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School and Physical Education as Co-evolutionary Ecosystems: Intersections between Body, Environment, and Educational Technologies

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Abstract: This article explores the school context and physical education as co-evolutionary ecosystems shaped by the dynamic interplay among body, environment, and educational technologies. Within an ecological–pedagogical perspective, learning is understood as an adaptive process in which students, teachers, and technological tools mutually influence and transform one another. Physical education emerges as a privileged field for analysing these dynamics, as it integrates embodied practices, spatial and environmental variables, and digital innovations that mediate movement, assessment, and participation. The study highlights how technological artefacts, such as sensor-based devices, immersive environments, and data-driven platforms, reconfigure corporeality and reshape traditional educational relationships, offering new opportunities for inclusion, feedback, and personalization. At the same time, the article critically examines potential risks related to digital dependence, reductionist quantification of performance, and unequal access to technological resources. By framing schools and physical education as co-evolutionary systems, the paper argues for pedagogical approaches capable of fostering ecological awareness, embodied intelligence, and responsible technological mediation, promoting sustainable and inclusive educational practices.

Keywords: Embodied Learning; Ecological Approach; Inclusive Pedagogy.

1. Introduction

In current debates on education, it has become increasingly difficult to describe schools as neutral settings where teaching simply takes place. What we call "school" is, more realistically, a living environment: a system made of bodies, spaces, routines, expectations, and relationships, all of which influence learning in ways that are often subtle but deeply consequential (Chun, 2023). This view

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becomes even more relevant today, as education is simultaneously shaped by two major pressures. On the one hand, digital technologies are rapidly becoming part of ordinary school life, not only as tools but as infrastructures that reorganize communication, evaluation, and participation (Timotheou et al., 2023). On the other hand, ecological concerns are no longer confined to environmental education as a topic; they increasingly challenge the way we think about responsibility, interdependence, and the long-term effects of educational choices. When these two transitions intersect, learning can hardly be understood as a linear process of transmitting content. Rather, it appears as something adaptive and situated, produced through ongoing adjustments between students, teachers, environments, and the artefacts that mediate educational experience (Golden, & Earp, 2012).

Within this broader picture, Physical Education (PE) offers a particularly revealing lens. Unlike many classroom subjects, PE makes the embodied dimension of learning immediately visible. Here, students do not only "understand" tasks: they experience them through movement, effort, coordination, emotions, and social exposure (Forte et al., 2023). The body is not a secondary element, nor a simple instrument of execution; it is where learning becomes concrete, sometimes empowering and sometimes uncomfortable. Space matters as well, because movement always happens somewhere: in a gym, on a field, outdoors, within constraints that can enable participation or silently discourage it. PE therefore highlights how learning emerges from the relationship between what a person can do, what the environment allows, and how others respond. This is also why PE is often a sensitive terrain for inclusion (Aartun et al., 2022). Differences in confidence, motor competence, and physical ability tend to become visible very quickly, and the educational meaning of "participation" is negotiated in real time, through bodies and interactions rather than only through words.

The growing presence of educational technologies in PE intensifies these dynamics. Wearable sensors, tracking apps, immersive experiences, and data-based platforms promise more detailed feedback and more individualized learning pathways. In many cases, they can indeed support students who benefit from clearer guidance, immediate information, or adaptive tasks (Yu, 2022). Yet it would be misleading to treat these technologies as neutral additions. Once movement is translated into data, the meaning of bodily experience can change. What counts as "progress" may increasingly align with what is measurable, while what is harder to quantify, such as awareness, cooperation, enjoyment, or the ability to attune to others and to the environment, risks being pushed to the margins. In other words, digital tools can subtly shift the pedagogical focus, sometimes in productive

directions, sometimes in ways that narrow the educational horizon of PE (Martín-Rodríguez, & Madrigal-Cerezo, 2025).

