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Extended Learning and New Technologies in Physical Education and Sport

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Abstract: Physical activity and sport, in light of the contribution of new technologies, constitute an extended learning environment in which the physical dimension is integrated with the cognitive and digital dimensions. This paper analyses the role of technology in the construction of extended learning environments. In particular, starting from an analysis of digital match analysis tools, from a pedagogical and ecological perspective, it highlights how learning does not end at the moment of action, but is distributed across different environments and times, including the pitch, the digital space and social interaction. The analysis highlights how technologies amplify learning opportunities, making normally implicit processes visible, supporting the personalisation of training programmes and promoting the athlete's autonomy. This leads to a view of sporting activity as a dynamic educational ecosystem, in which mind and body operate in synergy and technologies take on the role of cognitive mediators, fostering the development of technical, decision-making and metacognitive skills.

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1. Introduction

In recent years, the concept of the learning environment has undergone a profound redefinition, shifting from a static, restrictive view to a dynamic, relational and ecological perspective. Physical, digital and social environments are no longer regarded as mere contexts in which learning takes place, but as active agents that influence knowledge construction, decision-making processes and the ways in which individuals interact (Hodges et al., 2020; Carvalho & Yeoman, 2019). From this perspective, learning emerges as the result of a complex system of relationships between the individual, tools and context, in line with the most recent ecological and situated theories of education.

The acceleration of digitalisation processes, further amplified in recent years, has contributed to the spread of hybrid and post-digital learning environments, characterised by the continuous integration of physical and virtual dimensions. As highlighted by Bond et al. (2021) and Jandrić et al. (2020), such environments transcend the traditional dichotomy between presence and distance, taking the form of fluid, interconnected and distributed spaces in which learning can occur continuously and in a multimodal manner. In the context of physical and sporting activities, this trans-

formation is particularly significant, as training is no longer limited to the physical space of the pitch or the gym, but extends to digital ecosystems. In this regard, the concept of match analysis is introduced, understood as a systematic process of observation, collection and analysis of sporting performance, which takes on significant pedagogical value. In particular, match analysis technologies, analysed from a pedagogical perspective, transform physical activity into a complex educational experience distributed across time and space (Farrow & Robertson, 2021). It is no longer merely a detailed analysis of sporting performance aimed at improving the performance of athletes and teams, but becomes an integrated strategy that combines the real and digital worlds, objective data and cognitive reflection, transforming sporting performance into an opportunity for continuous learning. Match analysis thus transforms physical and sporting activity into an extended learning environment, as it integrates sporting practice with digital tools and strategies for critical reflection. Indeed, during physical activity, the athlete does not merely execute movements or tactical patterns, but is an active participant in their own learning process, observing, analysing and evaluating their own actions through video, wearable technologies and virtual reality.

This process creates a distributed learning ecosystem, in which technical, tactical and cognitive skills develop both in the real-world context of the pitch and through objective feedback and digital simulations. Therefore, in light of these considerations, digital technologies take on a central role. In particular, they function not only as support tools, but as genuine cognitive mediators capable of influencing perceptual, attentional and decision-making processes. Recent studies demonstrate how the use of technologies such as wearable devices, video analysis and virtual reality helps to modify motor learning processes, making them more conscious, adaptive and based on interaction with real-time information (Panchuk et al., 2021; Gray, 2020; Faure et al., 2022). In particular, the integration of data, immediate feedback and simulated environments enables athletes to develop not only technical skills, but also cognitive and metacognitive skills, such as the ability to anticipate, make decisions and self-regulate. This approach forms part of the so-called data-informed learning paradigm, in which technologies support the active construction of knowledge through the analysis and interpretation of information (Li et al., 2022). Indeed, the interaction between the body, data and the environmental context enables athletes to take an active role in learning, improving self-awareness, decision-making and problem-solving skills, thereby transforming physical activity into a continuous educational laboratory.

