RE-EMBODIED EDUCATION: TOWARD AN INTEGRATED EMBODIED PHYSICAL LITERACY FRAMEWORK (IEPLF)

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ABSTRACT

Physical literacy (PL) and embodied cognition share a common theoretical ground in recognizing the body as central to learning and thinking. This contribution explores their connection, proposing PL as a practical framework through which embodied cognition can be operationalized and empirically investigated. Movement experience is not merely an output, but a process that shapes perception, supports executive functions, and provides the biological basis for conceptual meaning and social interaction. PL fosters a reciprocal relationship between action and cognition, where skills, motivation, and understanding co-develop. This perspective highlights a virtuous cycle in which bodily engagement enhances cognitive functions, while cognitive awareness refines movement quality. Integrating these domains offers valuable implications for education and training, suggesting that promoting PL can support holistic development, bridging motor competence with cognitive growth and lifelong learning.

KEYWORDS

Embodied cognition; physical literacy; cognitive development.

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1. Introduction

Over the last three decades, educational research has progressively moved beyond Cartesian dualism, embracing embodied and situated models of learning. Within this perspective, cognition emerges through the dynamic interaction of brain, body, and environment, while perception, action, and emotion are understood as inseparable dimensions of human experience (Barsalou, 2008; Faella, Digennaro, et al., 2025; Merleau-Ponty, 1945; Varela et al., 1991; Wilson, 2002).

Within this perspective, learning is understood as embodied, situated, and relational. Perception, action, and emotion are deeply intertwined, and knowledge is grounded in sensorimotor experience (Barsalou, 2008; Wilson, 2002). Embodied Cognition (EC) provides a robust theoretical framework explaining how cognitive processes arise from bodily engagement with the environment (Gallese & Lakoff, 2005; Lakoff & Johnson, 1999).

In parallel, Physical Literacy (PL) has emerged as a holistic construct integrating physical competence, motivation, confidence, and understanding, supporting lifelong engagement in physical activity (Whitehead, 2010, 2019). Although EC and PL are conceptually similar, they have developed within different academic disciplines. Embodied Cognition primarily originates from cognitive science, phenomenology, and neuroscience, while Physical Literacy has its roots in physical education, sport pedagogy, and public health. Recent research has begun to emphasize the potential for these two perspectives to converge, especially in the contexts of embodied learning and holistic educational development (Castro-Alonso et al., 2024; Cereda, 2025). However, a clear integrative framework connecting EC and PL within educational research remains underdeveloped. Bridging this gap represents a key opportunity to translate theoretical insights from cognitive science into educational practice.

Furthermore, growing digitalization and the expansion of Artificial Intelligence (AI) in education raise concerns about increasingly disembodied learning environments. In this context, preserving the embodied and affective dimensions of learning becomes essential (Faella, Digennaro, et al., 2025).

The present article addresses a different research objective. Whereas the previous review (Faella, Digennaro, et al., 2025) focused on identifying and synthesizing empirical evidence concerning embodied learning practices in school-based physical education, the current study undertakes a theoretical integration of Embodied Cognition and Physical Literacy. The previous review therefore represents an empirical input to the conceptual development of the IEPLF rather than the empirical validation of the framework itself.

More specifically, the IEPLF was informed by the recurring constructs and relationships identified in the previous review, particularly the centrality of embodied experience, physical literacy, engagement, identity, and interdisciplinary learning. These findings were integrated with theoretical propositions from Embodied Cognition concerning sensorimotor interaction, perception–action coupling, embodied meaning-making, and cognitive development. The IEPLF thus represents a subsequent conceptual synthesis rather than a re-analysis of the data included in the previous review.

Therefore, the present paper aims to: i) to synthesize Embodied Cognition and Physical Literacy; ii) to propose the Integrated Embodied Physical Literacy Framework (IEPLF); iii) to discuss its implications for educational research and practice.

Methodological Approach

The present study adopts an integrative theoretical synthesis aimed at developing a conceptual bridge between Embodied Cognition (EC) and Physical Literacy (PL). Rather than conducting a new systematic review or deriving an empirically validated causal model, the objective was to articulate a theoretically coherent framework capable of integrating explanatory mechanisms from EC with the developmental and pedagogical dimensions of PL.

The construction of the IEPLF drew upon three complementary sources of knowledge. First, foundational and contemporary scholarship on EC and PL was examined to identify recurring concepts and mechanisms relevant to embodied learning, including perception-action coupling, embodied experience, executive functions, meaning-making, agency, adaptation, and lifelong engagement in movement. Second, empirical evidence from embodied learning research was considered, with particular reference to the scoping review by Faella, Digennaro, and Iannaccone (2025), which identified Physical Literacy, embodied identity, and multidisciplinarity as central themes within school-based educational contexts. Third, the concepts emerging from these theoretical and empirical sources were reorganized within a developmental framework that distinguished contextual conditions, experiential antecedents, proximal cognitive processes, integrative mechanisms, and adaptive outcomes.