At the same time, it would be equally simplistic to frame technological mediation only as a problem. The key issue is not whether technology belongs in PE, but what kind of PE is produced when technology becomes part of the learning ecology. In some contexts, digital devices can enhance inclusion and strengthen formative assessment by making feedback more transparent and supporting differentiated goals. In others, they may reinforce performance-oriented logics, generate pressure through constant measurement, and encourage forms of self-surveillance. Moreover, unequal access to devices, infrastructure, and digital competences can reproduce existing disparities, turning innovation into yet another factor that separates rather than connects students. These tensions suggest that the educational value of technology depends less on the tool itself and more on how it is embedded within pedagogical intentions, institutional cultures, and ethical considerations (Bai, 2025).

For these reasons, this article proposes to interpret schools, and PE in particular, as co-evolutionary ecosystems. The concept of co-evolution helps avoid both technological enthusiasm and technological pessimism, because it emphasizes reciprocal adaptation. Students and teachers change their practices in response to technological affordances; technologies are interpreted and repurposed within specific school cultures; environments are reorganized through new patterns of interaction, assessment, and participation. From this perspective, bodies, spaces, and artefacts do not simply coexist: they actively shape one another over time. The aim of the paper is to clarify how these processes reconfigure corporeality and educational relationships, and to outline pedagogical orientations capable of fostering ecological awareness, embodied intelligence, and responsible technological mediation, so that innovation can support sustainable and inclusive educational practices rather than merely efficiency-driven or performance-centred models.

2. School as a Co-evolutionary Ecosystem

Thinking about the school as an ecosystem may sound, at first, like a metaphor. Yet it becomes much more than that when we use it as a conceptual tool to understand how educational processes actually take shape. An ecosystem is not defined by a single element. It is defined by relationships, and by the way living beings interact with each other and with the conditions that surround them. In the same way, schooling is not simply the sum of teachers, students, curricula, and classrooms. It is a dynamic environment where learning emerges from continuous

exchanges between people, spaces, routines, norms, and material artefacts (Herrmann-Pillath et al., 2022). What matters, in this perspective, is not only what individuals know or intend to do. It is also what the environment makes possible, what it encourages, and what it silently restricts. This is one of the reasons why ecological approaches have gained relevance in educational research. They offer a language for describing learning as something situated, relational, and context-dependent, rather than as an isolated mental event that happens "inside" the learner (Berglund, 2024).

From an ecological–pedagogical standpoint, learning is often described as an adaptive process. This does not mean adaptation in a simplistic sense of "fitting in." It refers to a richer process of adjusting, negotiating, and transforming one's ways of acting and understanding in response to a changing context. Students learn not only by receiving information. They learn by engaging with tasks, interpreting feedback, coordinating with peers, and making sense of the expectations embedded in educational settings. Teachers, in turn, are not external controllers of the system. They are participants within it, and they constantly adjust their pedagogical choices in relation to students' responses, institutional constraints, available resources, and the material conditions of teaching (Obidova, & Tursunova, 2023). The environment itself is not passive. Space, time, equipment, and technological infrastructures all play an active role in shaping educational possibilities. Even seemingly minor details can matter. How a gym is organized, how much time is available for an activity, or how feedback is delivered can influence participation and learning outcomes. In this sense, an ecological view invites us to treat educational contexts as "active partners" in the learning process, rather than as neutral backgrounds (Wood et al., 2023).

The idea of co-evolution strengthens this framework by highlighting reciprocity and mutual change. Co-evolution suggests that elements within a system do not simply interact. They develop together over time. When applied to education, this means that students, teachers, and tools are not fixed entities operating independently. They are parts of a system that reshapes itself through repeated interactions. For instance, when a new technological platform is introduced, teachers may reorganize their instructional strategies to make use of it. Students may alter their engagement patterns depending on the type of feedback they receive (Seifert et al., 2022). The technology itself may also be adapted, resisted, or repurposed in ways that its designers did not anticipate. Over time, these adjustments can modify the culture of the learning environment. They can change what counts as success, what behaviours are rewarded, what forms of participation are visible, and what kinds of knowledge are valued. Co-evolution, therefore, helps

capture the slow but significant shifts that occur when educational practices and mediating artefacts become entangled (Ekrem, & Demirbulak, 2025).