At the same time, recent literature highlights how technologically mediated learning environments foster more personalised and inclusive forms of learning, adapting to athletes' individual characteristics and promoting flexible training pathways (Bond et al., 2021). In this sense, technologies supporting match analysis contribute to the construction of extended learning environments, in which the boundaries between formal, informal and non-formal contexts are becoming increasingly flexible.

The interaction between the individual, the environment and technology generates new forms of situated and adaptive knowledge, in which learning emerges as a continuous, distributed process deeply interconnected with the context.

From this perspective, it is essential to understand how technologies can be designed and integrated into sporting contexts not only to improve performance, but

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above all to enhance learning processes, contributing to the creation of innovative, sustainable and athlete-centred educational environments.

2. Technology and Match Analysis in Physical Activity: Extended Learning Environments

Digital technologies in sport cannot be regarded merely as tools to support performance, but must be understood as genuine cognitive agents. Cognitive agents are components that participate in cognitive processes – that is, in the way knowledge is acquired, processed and applied. In practice, they are not merely passive tools; rather, they interact with, guide and shape the way we think and learn. In the context of sport, athletes do not learn solely 'on their own' or from their coach, but also through technology. For example, videos, sensors and VR do not merely provide data but highlight tactical patterns, point out errors and offer alternatives, and enable decision-making simulations. In this way, technology becomes a 'partner' in learning, a genuine agent that supports thought and reflection. Cognitive agents are characterised by being reflective and interactive. In the first instance, reflective agents do not merely record data, but process it and present it in a meaningful way; interactive agents, on the other hand, adapt their behaviour in response to the athlete's actions, creating a dynamic dialogue between the real and digital worlds. Furthermore, some cognitive agents, particularly those based on artificial intelligence, personalise training based on the data collected. In this case, the agent learns from past performance by identifying recurring patterns, strengths and weaknesses, and proposes individualised improvement pathways. This creates a continuous cycle of learning, in which the system and the athlete co-evolve: the athlete improves thanks to feedback, and the system becomes increasingly effective at adapting to their needs. Thus, technologies actively participate in knowledge-building processes, influencing the way athletes perceive the environment, select relevant information, make decisions and adjust their actions in real time.

This perspective aligns with theories of situated and distributed learning, according to which cognition emerges from the interaction between the individual, tools and context, rather than residing exclusively within the subject's internal processes (Panchuk et al., 2021). In the sporting context, this implies that technologies are not external elements, but integral components of the athlete's cognitive system, capable of extending their perceptual, analytical and decision-making abilities.

From a pedagogical perspective, this vision entails a significant transformation of teaching-learning models. Learning is no longer conceived as the mere acquisition of motor patterns, but as an active, situated and reflective process, in which the athlete constructs meaning through interaction with data, feedback and technologically mediated environments (Farrow & Robertson, 2021).

In particular, comparing oneself with objective data derived from individual and collective statistics allows one to identify strengths and weaknesses, and this type of feedback enables the athlete to reflect critically on their actions in relation to the set objective. In this sense, technologies make normally implicit processes visible, facilitate awareness and amplify learning opportunities. Their integrated use in sporting activity allows for the creation of information-rich environments, in which the athlete is constantly exposed to stimuli and feedback that guide behavioural adaptation. This

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fosters the development of adaptive, flexible and transferable skills, which are fundamental in sports characterised by uncertainty and variability (Gray, 2020). From this perspective, technologies become tools for building extended learning environments that guide and support the learning process in which the athlete plays a central role. In particular, technologies enhance and enrich the concept of match analysis, transforming the entire process into a dynamic and participatory experience that encourages critical and structured reflection on the actions, decisions and strategies adopted during sporting performance. Match analysis is not merely a tool for improving sporting performance; it can be seen as a genuine learning tool. Through the observation, collection and analysis of match data, athletes not only correct technical or tactical errors, but also develop cognitive and metacognitive skills, such as critical reflection, action planning and decision evaluation.