The resulting framework conceptualizes embodied learning as a recursive and dynamic process in which interaction with the environment gives rise to developmental processes that are continuously reorganized through experience. Consequently, the IEPLF should be understood as a theory-informed heuristic model rather than an empirically validated causal structure.

Its primary purpose is to make explicit theoretically plausible relationships, generate testable propositions, and identify potential indicators capable of guiding future empirical investigation.

2. Embodied Cognition: Theoretical Foundations

EC represents a major paradigm shift in cognitive science, challenging the classical computational model of the mind. Rather than conceptualizing cognition as abstract information processing, EC emphasizes that cognitive processes emerge from sensorimotor interaction with the environment (Barsalou, 2008; Varela et al., 1991).

The conceptual roots of this approach can be traced back to phenomenology, particularly the work of Merleau-Ponty (1945), who argued that perception is not a passive reception of sensory input but an active, embodied engagement with the world. According to this perspective, the body is not an object within the environment but the very condition through which the environment is experienced and understood (Digennaro, 2023).

The enactive approach further develops this idea by proposing that cognition is "brought forth" through action. Varela et al. (1991) argue that knowledge emerges through recurrent perception–action cycles, in which individuals actively construct meaning through interaction with their surroundings. In this sense, cognition is not representational but relational and dynamic.

Neuroscientific research has reinforced these insights. The discovery of mirror neuron systems shows that observing and performing actions activates similar neural circuits, indicating that understanding others is based on embodied simulation processes (Gallese, 2005; Rizzolatti & Sinigaglia, 2010). This highlights the embodied nature of social cognition and intersubjectivity.

Recent developments in grounded cognition and predictive processing further support the view that cognition emerges from dynamic brain-body-environment interactions (Barsalou, 2020; Clark, 2016; Friston, 2010).

Across these perspectives, a common conclusion emerges: cognition is not confined to internal mental processes but arises through the continuous coupling of the embodied self and the environment. Knowledge, perception, and action are therefore understood as emergent properties of dynamic organism–environment interactions rather than as functions of the brain alone (Digennaro, 2023; Faella et al., 2025).

This redefinition has profound implications for educational theory, suggesting that learning is fundamentally grounded in embodied participation, relational experience, and meaningful interaction with the world.

4. Physical Literacy: Beyond Physical Competence

PL has emerged as a key construct within contemporary educational and health-related disciplines, representing a shift toward a more holistic understanding of human movement and development. Originally conceptualized by Whitehead (2010, 2019), PL refers to the integration of motivation, confidence, physical competence, knowledge, and understanding that enables individuals to engage meaningfully in physical activity throughout life.

Unlike traditional approaches focused primarily on motor skill acquisition or performance outcomes, PL conceives the movement as a medium through which individuals perceive, interpret, and engage with their environment. As such, it aligns with educational perspectives that emphasize experiential learning, personal development, and meaning-making through action.

A central characteristic of PL is its multidimensional nature. The construct encompasses physical competence, affective engagement, and cognitive understanding, which evolve dynamically through lived experiences and interactions with the environment (Cairney, Dudley, et al., 2019; Dudley, 2015). Rather than representing separate domains, these dimensions operate as an integrated system supporting participation, agency, and lifelong engagement in movement.

International organizations, including UNESCO (2015) and the International Physical Literacy Association (IPLA, 2017), have contributed to the dissemination of PL as a framework for promoting holistic development and well-being. More recently, research has emphasized its relevance across educational, sport, and health contexts, highlighting the need for context-sensitive approaches capable of addressing individual and environmental variability(Barnett et al., 2023; Edwards et al., 2017; Iannaccone et al., 2025).

Contemporary perspectives increasingly view PL as a lifelong developmental process rather than a fixed outcome. Through diverse movement experiences, individuals continuously refine their relationship with physical activity, developing adaptive capacities, self-awareness, and meaningful patterns of engagement (Cairney, Dudley, et al., 2019; Fortnum et al., 2025). This perspective is also consistent with ecological dynamics approaches, which conceptualize Physical Literacy as a lifelong process of enrichment emerging from continuous interactions between individuals and their environments. From this viewpoint, functional movement skills, exploration, and adaptation develop through diverse and meaningful experiences that support long-term engagement in physical activity (Rudd et al., 2020).

This dynamic orientation is consistent with ecological and constructivist approaches, according to which learning emerges through active interaction with the environment.