This perspective also aligns with approaches that emphasize distributed and relational forms of agency. In everyday educational thinking, agency is often attributed mainly to human subjects. Teachers decide, students respond, and tools remain secondary. Yet in real school settings, agency is more dispersed and more complex. Artefacts and technologies do not "act" in the human sense, but they do shape action by structuring choices, enabling certain behaviours, and discouraging others. A wearable device that tracks movement, for example, does not merely record physical activity. It frames attention, it suggests what should matter, and it produces a certain type of feedback that can influence motivation and self-perception. Similarly, a digital platform that ranks performance or visualizes progress introduces implicit norms about improvement and comparison. These mediations can affect not only what students do. They can also affect how students interpret their own bodies and abilities. From an ecological standpoint, it becomes important to recognize that educational agency is not located in a single point. It circulates through relationships between people, environments, and mediating artefacts (Collins et al., 2025).

Physical Education makes these dynamics particularly visible because it is grounded in embodied action and in immediate interaction with space. In PE, learning is not only about understanding instructions. It is also about coordinating perception and movement, regulating effort, responding to others, and adapting to changing conditions. The educational environment is therefore experienced directly through the body. The body becomes the place where constraints and affordances are felt. This is crucial, because it reminds us that learning is not simply cognitive. It is also sensory, emotional, and relational. When technologies enter PE, they become part of this embodied ecology. They do not only provide information. They can change the rhythm of practice, the meaning of feedback, and the ways students relate to each other and to themselves. A sensor-based tool may encourage students to focus on intensity or speed. A video analysis app may highlight technique and precision. An immersive environment may change how space is perceived and navigated. Each of these mediations can influence what is learned and how learning is experienced (Rothwell et al., 2025).

At this point, the ecological–pedagogical framework becomes especially useful because it allows us to hold together two dimensions that are often separated. On the one hand, it helps explain the potential of technologies to support personalization, feedback, and inclusion, particularly when tools are designed and used with pedagogical sensitivity. On the other hand, it also helps illuminate the

risks of reductionism. This happens when the complexity of movement and corporeal experience is narrowed to what can be measured and compared. The ecological lens does not treat these outcomes as inevitable. Instead, it suggests that they depend on how the system evolves, on what values guide pedagogical choices, and on whether technologies are integrated in ways that respect the relational and contextual nature of learning (Xiong et al., 2025).

Therefore, conceptualizing school and Physical Education as co-evolutionary ecosystems means taking seriously the idea that educational change is rarely linear. It is not a simple story of innovation being "implemented" and producing predictable results. Rather, it is a process of continuous negotiation. Bodies, environments, and technologies shape one another. This theoretical framing sets the stage for analysing, in the following sections, how educational technologies reconfigure corporeality, reshape educational relationships, and open both promising opportunities and critical challenges for sustainable and inclusive PE practices.

3. Embodiment and Learning: The Body as an Ecological Interface

Any serious discussion of Physical Education inevitably brings us back to a basic point that is sometimes overlooked in educational theory. Learning is not something that happens only "in the mind". It happens through the body, with the body, and often because of the body. This is not a rhetorical claim. It is an empirical and pedagogical one. Students learn by perceiving, moving, adjusting, and trying again, gradually developing a sense of what actions feel possible, effective, or meaningful in a given situation (Kraus, & Wulf, 2022). In PE, this is particularly evident because movement is not simply the outcome of learning. It is the medium through which learning unfolds. For this reason, an embodied perspective is essential if we want to understand PE as more than training, exercise, or performance enhancement. It allows us to see PE as a domain where knowledge is enacted, where competence is built through lived experience, and where the educational value of movement lies in the ways it shapes perception, identity, and relationships (Liu et a., 2025).

From an ecological standpoint, the body can be understood as an interface between the person and the environment. This does not mean the body is a passive "channel" through which information flows. Instead, it is an active system that continuously interprets and responds to context. Movement is always a form of dialogue with the environment. It involves adapting to space, negotiating balance and rhythm, anticipating obstacles, coordinating with others, and responding to feedback that is often immediate and sensory. Even a simple motor task, such as

throwing, jumping, or changing direction, requires a fine-grained alignment between perception and action. In this sense, learning in PE is deeply situated. It depends on where the activity takes place, what materials are available, how the task is framed, and how students experience the social atmosphere around them. What looks like a "skill" on the surface is often the result of a complex ecological coordination between body, space, and interaction (Hung et al., 2014).