Digital technologies such as wearables, video analysis and virtual reality amplify this potential by transforming sporting performance into an extended learning environment, in which on-field experience is integrated with digital tools and contexts for reflection. The athlete thus becomes a central figure in their own learning, participating actively and consciously in the evaluation of their own actions and strategies. Below, a pedagogical analysis of the main match analysis technologies was conducted with the aim of highlighting their educational value in sport and their role in the construction of extended learning contexts. The study showed how digital tools such as wearables, video analysis and virtual reality do not merely provide objective performance data, but become active tools for reflection and learning.

In this context, physical and sporting activity is transformed into an extended learning environment, in which mind and body interact in an integrated manner. The athlete does not simply perform movements or tactical patterns, but observes, analyses and evaluates their own actions, developing cognitive, metacognitive and collaborative skills. Thanks to this integration of real-world practice and digital tools, sporting performance becomes a dynamic and participatory learning laboratory, in which on-field experience is linked to critical reflection, simulation and continuous feedback.

2.1 Wearables and data-driven learning

Wearable devices are one of the most striking examples of technology acting as a cognitive agent in modern sport. Through the continuous collection and real-time processing of physiological, biomechanical and performance data (such as heart rate, heart rate variability, external load, speed, acceleration and movement parameters), wearables transform the training experience into a dynamic learning process based on the analysis, interpretation and integration of information.

Unlike traditional technologies, which provide post-hoc feedback, wearables operate on the principle of immediate and continuous feedback, helping to redefine the relationship between perception, action and behavioural regulation. In this sense, they act as cognitive extensions of the athlete, supporting real-time monitoring processes and facilitating instant adaptation to the demands of the task and context.

Recent literature highlights how the systematic use of such devices promotes the development of body awareness and self-regulation, enabling athletes to understand more accurately the relationships between subjective perception of effort and physiological response (Li et al., 2022; Jones et al., 2021). This process of aligning objective

data with internal sensations represents a crucial step in the development of refined perceptual competence, enabling the athlete to 'feel' their body better and make more effective decisions.

Furthermore, wearables contribute to the construction of embodied and situated knowledge, in which understanding is not abstract but rooted in direct experience and continuously updated through feedback. The athlete does not merely perform a task but learns to interpret complex signals, developing a form of adaptive intelligence that integrates physiological, cognitive and emotional dimensions. From a pedagogical perspective, wearables support data-informed and data-driven learning models, in which the athlete takes an active and reflective role in the construction of knowledge. Data interpretation becomes an integral part of the training process, fostering the development of advanced metacognitive skills, such as the ability to monitor one's own performance, evaluate the effectiveness of the strategies adopted and adjust behaviour in line with objectives (Krause et al., 2021). In this sense, the athlete evolves from a mere performer to an epistemic subject, capable of engaging critically with data.

A further significant aspect concerns the role of wearables in promoting autonomy and self-directed learning. The availability of accessible and personalised data enables athletes to take greater responsibility for their own training journey, making informed decisions and actively participating in the planning and management of their training. At the same time, the data generated by wearables offers coaches new possibilities for designing adaptive and individualised learning environments. Through data analysis, it is possible to adjust task constraints, precisely calibrate the training load, and design training experiences consistent with the athlete's specific characteristics. This approach moves beyond standardised and prescriptive models, promoting a differentiated and person-centred pedagogy.

From a systemic perspective, wearables also contribute to the construction of integrated learning ecosystems, in which the data collected can be combined with other sources (video analysis, digital platforms, tracking systems) to generate a more comprehensive and multidimensional view of performance. In these contexts, knowledge emerges from the interaction between different information flows, reinforcing the distributed nature of cognition. Finally, the motivational and emotional dimensions should not be overlooked. Data visualisation, progress monitoring and the ability to set personalised goals help to strengthen engagement, the perception of self-efficacy and intrinsic motivation. However, it is important to emphasise that an uncritical use of data can generate adverse effects, such as dependence on external feedback or an excessive focus on quantitative indicators. For this reason, it is essential to accompany the use of wearables with training in reading and interpreting data, so that they become tools for awareness rather than mere monitoring devices. From this perspective, wearables are not merely technological tools, but genuine cognitive mediators that are redefining the way we learn in sport, helping to develop athletes who are more self-aware, independent and adaptable.