Recent studies have further highlighted how playful and embodied movement experiences contribute not only to physical competence but also to enjoyment, engagement, and meaningful learning. For example, Aartun et al. (2023) demonstrated that playfulness in physical education creates opportunities for both pleasure and educational development, reinforcing the experiential and relational dimensions of Physical Literacy.

Despite its strengths, PL offers only a partial explanation of the cognitive mechanisms underlying development. While it acknowledges the importance of perception, decision-making, and understanding, it does not explicitly explain how these processes emerge through embodied interaction. EC provides a complementary perspective by offering a theoretical account of how movement contributes to the formation of cognitive structures, conceptual knowledge, and executive functions (Gomez Paloma, 2013). Nevertheless, the convergence between PL and EC is evident. Both perspectives emphasize the inseparability of perception and action, the importance of environmental interaction, and the central role of lived experience in learning and development. While EC explains the mechanisms through which cognition emerges from bodily engagement, PL provides a pedagogical framework through which such processes can be intentionally fostered. This complementarity forms the basis for the integrated model proposed in the following sections (Barnett et al., 2023; Iannaccone et al., 2025).

5. Theoretical Convergence Between Embodied Cognition and Physical Literacy

Despite emerging from different disciplinary traditions, EC and PL converge on a common assumption: learning and development arise through the dynamic interaction between body, mind, and environment (Faella, Digennaro, et al., 2025; Merleau-Ponty, 1945; Varela et al., 1991; Whitehead, 2010). Both perspectives challenge dualistic conceptions of human functioning and emphasize the interdependence of perception, action, cognition, and experience.

A first area of convergence concerns the role of sensorimotor interaction in learning. EC argues that cognition emerges through continuous perception–action cycles, in which individuals actively engage with environmental affordances (Bornstein & Gibson, 1980; Varela et al., 1991). Similarly, PL views movement as a meaningful exploration of the environment through which individuals progressively develop competence, confidence, and understanding. In both frameworks, learning is conceived as an active and situated process rather than the passive acquisition of information.

A second point of convergence relates to the construction of knowledge and understanding. EC proposes that concepts are grounded in bodily experiences and that abstract reasoning develops from recurrent sensorimotor interactions (Barsalou, 2008; Lakoff & Johnson, 1999). PL reflects this view by emphasizing that understanding movement, health, and physical activity emerges through lived experience rather than through purely abstract instruction. Knowledge is therefore conceived as embodied, contextual, and action-oriented.

Particularly significant is the overlap between the two frameworks regarding executive functions and self-regulation. Research in developmental neuroscience suggests that complex movement experiences contribute to the development of working memory, inhibitory control, and cognitive flexibility (Diamond, 2013). These abilities are essential for adaptation, problem-solving, and learning across educational contexts. Although PL does not explicitly describe these processes in cognitive terms, its emphasis on adaptability, decision-making, and effective engagement in dynamic environments reflects similar developmental outcomes (Cairney, Kiez, et al., 2019). This convergence suggests that movement experiences may simultaneously foster motor competence and higher-order cognitive functioning.

A further area of overlap concerns agency and identity formation. PL highlights motivation, confidence, and personal engagement as key dimensions supporting lifelong participation in movement (Whitehead, 2019). Similarly, embodied approaches conceptualize the self as emerging through action and interaction with the environment (Thompson, 2007a). From this perspective, agency is not simply an individual characteristic but a capacity that develops through embodied experiences. Both frameworks therefore recognize that learning involves not only acquiring skills and knowledge but also developing a sense of self-efficacy, autonomy, and personal meaning. Ecological dynamics perspectives further reinforce this convergence by emphasizing exploration, adaptation, and the continuous coupling between learners and their environments as fundamental mechanisms underlying both movement learning and human development (Rudd et al., 2020).

Finally, both perspectives emphasize the social and relational nature of learning. EC underscores the role of embodied simulation and intersubjectivity in understanding others and participating in social life (Gallese, 2005). PL

similarly acknowledges that movement experiences are often collaborative and socially situated, creating opportunities for communication, cooperation, and shared meaning-making (Dudley, 2015; Whitehead, 2019). Learning is therefore understood not as an isolated cognitive activity but as a process embedded within social relationships and cultural contexts.

The main points of convergence and their educational implications are summarized in Table 1.

