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REVIEW PAPER

Physical Education and Embodied Learning: A Review

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Abstract

Recent neuroscientific research highlighted interesting interactions between superior cognitive functions and the sensorimotor system. Overcoming the traditional views of the philosophy of mind and cognitive sciences, current empirical evidence shows that bodily states are the basis of information processing and that incarnation contributes to various aspects of mental phenomena. Starting from this theoretical framework, the purpose of this contribution is to outline, through exposure to the most significant discoveries in the world of neuroscience, the importance of Embodied Cognition as an emerging vision that considers the cognitive processes deeply rooted in the interaction of the body with the world. After careful selection and analysis of studies on neuroscience applied to teaching, the study focused on those who experienced in the school context embodied-teaching approaches aiming to promote transversal learning through movement and corporeality in action and interaction. The analysis highlights the strengths and critical points of the studies implemented in recent decades that focus on the integration and transversality of the body in learning. This is to understand whether embodied learning environments involving all spheres of personality can foster perception, knowledge, and conscious action in teaching and learning processes. An important result from the overview is the potential of theory in different educational environments and disciplines. The contemporary theoretical framework highlights the great potential of corporeality and physical education as actors in learning, but at the same time place in the foreground the need to experiment and disseminate new teaching approaches and perspectives.

Keywords: *neuroscience, corporeality, embodied learning, physical education, teaching-learning process, transversal skills*

Introduction

The body dimensions have taken on a central role in learning nowadays (Bresler, 2013). This highlights its educational, social, and inclusive potential and brings about the necessity to analyze the interweaving between body movement and learning in terms of efficiency and quality. The body can convey information that, if thoroughly investigated and understood, can enrich the knowledge about the dynamics of decision-making processes, both in individual and social contexts. It is within Embodied Cognition that these studies are rooted; the theoretical frameworks focusing on bodily states and the consequent sensorimotor interactions with the outside world helped better understand the link between the environment and the different cognitive states and effects (Farina, 2021). Within this perspective, Embodied Cognition represents one of the most emerging scientific approaches in the field of Educational Neuroscience (Fischer, 2009; Gomez Paloma, 2009; Fischer, 2010) and the awareness of this new vision of the body is the basis of the research conducted in this field (Ledoux, 2002).

The birth of embodied cognitive science, or embedded cognitive science, dates back to the late 1980s. Embodiment implies that the mind is no longer independent from the body, however, inscribed in it. Nowadays, the embodiment approach is getting more attention and is defined as "incarnation". Research in the field of education science can fuel new neuro didactics that focus both on the complexity of the body as a bio-dynamic entity in formation and considers unfolding the mechanisms underlying our perception of the living reality. The adoption of heuristic and synergistic approaches alone can not define global objectives (Rivoltella, 2012; Caruana et al., 2016; Shapiro et al., 2019).

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But, they can shape and define helpful research tools to better understand through practical experiences the complexity and uniqueness of the individual (Gomez Paloma, 2016). Embodied cognition considers that human cognition is fundamentally grounded in sensory-motor processes and our body's morphology and internal states (Ionescu et al., 2014). In particular, it is important to consider the essential role that body movements can play in achieving high-quality education for children (Chandler et al., 2015). Numerous studies have shown that body movements can have substantial positive effects on children's cognition, learning, and academic achievement (Tomporowski et al., 2008; Bartholomew et al., 2011; Donnelly et al., 2011; Fedewa et al., 2011; Erickson et al., 2015). Based on their review study, Tomporowski et al. (2008) concluded that exercise is a simple and promising method of improving the aspects of children's mental functioning that are central to their cognitive development. For effective teaching to improve skills, children must take action, experiment and actively participate in classes. Numerous scientific evidence emphasizes the important role of the body and movement in cognitive development even in childhood (Thelen et al., 1994; Robertson et al., 2009). Research on embodied co-cognition has radically changed the conception of how action, perception, and cognition relate and interact with each other. Sensory and cognitive abilities, as well as their interactions, are more fragile during the developmental age, thus offering a unique window on the emergence of embedded cognitive effects and age-related differences. The gestures that children and adults make when they speak are a revealing window into the processes of cognitive change: the body represents, in an incarnate context, a source of basic information, understanding, and cognition (Samuelson, 2011). Neuroscience focuses its attention on the study of mind and body, which are fundamental aspects, especially in terms of individualized and personalized teaching. Such learning implies a commitment of mind and body, biological and psychological factors. The representation of one's own body is the foundation of feelings and thought: it is indispensable for subjectivity (Blaesi et al., 2010). The motor system allows the subject a complete understanding. The physical body and movement are involved in processes related to cognition in schools such as language and logical-mathematical learning and, at the same time, play a fundamental role in the development of emotional and interpersonal skills (Gallese, 2005). Embodied learning should also be the cornerstone of physical education programs (Thorburn et al., 2017), as classes during motor activity class are engaged, not only physically, but also cognitively, facilitating the development in children of key cognitive skills, in particular executive functions (D'Anna, 2023).