2.2 Video analysis and the construction of visual knowledge

Video analysis is a key tool for the construction of visual knowledge and for developing awareness of motor movements within technologically mediated learning environments. Unlike traditional forms of feedback, which are often limited to verbal

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cues, it makes it possible to visualise and analyse complex aspects of performance, fostering a deeper and more nuanced understanding of movement.

Through the recording, review and analysis of performances, athletes can observe their own motor behaviour from an external perspective, developing a more accurate mental representation of their actions. This process is particularly relevant in sporting contexts, where many components of the movement are difficult to perceive during execution. Recent studies highlight how visual feedback significantly improves motor learning, facilitating error correction and the consolidation of skills (Ranganathan et al., 2020; Otte et al., 2021).

From a pedagogical perspective, video analysis serves as a fundamental tool for promoting reflective practice, that is, the ability to critically reflect on one's own actions. The athlete becomes an active protagonist in the learning process, moving from a passive position to one of analysis, interpretation and meaning-making (Farrow & Robertson, 2021). This fosters the development of metacognitive skills, such as the ability to self-assess, identify errors and plan for improvement. A central element of video analysis is the ability to compare different performances, both over time (longitudinal analysis) and against reference models. This enables athletes to identify recurring patterns, understand the dynamics of the movement and develop more effective strategies. In this sense, technology supports learning based on comparison and variation, in line with the latest theories of motor learning. Recent technological developments have further expanded the pedagogical potential of video analysis. The integration of artificial intelligence and machine learning systems now makes it possible to automate the identification of motor patterns, highlight critical elements and provide personalised feedback in real time. This makes the learning process more immediate, continuous and accessible, even in non-professional contexts.

Furthermore, video analysis is not limited to the technical dimension but can be used to explore cognitive and decision-making aspects of performance. Analysing the choices made in game situations, trajectories, reaction times and interactions with the environment allows for the development of a broader understanding of sporting performance. In this sense, technology becomes a tool for coaching not only the 'how' of performing a movement, but also the 'when' and 'why' of acting.

From the perspective of the ecology of learning, video analysis helps to create information-rich environments, in which the athlete can interact with multiple representations of their own actions. This promotes multimodal learning processes, in which visual, verbal and kinesthetic information are integrated, enhancing the quality of understanding.

A further significant aspect concerns the social dimension of learning. The sharing of videos between athletes and coaches, as well as within peer groups, fosters collaborative learning processes. Discussion, comparison and the co-construction of meaning enrich the training experience, transforming video analysis into a tool for collective learning.

Finally, the systematic use of video analysis helps to develop a culture of reflection in sport, in which mistakes are not seen as negative, but as opportunities for learning. This approach fosters a more open, self-aware and continuous improvement-oriented educational environment.

In summary, video analysis acts as a powerful pedagogical mediator, capable of transforming the sporting experience into a reflective, self-aware learning process geared towards the active construction of knowledge. It enables the integration of

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technical, cognitive and social dimensions, contributing significantly to the development of complex and transferable skills.

2.3 Virtual Reality and Immersive Learning

Immersive technologies, particularly virtual reality (VR), represent one of the most significant innovations in the transformation of learning environments in contemporary sport. They enable the creation of highly realistic simulated environments in which athletes can actively interact with dynamic and complex scenarios, experiencing situations that are difficult to replicate in real-world practice.