Table 1. Convergence between Embodied Cognition and Physical Literacy

Embodied Cognition	**Physical Literacy**	**Educational Implication**
Cognition emerges from sensorimotor interaction	Movement as meaningful lived experience	Learning through embodied activity rather than passive instruction
Perception–action coupling	Engagement with diverse movement environments	Experiential and situational learning design
Grounded conceptual knowledge	Knowledge and understanding of movement and health	Integration of practical experience and conceptual reflection
Executive functions are embodied and action-based	Confidence, decision-making, adaptability	Development of self-regulation through movement experiences
Self as enacted through action	Motivation, identity, agency	Support for autonomous and meaningful participation
Social cognition is embodied and relational	Cooperative and shared physical activity experiences	Collaborative learning and social interaction in movement contexts

Following this comparison, it becomes clear that EC and PL should not be viewed as overlapping constructs but as complementary levels of analysis. EC provides an explanation of the mechanisms through which cognition emerges from bodily engagement, whereas PL offers an educational framework through

which these processes can be intentionally cultivated. This complementarity provides the theoretical rationale for the IEPLF, presented in the following section.

6. Physical Literacy as an Operational Framework for Embodied Cognition

The previous sections have argued that EC and PL converge in conceptualizing learning as an embodied, situated, and dynamic process (Varela et al., 1991; Barsalou, 2008; Whitehead, 2010). Despite this convergence, the two frameworks operate at different levels of analysis. EC provides a theoretical explanation of how cognition emerges from sensorimotor interaction, whereas PL offers a pedagogical and developmental framework for fostering engagement in movement (Gallese & Lakoff, 2005; Cairney et al., 2019). Bridging these perspectives requires an integrative model capable of connecting explanatory mechanisms with educational practice.

In response to this need, the present paper proposes the IEPLF, which positions PL as the operational dimension through which embodied cognitive processes can be cultivated within educational contexts. In this perspective, the processes described by EC are translated into structured, meaningful, and developmentally coherent learning experiences (Clark, 1997; Gomez Paloma, 2013).

6.1 Conceptual Foundations of the IEPLF

The IEPLF is grounded in a systemic and non-linear understanding of learning (Varela et al., 1991; (Hutchins, 1995). Development is not conceived as a sequence of discrete stages but as an emergent process generated through continuous interaction between the embodied self and the environment (Digennaro, 2023)**.** Within this dynamic system, movement assumes a

foundational role, not as an outcome of cognition but as one of the primary conditions through which cognition emerges (Merleau-Ponty, 2013; Noë, 2004).

The central assumption of the framework is that embodied experience constitutes the fundamental unit of learning. This assumption aligns with ecological dynamics perspectives that describe Physical Literacy as a process of individual enrichment based on exploration, discovery, and adaptation within diverse environments. Learning emerges through the continuous interaction between the learner and contextual affordances rather than through the acquisition of predetermined movement patterns (Rudd et al., 2020).

Through direct engagement in movement-rich environments, individuals encounter affordances, regulate their actions, and progressively refine their perceptual and cognitive systems (Gibson, 1979; Barsalou, 2008). Learning, therefore, is not passively acquired but emerges through iterative perception–action cycles in which action and understanding co-develop over time (Varela et al., 1991).

To provide a visual representation of the relationships among embodied experience, cognitive development, PL, and adaptive action, the IEPLF is presented in Figure 1.

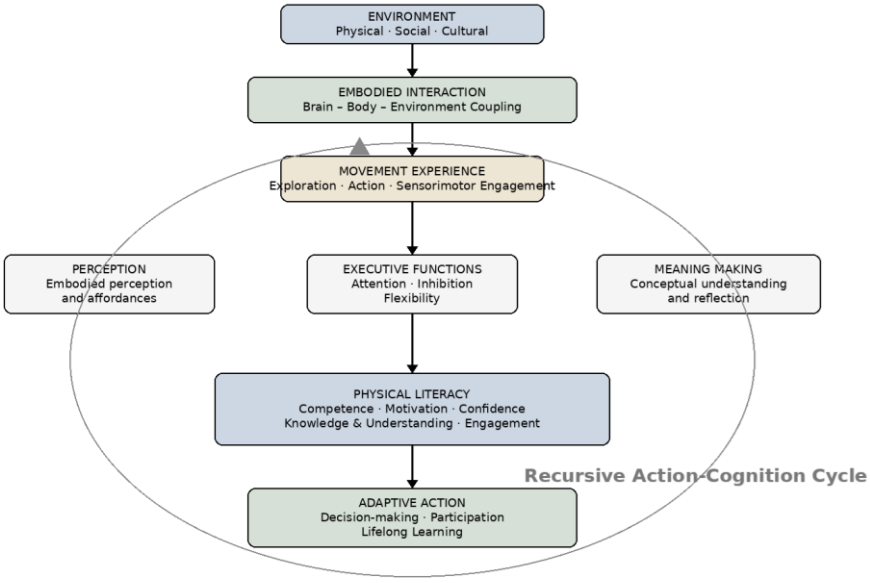


Figure 1. Integrated Embodied Physical Literacy Framework (IEPLF).