This is why the concept of embodied intelligence becomes so relevant. Embodied intelligence refers to the idea that the body does not simply execute instructions coming from the brain. It contributes to thinking, decision-making, and problem solving in its own right. In PE, students develop forms of understanding that are difficult to reduce to verbal explanations. These include timing, coordination, spatial awareness, tactical sensitivity, anticipation, and the ability to modulate effort. These competences often emerge before students can fully describe them in words (Macedonia, 2019). They are learned through repetition, variation, and feedback, but also through the gradual refinement of perception. Students notice the position of their bodies, the movement of others, and the feel of contact with the ground. They learn the rhythm of breathing, and the difference between tension and relaxation. Importantly, this kind of learning is not purely technical. It is also experiential. Students learn what it feels like to succeed, to struggle, to improve, to cooperate, or to fail in front of others. These experiences shape motivation and self-confidence, and they can influence long-term attitudes toward physical activity, health, and participation (Sullivan, 2018).

Emotions, in this context, are not secondary variables. They are part of the learning ecology. PE can generate enjoyment, curiosity, and a sense of competence. But it can also produce anxiety, embarrassment, or fear of judgement, especially when performance is highly visible. Students' willingness to engage is often shaped by these emotional conditions. A learner who feels safe and supported is more likely to experiment and take risks, which are essential for motor learning. Conversely, a learner who feels exposed or evaluated may avoid participation. This may happen not because of lack of ability, but because the environment makes engagement feel costly (Fugate et al., 2019). This is one reason why embodied learning cannot be separated from the social and relational dimension of PE. The body is not only biological. It is also social. It is seen, compared, and interpreted, and students often internalize these interpretations in ways that affect how they move and how they see themselves as learners.

From a pedagogical point of view, recognizing embodiment means shifting the focus from "correct performance" to meaningful experience. This does not imply abandoning technique or standards. However, it requires a more careful

understanding of what counts as learning. In embodied learning, progress may involve subtle changes. It may include improved coordination, better self-regulation, greater willingness to participate, more effective collaboration, or a more reflective awareness of one's own movement patterns (Mavilidi et al., 2021). These forms of learning are real, but they do not always show up in simple metrics. They are often visible in the quality of engagement rather than in the final outcome. This is particularly important in inclusive PE, where students may have different starting points, different bodily histories, and different ways of expressing competence. An embodied approach supports the idea that learning goals should not be reduced to uniform benchmarks. They should also include the development of agency, confidence, and adaptive participation.

The introduction of educational technologies adds another layer to this discussion. It changes how the body is perceived and interpreted within the learning environment (Macrine, & Fugate, 2021). When students wear sensors or use tracking apps, their bodily activity is translated into data. This may include steps, heart rate, speed, repetitions, intensity, or performance scores. This translation can be useful. It can help students become more aware of effort, regulate pacing, and receive feedback that is difficult to provide through observation alone. For some learners, data can support motivation and self-monitoring in constructive ways. Yet it also raises a delicate pedagogical issue. The body risks becoming visible mainly through what can be measured. When the learning experience is strongly mediated by numbers, students may begin to focus more on outcomes than on sensations, strategies, and meanings. In extreme cases, the body can be experienced as something to manage and optimize rather than something to inhabit and understand. This does not happen automatically. But it becomes more likely when technological feedback is treated as the primary indicator of learning (Kontra et al., 2012).

For this reason, an ecological view of embodiment encourages a balanced approach. Technologies can enrich PE, but they should not replace the experiential dimension of movement. Instead, they can be framed as tools for reflection, not as substitutes for lived bodily knowledge. The educational task, then, is to help students integrate different forms of feedback. This includes what they feel in their bodies, what they observe in the environment, what they learn through interaction with others, and what data might reveal. When these layers are connected thoughtfully, technologies can support embodied learning rather than narrowing it. They can become part of a pedagogy that values awareness, participation, and ecological attunement, rather than one that reduces the body to performance indicators (Hirose, 2002).

