; Yan et al., 2024).

The present study argues, however, that the significance of generative AI cannot be fully captured by describing it as a more advanced educational tool. Generative AI introduces a transformation in the epistemic position of the learner. Learners increasingly encounter knowledge that has already been selected, organized, interpreted, and articulated by an artificial system. Their task may consequently shift from generating and organizing knowledge toward evaluating and managing machine-generated outputs.

This transformation produces both an opportunity and a risk. AI can augment learning when it provides alternative explanations, stimulates inquiry, supports reflection, and expands opportunities for exploration. However, it can become epistemically problematic when learners delegate activities that are constitutive of learning itself, such as questioning, reasoning, interpreting, and formulating arguments. The critical distinction is therefore not between “AI use” and “non-use,” but between AI as augmentation and AI as substitution.

This argument extends current discussions of AI literacy and responsible AI use. Rather than defining AI literacy primarily as the ability to operate AI systems or recognize AI-generated misinformation, an embodied-technological epistemology suggests that AI literacy should also involve awareness of how AI changes the learner’s own process of knowing. Learners need to recognize when technological assistance strengthens their agency and when it begins to replace the cognitive, embodied, and interpretive engagement through which meaningful learning occurs.

From Cognitive Offloading to Epistemic Displacement

The relationship between AI and human agency also requires a more nuanced distinction between cognitive offloading and epistemic displacement. Cognitive offloading is not inherently problematic. Humans have always used external tools – writing, diagrams, calculators, maps, and other technologies – to extend cognitive capacities. From this perspective, AI can legitimately function as an external cognitive resource.

The problem emerges when offloading moves beyond the delegation of routine cognitive operations and begins to displace the learner’s epistemic responsibility. When a learner accepts an AI-generated explanation without questioning its assumptions, verifies neither its evidence nor its reasoning, or allows AI to formulate conclusions that the learner cannot independently defend, the issue is no longer simply reduced cognitive effort. It concerns the transfer of responsibility for knowing and judging.

This distinction provides an important theoretical contribution of the present study. The relevant educational question is not whether learners should avoid cognitive offloading but whether they retain epistemic ownership of the learning process. AI may perform certain cognitive tasks while the learner remains responsible for interpretation, evaluation, contextualization, and judgment. Such an arrangement represents augmentation rather than displacement.

Toward an Embodied-Technological Understanding of Learning

The central theoretical contribution of this study is the integration of three dimensions that are often treated separately: embodied perception, technological mediation, and human meaning-making. Merleau-Ponty explains why learning begins from an embodied subject situated within a meaningful world. Embodied cognition reinforces the interdependence of bodily, cognitive, and environmental processes. Postphenomenology explains how technologies mediate these relationships. Contemporary AI research demonstrates that this mediation has become increasingly active because AI can participate directly in knowledge production.

The proposed framework therefore moves beyond both technological instrumentalism and technological determinism. Technology is neither a neutral tool whose effects depend entirely on the user nor an autonomous force that inevitably determines the future of learning. Its educational significance emerges through the interaction between technological affordances and embodied human agency.

This position also allows the study to reinterpret the role of the teacher. If AI increasingly performs informational and explanatory functions, the teacher's significance should not be reduced. Instead, educational authority can shift toward facilitating embodied engagement, dialogue, interpretation, ethical judgment, and critical evaluation. The teacher becomes increasingly important in creating learning situations in which students do not merely receive technologically generated answers but learn how to question, contextualize, evaluate, and meaningfully respond to them.

Implications for AI-Mediated Education

The findings have three principal implications for educational practice. First, technology design should be evaluated according to the quality of human engagement it enables, rather than solely according to efficiency or personalization. Second, AI integration should preserve epistemic agency by requiring learners to interrogate and evaluate AI-generated outputs rather than simply reproduce them. Third, learning environments should maintain opportunities for embodied, interpersonal, and experiential engagement because digital mediation should complement rather than eliminate these dimensions of learning.