Figure 1 depicts the theoretical architecture of the IEPLF, distinguishing contextual conditions, experiential antecedents, proximal processes, developmental integration, and adaptive outcomes. The environment represents the physical, social, and cultural conditions within which embodied learning unfolds. Embodied interaction refers to the continuous coupling of learner, body, and environment, whereas movement experience constitutes the experiential domain through which exploration, action, perception, and adaptation occur.

Movement experience is theorized to influence three interrelated proximal processes, represented by directional arrows indicating theoretically plausible developmental influences rather than empirically established causal pathways: perception, executive functions, and meaning-making. Perception refers to sensitivity to environmental affordances and constraints; executive functions encompass attentional control, inhibition, working memory, and cognitive

flexibility; and meaning-making involves conceptual understanding, reflection, and the attribution of significance to embodied experience. These processes are conceived as mutually interacting dimensions of embodied development rather than as independent linear pathways.

Within the framework, Physical Literacy occupies an integrative and mediating position. Rather than constituting a direct outcome of movement experience, it represents the developmental organization of physical competence, motivation, confidence, knowledge, understanding, and engagement, mediating the transformation of embodied experiences into increasingly coherent and adaptive forms of participation.

Adaptive action represents the proximal expression of this developmental process, encompassing decision-making, participation, and effective adaptation to changing movement contexts. The framework is therefore conceptualized as a recursive feedback system rather than a linear causal sequence. The circular arrow denotes the proposition that adaptive action may subsequently reshape learner-environment interactions, generating further opportunities for embodied experience, development, and learning.

6.2 From Embodied Experience to Cognitive Development

Within the IEPLF, embodied experience represents the foundational layer of development. This experience involves active, situated interaction with physical and social environments through exploration and movement. Such engagement cannot be reduced to observable behavior alone, as it encompasses processes of perception, anticipation, and meaning-making (Gallagher, 2005; Shapiro, 2019).

Through repeated cycles of interaction, individuals develop increasing sensitivity to environmental constraints and opportunities, gradually acquiring

the ability to anticipate change and regulate their responses. These processes support the emergence of higher-order cognitive functions, including executive control, conceptual understanding, emotional regulation, and social cognition(Best & Miller, 2010; Cámara-Martínez et al., 2022; Diamond, 2013). Evidence from school-based interventions suggests that embodied learning approaches can positively influence conceptual understanding and academic performance. Physically active learning experiences have been shown to improve mathematical reasoning, vocabulary acquisition, and narrative comprehension, supporting the view that cognition develops through embodied engagement rather than through passive information processing alone (Bustamante et al., 2022; Cámara-Martínez et al., 2022). From this perspective, cognitive development is not independent of action but is rooted in structured patterns of embodied engagement.

As a result, thinking can be understood as an extension of action rather than as a detached internal process. Cognitive structures emerge from recurring interactions with the environment, and their organization reflects the history of embodied experience (Barsalou, 2010; Glenberg & Kaschak, 2002).

6.3 Physical Literacy as an Integrative Mechanism

Within the IEPLF, PL occupies an integrative and mediating developmental position between embodied experience and adaptive participation. Rather than being conceptualized as a discrete cognitive or behavioural outcome, PL is understood as a multidimensional developmental construct encompassing physical competence, motivation, confidence, knowledge, understanding, and engagement. From this perspective, PL represents the process through which repeated embodied experiences become progressively organized into coherent and transferable capacities, supporting adaptive participation across diverse

movement contexts. As such, PL functions as a central integrative mechanism linking embodied experience with the development of increasingly effective and context-sensitive forms of action.

Through the progressive development of PL, individuals become capable of coordinating motor, cognitive, and affective dimensions of action. According to Rudd et al. (2020), the development of Physical Literacy involves an ongoing process of enrichment in which perceptual, cognitive, and movement systems co-evolve through diverse experiences. This perspective supports the interpretation of PL as an integrative mechanism linking embodied interaction with long-term developmental outcomes.

Movement experiences are not isolated events but contribute to the formation of coherent patterns of behavior and understanding (Cairney et al., 2019; Edwards et al., 2017). Over time, this process facilitates the development of adaptive engagement in increasingly complex contexts, supporting both individual agency and participation.

In this sense, PL enables the transformation of lived experience into structured knowledge, supporting continuity across contexts and developmental stages. It mediates between immediate interaction and long-term learning, allowing individuals to construct meaningful relationships with movement and the environment (Longmuir et al., 2015).