Treating the body as an ecological interface means acknowledging that movement is never purely individual. It is shaped by environments, relationships, and mediations. In PE, learning happens when students are able to explore this relationship. They learn not only to move better, but to perceive more clearly, to adapt more intelligently, and to participate more confidently (Caiani, 2011). This embodied foundation is crucial for the broader argument of the article, because it clarifies what is at stake when educational technologies enter PE. The question is not only how technologies can improve instruction. It is also how they reshape the experience of being a body in an educational space, and what kinds of learners and citizens this experience helps to form.

4. Environment, Space, and Movement: The Pedagogical Role of Context

If Physical Education makes one thing clear, it is that movement never happens in a vacuum. Every action, from the simplest drill to the most complex game situation, is shaped by the space in which it takes place. It is also shaped by the materials available, by the social atmosphere, and by the way the activity is framed by the teacher (Gemmink et al., 2021). This is why, in an ecological perspective, the environment cannot be treated as a neutral backdrop. It is an active component of learning. It continuously interacts with students' bodies and intentions. In PE, the environment is not simply "where" learning happens. It becomes part of "how" learning happens. A change in space, surface, equipment, or group organization can alter the difficulty of a task. It can also change the emotional experience of participation, and even the meaning that students attach to movement. In this sense, the pedagogical value of PE is deeply connected to the way context shapes what students can perceive, attempt, and gradually master (Rosenberg, & Koehler, 2015).

A useful concept for describing this relationship is that of affordances. Affordances can be understood as the possibilities for action that an environment offers to a person. They are not fixed properties of objects or spaces. They depend on the relationship between the learner and the context. A climbing frame affords exploration and challenge, but not in the same way for everyone. It feels different for a confident student than for someone who feels insecure about balance. A large open field affords running, tactical positioning, and shared play. Yet it may also afford avoidance or disengagement for students who feel uncomfortable being constantly visible (Barker ET AL., 2023). Even the boundaries of a space can matter. Lines, cones, or goals can subtly guide attention and movement, encouraging some forms of action while limiting others. What matters pedagogically is that environments often "invite" behaviour, even without explicit instruction. When

teachers design PE tasks, they are therefore not only choosing content. They are shaping an ecology of participation, creating conditions that make certain forms of learning more likely to emerge.

Space also carries a social meaning. The gym is not just a physical structure. It is a cultural space where norms about performance, ability, and competition may be reinforced or challenged. In many school contexts, PE is associated with evaluation through visible performance. This can strongly influence how students approach participation. Some learners experience the gym as a place of freedom and expression (O'Connor, 2019). Others experience it as a place of exposure. The same activity can therefore produce very different learning conditions depending on how the space is organized and how the social climate is managed. This is one reason why environmental variables cannot be reduced to logistics. They are pedagogical variables. They shape not only movement opportunities but also confidence, motivation, and the willingness to take risks, which are all essential for learning.

The ecological role of context becomes even more evident when we consider the material and sensory dimensions of PE environments. Surfaces, lighting, noise levels, temperature, and equipment quality all influence how students move and how safe they feel. A slippery floor changes coordination and risk perception. Excessive noise can affect attention and communication. Poorly maintained equipment may limit exploration and increase anxiety. These are not minor issues. They can influence how students regulate effort, how they interact with peers, and whether they experience movement as something pleasurable or stressful. In this sense, the environment shapes the embodied experience of learning at a very concrete level. It affects not only performance, but also the conditions under which students can develop bodily awareness and agency (Hastie, & Siedentop, 1999).

Outdoor and hybrid contexts further expand this discussion. PE conducted outdoors introduces variability that is often absent in indoor spaces. Uneven ground, weather conditions, natural obstacles, and a wider range of sensory inputs all come into play. From an ecological point of view, this variability is not simply a complication. It can become an educational resource, because it encourages adaptability, attention, and situational awareness. Outdoor movement often requires students to adjust continuously. They need to read the environment and coordinate their actions in response to changing conditions. At the same time, outdoor PE also raises issues of accessibility and equity. Not all schools have safe outdoor facilities. Not all students have the same familiarity or comfort with outdoor activities. This highlights a key point: the environment is never only physical. It is also social and institutional, shaped by resources, infrastructure, and

policy decisions that can enable or restrict certain educational possibilities (Solmon, 2015).