Accordingly, the aim of AI-mediated education should not be to minimize human effort. Learning necessarily involves productive difficulty, uncertainty, interpretation, and judgment. An educational environment that removes all such difficulty through automated generation may become more efficient while becoming epistemically weaker. The more appropriate goal is to use AI to create expanded conditions for human learning while preserving the learner's responsibility for meaning and judgment.

Overall, the discussion demonstrates that the transformation of education by AI is not merely a technological transformation. It is an epistemological transformation concerning how human beings perceive, encounter, construct, and validate knowledge. The proposed Embodied-Technological Epistemology of Learning responds to this transformation by placing the embodied learner – not the technology – at the center of the educational process. Technology becomes educationally valuable when it expands the learner's capacity to perceive, interact, interpret, and act, while remaining accountable to human agency, critical judgment, and meaningful engagement.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that learning in the digital and AI era should be understood as an embodied, relational, and technologically mediated process, rather than merely as the transmission and processing of information. The synthesis of Merleau-Ponty's phenomenology, embodied cognition,

postphenomenology, and contemporary AI-in-education research demonstrates that learning is constituted through the interaction of embodied perception, technological mediation, and human meaning-making. Digital technologies and generative AI can extend access, perception, interaction, and cognitive capabilities; however, their educational value depends on whether they strengthen or displace learners' epistemic agency. The proposed Embodied-Technological Epistemology of Learning therefore positions technology as a mediator and potential extension of human learning, not as a substitute for embodied experience, critical judgment, and meaningful human interaction.

Based on these findings, several recommendations can be proposed. First, educators should design AI-mediated learning activities that preserve active learner engagement, requiring students to question, interpret, evaluate, and reflect on AI-generated content rather than merely reproduce it. Second, educational institutions should evaluate learning technologies not only through efficiency, achievement, or personalization but also through their effects on embodiment, interaction, attention, agency, and meaning-making. Third, AI literacy should be expanded beyond technical competence to include epistemic awareness, enabling learners to recognize how AI influences what they perceive, how they construct knowledge, and how they make judgments. Fourth, technology developers should consider embodied and relational dimensions of learning when designing educational AI systems, particularly by supporting reflection, dialogue, contextualization, and human oversight. Finally, future research should empirically examine the proposed framework across different educational levels and technological environments to determine how embodied perception, technological mediation, and epistemic agency interact in actual learning practices.

The principal implementation of this research is therefore a shift in the orientation of AI-mediated education: from technology-centered learning toward human-centered technological mediation. The question should not simply be how much AI can do for learners, but how AI can be designed and used so that learners remain capable of perceiving, questioning, interpreting, judging, and acting meaningfully. In this sense, the future of technologically mediated education should be measured not by the extent to which technology replaces human learning activities, but by its capacity to expand human possibilities for knowing without displacing the embodied agency through which meaningful learning occurs.

ADVANCED RESEARCH

This study has several limitations that provide directions for further research. First, as a philosophical-conceptual study, the proposed Embodied-Technological Epistemology of Learning is derived primarily from the synthesis and interpretation of existing literature rather than empirical observation. Its explanatory value therefore requires validation through empirical studies involving learners and educators in diverse educational contexts. Second, although the framework integrates phenomenology, embodied cognition, postphenomenology, and AI-in-education research, it does not exhaust all perspectives relevant to technologically mediated learning, particularly

sociocultural, affective, and critical approaches to AI. Third, the rapid development of generative AI means that technological capabilities and educational practices may change faster than theoretical frameworks can accommodate.

Future research should therefore empirically investigate how embodied perception, technological mediation, and human epistemic agency interact in actual AI-mediated learning environments. Mixed-method and phenomenological studies could examine learners' lived experiences when interacting with generative AI, while experimental and longitudinal research could investigate whether different forms of AI use strengthen or weaken critical thinking, agency, and meaningful engagement over time. Comparative research across disciplines, educational levels, cultures, and types of AI systems would also be valuable for examining the contextual applicability of the framework. Finally, future studies could operationalize the three dimensions of the proposed framework—embodied perception, technological mediation, and human meaning-making—into empirically observable indicators, enabling systematic evaluation of whether AI functions as an extension of human learning or gradually becomes a substitute for human epistemic agency.

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