6.4 A Recursive and Self-Reinforcing System

A defining characteristic of the IEPLF is its recursive and self-reinforcing nature. The recursive structure of the IEPLF should not be interpreted as evidence of an empirically established reciprocal causal relationship. Rather, it represents a theoretically grounded proposition suggesting that adaptive action and the progressive development of Physical Literacy may subsequently shape both the

opportunities for and the quality of future embodied engagement. This recursive relationship, represented in Figure 1 as an action–cognition feedback cycle, highlights how embodied experience, PL, and cognitive development continuously reinforce one another.

As individuals develop higher levels of PL, they tend to engage in richer and more complex movement experiences. These experiences, in turn, further stimulate cognitive and affective development, creating conditions for more adaptive and meaningful interaction (Álvarez-Bueno, Pesce, et al., 2017; Hillman et al., 2008). Over time, this dynamic generates a feedback process in which development becomes progressively self-sustaining.

Within this system, learning is not directed toward fixed endpoints but is characterized by continuous adaptation and transformation. Individuals reorganize their perceptual and cognitive structures in response to new experiences, maintaining an ongoing process of development that reflects the reciprocal relationship between action and understanding (Varela et al., 1991; Barsalou, 2020).

6.5 Conceptual Positioning and Theoretical Contribution

The IEPLF can be positioned at the intersection of cognitive science, educational theory, and developmental neuroscience. It integrates the explanatory power of EC with the pedagogical orientation of PL, providing a unified framework that connects theory and practice (Cairney et al., 2019).

Although theoretically applicable across the lifespan, the present formulation of the IEPLF is primarily intended for educational contexts and school-aged populations, reflecting the empirical and theoretical literature from which the framework was derived.This positioning allows the IEPLF to function as a translational model. It offers a structured interpretation of how embodied

processes can be intentionally fostered within educational environments, transforming abstract theoretical principles into actionable pedagogical strategies (Gomez Paloma, 2013; Lindgren & Johnson-Glenberg, 2013). At the same time, it contributes to the theoretical advancement of PL by embedding it within a broader cognitive framework. Recent transdisciplinary educational studies have similarly advocated for integrative pedagogical models capable of connecting bodily experience, cognition, and curricular learning, particularly within STEM education (Almarcha et al., 2023).

It is important to recognize that the IEPLF should be understood as a theoretical and heuristic proposal rather than as a fully validated empirical model. Its primary contribution lies in articulating a coherent conceptual structure capable of guiding future research and informing educational design. By linking embodied experience with developmental processes and educational practice, the framework provides a foundation for interdisciplinary dialogue.

6.6 Implications for Research and Educational Design

The IEPLF opens new directions for both research and educational practice. From a research perspective, it highlights the need to investigate how embodied experiences influence cognitive development across different contexts and stages of life (Álvarez-Bueno, Pesce, et al., 2017), and it also suggests examining the role of PL as a mediating construct linking movement and learning outcomes (Edwards et al., 2017; Fortnum et al., 2025).

Emerging evidence also points to the potential of technology-enhanced Physical Literacy interventions. Recent pilot research with adolescents suggests that digital platforms may support Physical Literacy development and engagement when aligned with pedagogical approaches that maintain the central role of embodied participation. Future studies should therefore

investigate how technology can complement, rather than replace, movement-based learning experiences (França et al., 2026).

From a pedagogical perspective, the framework supports the design of learning environments that emphasize interaction, exploration, and meaningful engagement. Rather than focusing on the transmission of abstract knowledge, educational practice can be oriented toward experiences that integrate perception, action, and reflection, allowing learners to construct understanding through embodied participation (Faella, Digennaro, et al., 2025; Faella, Iannaccone, et al., 2025; Kontra et al., 2015; Lindgren & Johnson-Glenberg, 2013).

In this sense, the IEPLF contributes to redefining education as a process grounded in lived experience, where cognition is not separated from action but emerges through it. This perspective becomes particularly relevant in contemporary contexts, where the increasing digitalization of learning environments raises important questions about the role of the body in cognitive development (Georgiou & Ioannou, 2019).

6.7 Testable Propositions and Potential Indicators

To further clarify the theoretical architecture of the IEPLF, the model can be translated into a set of theoretically derived propositions that may guide future empirical investigation. These propositions are not intended to represent empirically established causal relationships, but rather to make explicit the expected relationships among the constructs included in the framework. Accordingly, Table 2 distinguishes the theoretical function of each construct within the model and provides examples of potential indicators that could be used to operationalize them in future studies. This distinction is particularly important for differentiating contextual conditions, experiential antecedents,

proximal cognitive processes, the integrative developmental construct of Physical Literacy, and proximal outcomes. The proposed indicators should therefore be understood as illustrative rather than exhaustive, and their empirical validity and measurement properties should be examined in future research.