From an inclusion perspective, context plays a decisive role. Participation is not only a matter of individual ability. It is strongly influenced by how tasks and environments are designed. A space that allows multiple entry points, varied roles, and flexible pacing tends to support broader participation. Conversely, environments organized around narrow performance expectations may intensify exclusion. This is especially true for students with different motor histories, disabilities, or lower confidence. In PE, inclusion is often built through small design choices. These include how groups are formed, how rules are adjusted, whether students can choose levels of challenge, and how success is defined. These contextual decisions shape whether students feel that the environment is "for them" or not. They also shape the kind of learning that becomes possible. Students may focus on exploration and improvement, or they may become preoccupied with avoiding failure and judgement (Hastie, 2016).

Educational technologies interact with these environmental dimensions in important ways. Technologies do not enter PE as abstract tools. They become part of the learning space, influencing how it is organized and experienced. A digital platform that structures activities through timed tasks or ranked results may push the environment toward competitiveness, even if that was not the teacher's intention. A wearable device that provides constant feedback can shift students' attention inward, toward monitoring numbers. This can reduce engagement with the social and spatial aspects of the activity (Tohănean ET AL., 2025). On the other hand, technologies can also enrich environmental affordances. Video feedback can help students see movement patterns they struggle to perceive in real time. Interactive systems can create new forms of engagement, especially when tasks are designed to support cooperation and reflection rather than mere performance comparison. Immersive or augmented environments can introduce scenarios that expand spatial imagination, offering new ways of exploring movement and coordination. In each case, technology becomes an ecological factor. It modifies the environment by reshaping attention, feedback, and interaction.

This is where the ecological–pedagogical perspective becomes especially useful, because it helps avoid simplistic assumptions about context. The environment is not "good" or "bad" in itself. Neither are technologies. What matters is how the learning ecology is composed, and how space, tools, tasks, and relationships come together to support meaningful participation. In PE, the goal is not to control every variable (Seifert, & Davids, 2016). It is to design conditions that allow students to engage, adapt, and learn in ways that are both embodied and socially grounded. A

well-designed environment does not eliminate challenge. It makes challenge accessible. It does not remove differences. Instead, it creates pathways through which differences can be included without becoming stigmatizing.

Understanding the pedagogical role of context means, therefore, taking seriously the fact that movement is always relational. Students learn through the interplay between their bodies and the spaces they inhabit. They learn through the relationship between their intentions and the constraints they encounter, and between individual effort and collective coordination. PE offers a powerful reminder that learning is not only what happens inside a learner. It is also what emerges between learners and the environments that shape their possibilities of action. This ecological foundation is crucial for the next steps of the article. It clarifies why technologies can never be treated as external add-ons, because they become part of the environment itself, and therefore part of the conditions through which embodied learning is enabled, transformed, or constrained.

5. Educational Technologies in Physical Education: Tools that Transform Relations

When educational technologies enter Physical Education, they rarely behave like simple "add-ons." They do not just provide extra resources. They do not simply make existing routines more efficient. In many cases, they change the texture of the lesson itself. They influence what teachers pay attention to, what students notice about their own bodies, how feedback is delivered, and even what counts as progress (Yu, 2022). This is why it is useful to treat technologies not merely as instruments, but as mediating artefacts that participate in shaping the educational ecology. In PE, where learning is grounded in movement, perception, and interaction, mediation becomes particularly visible. A device that measures effort, a platform that organizes tasks, or an immersive environment that alters spatial perception can quietly reshape relationships. It can affect relationships between students and teachers, between students and peers, and also between students and their own embodied experience (Jastrow ET AL., 2022).