Unlike traditional technologies, VR does not merely provide information, but constructs experiential environments in which learning emerges from the direct interaction between perception and action. This makes it particularly consistent with ecological theories of learning, according to which knowledge develops through the active involvement of the individual in meaningful and situated contexts (Panchuk et al., 2021).

Recent literature highlights how the use of virtual reality promotes the development of fundamental cognitive skills, such as anticipation, decision-making and selective attention (Gray, 2020; Faure et al., 2022). In particular, the ability to expose the athlete to multiple variations of the same situation allows for the training of the ability to recognise patterns and adapt behaviour in contexts characterised by uncertainty. In the pedagogical sphere, VR enables the design of highly situated and intentional learning environments, in which every element of the context can be controlled and modulated according to the training objectives. This enables coaches to create progressive learning experiences, in which complexity is dynamically calibrated, fostering gradual and meaningful learning.

A particularly significant aspect concerns the ability to manipulate environmental and informational constraints. In virtual reality, it is possible to modify parameters such as time, space, speed and the number of stimuli, creating adaptive scenarios that evolve in response to the athlete's reactions. This approach is consistent with pedagogical perspectives based on non-linear learning, in which behaviour emerges from interaction with the context. Furthermore, VR allows specific components of performance to be isolated, enabling targeted training on individual cognitive or perceptual skills. For example, it is possible to focus exclusively on reading trajectories, spatial awareness or decision-making, reducing the complexity of the real-world context and facilitating learning. In the field of experiential learning, virtual reality offers a safe environment in which the athlete can experiment, make mistakes and learn without the typical consequences of real competition. This encourages an exploratory approach, in which error becomes an integral part of the learning process rather than something to be avoided.

A further element of significant pedagogical importance is the level of immersion and engagement. Immersive technologies generate a strong sense of presence, which increases the athlete's attention and active participation. Recent studies highlight how this high level of engagement helps improve the quality of learning and information retention (Faure et al., 2022). Furthermore, VR allows for the integration of multimodal feedback (visual, auditory, and sometimes haptic), creating information-rich environments that foster integration between different perceptual modalities. This

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helps develop a more comprehensive and nuanced understanding of performance, improving the transfer of skills to real-world practice.

In the field of learning ecology, virtual reality functions as a hybrid space where physical, digital and cognitive dimensions converge. It extends the learning environment beyond traditional boundaries, allowing the athlete to access training experiences that would otherwise be impossible or difficult to achieve.

It is therefore important to emphasise that the pedagogical effectiveness of VR depends on its integration with real-world practice. Recent studies highlight that the transfer of skills is maximised when the virtual experience is designed in a way that is consistent with the demands of real-world performance (Gray, 2020). In this sense, VR does not replace on-field training, but enriches it, offering new learning opportunities.

In summary, virtual reality represents a powerful pedagogical tool capable of transforming sports learning into an immersive, context-specific and highly personalised process. It enables the development of cognitive, perceptual and decision-making skills in an integrated manner, contributing to the creation of innovative and future-oriented learning environments.

3. Discussion

The analysis clearly shows that technology is profoundly changing the way we learn in sport. It is not simply a matter of more advanced tools, but a genuine shift in perspective: learning becomes more distributed, more conscious and more closely linked to interaction with data, environments and other individuals.

From a cognitive perspective, one of the most interesting aspects concerns the way in which technology enhances the athlete's capabilities. The match analysis tools examined do not merely provide information, but help athletes to better perceive what is happening and make more effective decisions; from this perspective, match analysis becomes a teaching tool, not just a diagnostic one. Recent studies show, for example, that the use of simulations and real-time feedback improves the ability to anticipate situations and adapt quickly to the context (Panchuk et al., 2021; Gray, 2020).

A key element is the role of data derived from match analysis; thanks to digital devices, the athlete can compare what they 'feel' with what is actually happening. This comparison, as highlighted by Li et al. (2022), promotes greater body awareness and better self-regulation. In other words, the athlete does not rely solely on intuition but develops a more refined ability to read and interpret their own performance.