Table 2. Testable propositions and potential indicators within the IEPLF

Construct	**Theoretical role within the IEPLF**	**Testable proposition**	**Potential indicators**
Environment	Contextual condition	Supportive, varied, and socially and culturally meaningful environments are expected to provide richer opportunities for embodied interaction and movement exploration.	Availability and diversity of movement opportunities; task and environmental affordances; physical and social characteristics of the learning environment; teacher support; opportunities for exploration and participation.
Embodied interaction	Experiential antecedent	Greater engagement in embodied interactions with the environment is expected to provide richer opportunities for sensorimotor exploration and learning.	Frequency and duration of embodied engagement; observed learner–environment interactions; degree of active exploration; sensorimotor engagement during learning activities.
Movement experience	Experiential antecedent	Greater diversity, complexity, and meaningfulness of movement experiences are expected to be associated with the development of perceptual, executive, and meaning-making processes.	Movement variability and diversity; task complexity; active participation; motor exploration; adaptation to changing task demands; observation-based measures of movement engagement.

Perception	Proximal cognitive process	Greater sensitivity to environmental affordances and perceptual information is expected to support more adaptive movement-related decisions and actions.	Affordance detector; perceptual-motor tasks; accuracy and speed of perceptual decisions; responses to changes in environmental information.
Executive functions	Proximal cognitive process	Engagement in cognitively demanding and varied movement experiences is expected to be associated with the development or mobilization of executive functions relevant to adaptive action.	Measures of inhibition, working memory, cognitive flexibility, attentional control, and task switching; performance on executive-function tasks embedded in or associated with movement activities.
Meaning-making	Proximal cognitive process	Opportunities to reflect on and interpret embodied experiences are expected to support conceptual understanding and the integration of experience into knowledge.	Reflective narratives; learner explanations; conceptual understanding measures; verbal or written reflections; ability to connect movement experiences with previously acquired knowledge.
Physical Literacy	Integrative developmental construct	The integration of competence, confidence, motivation, knowledge and understanding through embodied experiences is expected to support sustained engagement and increasingly adaptive participation in movement contexts.	Validated Physical Literacy assessment tools; indicators of physical competence, confidence, motivation, knowledge and understanding, and engagement; multidimensional PL profiles.
Adaptive action	Proximal outcome	Greater integration of embodied, perceptual, cognitive, and affective resources is expected to support more adaptive decision-making, participation, and responses to changing movement contexts.	Decision-making accuracy and adaptability; task-specific problem solving; successful adaptation to changing affordances; participation; persistence and adjustment of action strategies.

The propositions presented in this table are theoretically derived from the IEPLF and are intended to guide future empirical investigation. They should not be interpreted as empirically established causal relationships. The proposed indicators are illustrative rather than exhaustive and may require adaptation according to the population, educational context, and research design. In particular, the operationalization of Physical Literacy should rely, where appropriate, on validated multidimensional assessment approaches.

7. Educational Implications

The IEPLF offers significant implications for educational theory and practice. By positioning PL as the operational dimension of EC, the framework provides a foundation for rethinking how learning environments are designed, how teaching is enacted, and how educational outcomes are assessed. Rather than considering movement as a supplementary component of education, the IEPLF recognizes embodied engagement as a fundamental condition for cognitive, affective, and social development. This perspective encourages a shift from transmissive models of instruction toward educational approaches that acknowledge the central role of action, experience, and interaction in the construction of knowledge.

7.1 Curriculum Design: From Activity-Based to Experience-Based Learning

The framework supports a transition from activity-centered curricula toward experience-based learning environments. Within this perspective, movement is not conceived as an end in itself but as a medium through which learners interact with their surroundings, explore possibilities for action, and construct

understanding. Learning tasks should therefore encourage active engagement, adaptation, exploration, and problem-solving through meaningful embodied experiences.

This approach is consistent with contemporary educational perspectives that emphasize experiential and student-centered learning. By engaging learners in activities that require exploration, decision-making, and adaptation to changing situations, embodied experiences may simultaneously support motor competence and higher-order cognitive functions such as attention, inhibitory control, working memory, and cognitive flexibility. Curriculum design should therefore create opportunities for learners to actively negotiate environmental challenges, connecting perception, action, and reflection within coherent learning experiences.

From a broader perspective, an embodied curriculum should encourage the integration of physical, cognitive, and affective dimensions of learning. Rather than separating disciplinary domains, it promotes learning experiences in which abstract concepts can be grounded in action and experience, fostering deeper understanding and more meaningful participation.

This perspective also supports more exploratory and learner-centered pedagogies. Teachers are called to design conditions that facilitate interaction and reflection, encouraging learners to discover multiple solutions and progressively develop agency, self-regulation, and understanding through action (Barsalou, 2008; Lindgren & Johnson-Glenberg, 2013).