A first area where this transformation becomes evident is the use of sensor-based technologies. This includes wearable devices and tracking systems. These tools are increasingly employed to monitor variables such as heart rate, movement intensity, speed, acceleration, or repetitions. From a pedagogical perspective, the promise is attractive. Teachers gain access to information that is difficult to capture through observation alone, and students receive feedback that appears immediate and concrete (Suriya, & Arumugam, 2020). For some learners, this can be motivating, because it makes effort visible and helps them recognize

improvement over time. It can also support self-regulation. For instance, it may help students understand pacing, recovery, and workload. At the same time, sensor-based feedback introduces a subtle shift in attention. When the lesson becomes organized around metrics, students may begin to focus on what the device "says." They may focus less on what they feel, perceive, or learn through interaction. In other words, the body risks being experienced primarily through its measurable outputs. This is not inherently negative. Yet it becomes pedagogically problematic when numbers start to replace reflection, or when students internalize the idea that only what is quantified matters.

A second technological domain that is increasingly relevant in PE is the development of immersive and augmented environments. Virtual reality and augmented reality applications can create simulated scenarios for motor learning, tactical decision-making, or coordination tasks. These are scenarios that would otherwise be difficult to reproduce in a school setting. These environments can offer engaging experiences (Shutova, & Andryushchenko, 2020). They may be particularly valuable when they allow students to practice safely, repeat tasks with variation, or receive guidance through multimodal cues. In some cases, immersive environments can lower barriers to participation. They can create playful and less socially exposed contexts, which can be helpful for students who experience anxiety in traditional PE settings. Yet immersive technologies also raise important questions about the relationship between movement and reality. PE is traditionally rooted in the concrete experience of the body in a physical environment, where surfaces, distances, and social presence matter. When learning shifts toward simulated contexts, it becomes essential to ask what is gained and what might be lost. Immersion can enrich learning. But it can also risk detaching movement from the unpredictability and relational complexity of real environments, especially if the experience becomes overly controlled or standardized (Villalba et al., 2017).

A third, increasingly influential area concerns data-driven platforms that support assessment, documentation, and personalization. These platforms may include apps for skill tracking. They may also include systems for recording performance indicators, dashboards for monitoring progress, or tools for organizing individualized training plans. In theory, such systems can support more formative and student-centred approaches. This is especially true when they help teachers focus on individual improvement rather than on comparison between students. They can also strengthen transparency by making goals and criteria clearer. In this way, students can see how their learning develops across time. However, the pedagogical effects of platforms depend strongly on how they are designed and used. A platform that encourages reflection and dialogue can support learning in

meaningful ways. But a platform that prioritizes ranking, constant monitoring, or competitive gamification can easily push PE toward performance-centred logics. This is particularly relevant because PE already carries cultural assumptions about athletic ability and success. Technologies may unintentionally reinforce those assumptions by making performance more visible and comparable (Papastergiou, 2009).

Across these technological forms, what changes most significantly is the nature of feedback. Feedback in PE has traditionally been relational and contextual. It emerges through observation, dialogue, and the teacher's capacity to interpret movement in its specific circumstances. Digital technologies introduce feedback that is often faster, more frequent, and seemingly more objective. This can be beneficial, especially when students need immediate cues to adjust technique or regulate intensity. Yet it can also create a pedagogical drift. The lesson can become centred on constant correction and optimization. In such cases, students may experience PE less as a space for exploration. Instead, it may feel like a space of continuous measurement. The educational relationship may shift accordingly. Teachers may feel pressured to rely on data as proof of learning, while students may learn to seek validation through numbers rather than through embodied awareness or shared experience. Over time, this can reshape the meaning of competence itself. It can move from a broad understanding of learning to a narrower focus on performance indicators (Alexander, & Vladislav, 2015).

The relational dimension of PE is also affected by technology in less obvious ways. PE lessons are not only about individual skill development. They are also about social coordination, cooperation, and shared rhythms of activity. When technologies become central, they can either strengthen or weaken these relational dynamics. For example, video-based feedback can become a collaborative tool when students analyse movement together, discuss strategies, and learn to give constructive feedback. In this case, technology supports interaction and shared learning. Conversely, wearable tracking may individualize attention to such an extent that students become absorbed in personal data. This can reduce the collective dimension of the lesson (Nuriddinov, 2024). Similarly, gamified systems may motivate some learners while discouraging others, particularly if competition becomes the dominant form of engagement. These outcomes are not determined by the technology itself. They depend on the pedagogical ecology in which it is embedded.