In this context, technologies supporting match analysis have significant pedagogical implications, as they transform physical activity into an extended learning environment where the athlete does not learn passively but is an active participant in the process. Continuous access to feedback, data and analytical tools leads them to reflect more on what they are doing, to ask themselves questions and to seek solutions. In this sense, fundamental metacognitive skills are developed, such as the ability to monitor one's own progress and adapt strategies (Krause et al., 2021).

Another key aspect concerns personalisation. Technologies enable training to be tailored to each athlete's characteristics, moving beyond overly standardised approaches. This is particularly useful in complex contexts, where individual differences

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have a significant impact on learning (Li et al., 2022). Training thus becomes more targeted and meaningful, and technologies also help to make learning a continuous process. Indeed, learning takes place not only during training, but also afterwards, through analysing data, reviewing videos or engaging with others.

In light of this, it is important not to adopt an overly enthusiastic or simplistic view; whilst technologies offer many opportunities, they do not automatically guarantee better learning. For example, excessive use of data can lead to an over-focus on numbers, losing sight of the complexity of performance. As highlighted by Jones et al. (2021), it is essential to develop critical thinking skills when using information. Similarly, an excess of feedback can create cognitive overload. If the athlete receives too much information, they risk being unable to manage it effectively. In this sense, the coach's role remains central: not so much as a transmitter of knowledge, but as a guide capable of selecting, interpreting and making sense of the data. Another important point concerns instructional design, as technologies only truly work when they are coherently integrated into the training programme. It is not enough to introduce innovative tools; it is necessary to understand how to use them to facilitate learning. Studies such as those by Otte et al. (2021) clearly show that it is the quality of the instructional design that makes the difference.

4. Conclusion

This paper has highlighted how technology is no longer merely a tool to support performance, but has become an integral part of learning processes. The use of technology helps to redefine the way in which athletes perceive, interpret and act within a sporting context, demonstrating how learning environments in sport are increasingly driven by the integration of physical, digital and social dimensions. One of the most significant findings concerns the recognition of technologies as genuine cognitive agents; indeed, typical match analysis tools such as wearables, video analysis, virtual reality and digital platforms do not merely provide data, but directly influence perceptual, decision-making and metacognitive processes. In this sense, sports learning increasingly appears as a distributed process, emerging from the continuous interaction between the individual, the environment and technology. From a pedagogical perspective, there is a strong need to move beyond transmissive and standardised models in favour of more active, reflective and athlete-centred approaches. When integrated thoughtfully, technologies enable the development of more personalised forms of learning, fostering autonomy, self-regulation and adaptability. At the same time, they make often implicit processes visible, facilitating greater awareness of one's own actions. A further key element concerns the extended nature of learning: the training experience, supported by technology, is not confined to the time and space of the training session, but is distributed across different moments, different tools and multiple contexts. This paves the way for a conception of sport as a continuous educational space, in which practice, reflection and analysis are constantly intertwined. However, the findings also highlight the need for a critical and intentional use of technology. The risk lies not so much in the tools themselves, but in the way they are used, as excessive reliance on data or information overload can in fact limit, rather than enhance, learning. From this perspective, the value of technology in sport lies not solely in improving performance, but in its ability to broaden and enrich learning processes. It offers new opportunities to develop not only technical skills, but also

cognitive, decision-making and metacognitive skills, contributing to the development of athletes who are more self-aware, autonomous and capable of adapting to complex contexts. Therefore, this paper suggests some directions for future research, namely that it is necessary to explore how to design truly integrated learning environments, in which technologies are used in a manner consistent with educational objectives. Sport, therefore, is increasingly emerging as a prime laboratory for observing and understanding the transformations of contemporary learning ecologies. In this context, technologies represent not only a challenge, but above all an opportunity to fundamentally rethink educational processes, orienting them towards more flexible, mindful and person-centred models.

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