7.2 Teacher Education: Developing Embodied Pedagogical Competence

The implementation of embodied approaches requires educators to develop competencies that integrate knowledge of movement, cognition, and learning

processes. Teacher education programs should therefore provide both theoretical foundations and practical experiences that enable future educators to design and facilitate movement-rich learning environments.

Beyond technical expertise, teachers need to develop what may be described as embodied pedagogical competence: the ability to recognize how movement, perception, emotion, and cognition interact within learning situations. Such competence involves creating educational conditions that encourage exploration, support learner agency, and foster meaningful engagement with tasks and environments.

This perspective also implies moving beyond instructional models centred primarily on verbal explanation and information transmission. Within the IEPLF, teaching is understood as the design of experiences through which learners construct understanding through action. Educators, therefore, become facilitators of embodied learning processes, supporting learners in connecting experience, reflection, and knowledge construction.

7.3 Assessment: From Performance Metrics to Holistic Evaluation

The IEPLF suggests a broader understanding of assessment than traditional performance-based models. Conventional evaluation practices often focus on isolated indicators of achievement, such as technical execution or measurable outcomes. While these measures may capture specific aspects of competence, they are insufficient for representing the multidimensional nature of learning within an embodied framework.

From the perspective of the IEPLF, evaluation should consider not only observable outcomes but also learners' engagement, adaptability, reflective

capacity, decision-making processes, and developmental trajectories. Assessment is therefore understood as a continuous and formative process that supports learning rather than merely measuring it.

A holistic approach may combine quantitative and qualitative indicators, including observation, self-reflection, learner narratives, participation, and adaptability in novel situations. Such practices are more consistent with the developmental nature of PL, which evolves through lived experiences and cannot be fully captured through isolated measures of performance. Assessment consequently becomes a tool for promoting self-regulation, awareness, and continuous growth rather than simply classifying achievement levels.

7.4 Toward Integrated Educational Ecosystems

The framework extends beyond physical education and may inform learning across disciplines by grounding abstract concepts in embodied experience. This perspective supports a more integrated vision of education, in which cognition and action are understood as mutually dependent dimensions of development. Movement-based approaches can therefore contribute to learning in diverse domains, including science, mathematics, language, and social education.

These considerations become particularly relevant within increasingly digitalized educational environments. While digital technologies and AI offer valuable opportunities for personalization, feedback, accessibility, and learner support, they may also contribute to forms of learning that are progressively detached from bodily experience and social interaction.

From the perspective of the IEPLF, technological innovation should not be viewed as an alternative to embodied learning but as a potential enhancement of it. AI can support personalized pathways, facilitate reflection, and provide

adaptive feedback, provided that bodily engagement remains a central component of the learning process. The challenge is therefore not to choose between technology and embodiment, but to design educational ecosystems in which both dimensions reinforce one another.

In this sense, the IEPLF offers a framework for balancing innovation with the preservation of the relational, affective, and experiential dimensions of learning. Such an approach may help ensure that future educational environments remain aligned with holistic human development, supporting learners not only as users of technology but as embodied individuals who construct knowledge through meaningful interaction with the world.

8. Conclusions

This paper has explored the theoretical convergence between EC and PL, highlighting their shared assumption that learning emerges through the dynamic interaction between body, mind, and environment. While EC provides a framework for understanding how cognition is grounded in sensorimotor experience, PL offers a pedagogical structure through which these embodied processes can be fostered across the lifespan.

Building on this convergence, the study proposed the IEPLF, conceptualizing learning as a recursive process in which embodied experience, cognitive development, and motivational-affective dimensions continuously influence one another. Within this framework, movement is understood not as a consequence of cognition but as a fundamental mechanism through which perception, understanding, and agency develop (Figure 1).

The proposed model carries important implications for education. It supports the design of experience-based curricula, embodied pedagogies, and holistic assessment practices that recognize the interdependence of cognitive,

physical, affective, and social dimensions of learning. These implications become particularly relevant in increasingly digitalized educational environments, where the need to preserve meaningful bodily engagement is becoming more urgent.

Rather than opposing technological innovation, the IEPLF suggests that emerging technologies, including AI, should be integrated within educational ecosystems that maintain the centrality of embodied experience. From this perspective, PL can be understood not only as a construct related to physical activity, but also as a broader educational resource capable of supporting human development in technologically mediated contexts.

Although the IEPLF remains a theoretical and heuristic model, it offers a foundation for future interdisciplinary research and educational innovation. Ultimately, re-embedding learning within bodily experience may represent a necessary step toward developing more holistic, relational, and sustainable approaches to education in the twenty-first century.

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