From an ecological–pedagogical perspective, it is therefore essential to resist the temptation to treat technologies as neutral solutions. Technologies reorganize practice. They shape what is visible and what is invisible, what is rewarded and

what is overlooked, what is experienced as meaningful and what is experienced as pressure. In PE, where learning is inseparable from embodied experience and social participation, these shifts matter greatly. A sensor does not only measure intensity. It can influence motivation and self-perception. A platform does not only store data. It can shape norms of comparison and progress (Kalemoglu Varol, 2014). An immersive environment does not only provide a new activity. It can reshape how students relate to space and challenge. Recognizing this mediating role is not an argument against innovation. It is a call for responsibility. Technologies should be integrated in ways that support educational aims rather than silently replacing them.

For this reason, the key question becomes pedagogical rather than technical. Instead of asking which devices are most advanced, it is more important to ask what kind of learning experience they help create. Do they support students in becoming more aware of their bodies, more capable of self-regulation, and more confident in participation? Do they expand inclusion, or do they amplify performance pressures and inequalities? Do they enrich the relational and ecological dimensions of PE, or do they narrow the lesson to what can be quantified? These questions are not secondary. They are central to understanding how schools and PE evolve when technologies become part of everyday practice.

In short, educational technologies in Physical Education are best understood as tools that transform relationships. They change how students relate to their bodies. They also change how teachers relate to evidence and assessment, and how the learning environment is organized. Their potential is real, but it is never automatic. The educational value of technological mediation depends on the broader ecosystem in which it operates, on the meanings that are attached to data and feedback, and on the pedagogical choices that guide integration. This provides the basis for the next section. It examines more closely how these mediations reconfigure corporeality itself, and how they shape what it means to experience the body in PE through digital technologies.

6. Conclusions

This article has argued that schools, and Physical Education in particular, can be understood as co-evolutionary ecosystems. They are not stable spaces where learning happens in a linear way. Learning emerges through relationships. It develops between bodies, environments, and everyday practices. It is also shaped by technologies that mediate attention, feedback, and participation. Physical Education makes these dynamics especially visible. In PE, learning is embodied. It happens through movement, perception, effort, and interaction. For this reason,

PE is a valuable context for observing how learning grows inside a complex educational ecology.

Throughout the paper, educational technologies have been described as mediators rather than neutral tools. Wearable sensors, immersive environments, and data-driven platforms can support learning in important ways. They can improve feedback. They can help personalization. They can also increase access for some students. These opportunities are real. However, they are not automatic. They also come with risks. When movement becomes data, learning can be reduced to numbers. The body can be seen mainly as something measurable. Other dimensions may become less visible. These include awareness, cooperation, enjoyment, and ecological sensitivity. In addition, access to technologies is not equal. Differences in resources and digital skills can create new forms of exclusion.

The co-evolutionary perspective helps avoid simple conclusions. It does not treat technology as inherently positive or negative. Instead, it focuses on change over time. Teachers adapt their methods when new tools are introduced. Students change their behaviour when feedback becomes constant and immediate. Learning environments also shift. New routines emerge. New expectations appear. These processes can redefine what counts as competence. They can also change what participation looks like. In this way, technology does not just enter PE. It contributes to shaping what PE becomes.

For this reason, the main challenge is not technical. It is pedagogical and ethical. The key question is how to use technology without losing the richness of embodied learning. Digital feedback can be useful. But it should not replace lived experience. Data can support reflection. But it should not become a form of control. Teachers need to pay attention to what technologies make visible. They also need to notice what technologies may hide. Emotional effects are important as well. Constant measurement can increase pressure. It can also affect motivation and self-perception. Inclusion must remain a central goal. It cannot depend only on having access to devices.

Overall, framing school and PE as co-evolutionary ecosystems offers a clear way to think about innovation. It keeps the focus on relationships. It highlights the role of context. It reminds us that learning is embodied and situated. Technologies can support more inclusive and sustainable practices. But this requires careful design and responsible use. PE can become a space where students develop awareness, participation, and adaptability. It can also help them build a more ecological and critical relationship with technology. This is essential if education aims to support not only performance, but also well-being and sustainable citizenship.

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