In light of this evidence, the aim of this paper was to analyze embodiment from studies on applied neuroscience in education. Studies have been selected based on their experimental aspect of embodied-based teaching approaches in the school environment, using transversal learning through movement and corporeality in action and interaction. Starting from the premise that the key principle of embodied cognition offers unprecedented opportunities to exploit the differences in learning processes (Boat et al., 2022), and is necessary for creating innovative teaching methodologies.

Methods

An analysis of the scientific literature was conducted by analyzing studies published with the following keywords: Physical Education, Corporeality, Learning, Education, Embodied Cognition, Neuroscience, Embodied Cognition Approach. In particular, studies have been analyzed that highlight how corporeity plays a decisive role in the learning processes and the design of training courses focused on the use of the body and movement as a mediator of knowledge.

Discussion

The body in Embodiment theories, relies on perception and action to act as a mediator for the learning process. It thus overcomes the classical scientific frameworks that consider it as a mere evaluation object used to acquire the dignity of a subject of cognition (Sgambelluri, 2020). Post-constructivist hypotheses (Rivoltella, 2012) investigated the relationship between the environment, the body, and cognition and studied the role of these interactions in generating Embodied Cognition (Merleau Ponty, 2002; Gomez Paloma, 2016). This theory centralizes the role of the body in cognitive implementation. And thus considers knowledge and cognition as active processes rooted within the body and its biological dimensions. This reformulation of the body as a protagonist in knowledge conceptualization and as a communication tool with oneself, others, and the environment significantly influences the neuroscience of cognition. This argument explains that every form of knowledge and cognition is "embodied" and passes necessarily through bodily experiences (Gola et al., 2023).

This review examines the recent available theoretical and experimental studies performed in identifying the role of embodiment in classroom learning. Then we will describe the advances in cognitive neuroscience research explaining the role of brain-body interaction and its role in learning.

Theoretical concepts of embodiment

The reference framework also includes recent educational contributions from neuroscience considering the body as an integral part of learning that can not be separated from the brain (Gomez Paloma, 2016). Through this concept, it is precisely within the body that there is an interrupted activity of exchange, information processing, and storage. Neuroscientific studies (Fisher, 2007; Bruer, 2016) are revisiting the theories and methodologies that support teaching and study design where education can transfer this interaction between emotions, mind, and body. New educational strategies are centering the body and consider movement as an active element for cognitive processes (Sibilio, 2017). This embodied cognition perspective demonstrates that cognition is grounded in bodily interactions with the environment and culture and that abstract concepts are tied to the body's sensory and motor systems (Leung et al., 2011).

The principles of embodiment are methodologically opposite to Cartesian visions in the way that the brain is not the center of cognitive processing but is however part of a more complex machinery including the body and the external environment. Not only that, the body has a primary role in integrating and generating cognitive processes. It is, therefore, an interactive "tool" that allows observation, analysis, and collection of external information through sensorimotor networks and can serve for cognitive and behavioral adaptation through communication with external cues (Palmiero, 2018).

The body is a tool that serves for integrating cognition to experience a subject during learning. In this context, the environment is the place where transformation takes place: meanings are generated based on external elements and representations; the body interacts with its surroundings through sensorimotor networks (Bersalou, 2008; Alibabi et al., 2012). From this, ideas emerge, and cognitive processes are generated within very complex neurofunctional networks and paradigms. For example, bio-psycho-social cues and neurodiversity rely on holistic approaches, whose dimensions require an interaction between the living system and its surroundings, linking its biological, psychological, and social dimensions. The different theoretical approaches that have investigated the relationship between body cognition and movement from a plurality of perspectives have recognized the centrality of the body-kinesthetic dimension in the mechanisms of construction of knowledge, creating the conditions for a reconsideration of the potential learning, expressive, and communicative of the body in the didactic action. Specifically, the results of research in the field of Embodied Cognitive Science (ECS) have enriched the teaching of further reflections on vicarious processes and embodied simulation (Gallese et al., 1998; Rizzolatti et al., 2007) that can contribute to a better understanding of the complexity of the individual and, in a broad sense, of the actors involved in the teaching-learning process (Sibilio et al., 2022).

Experimental studies about embodiment in classroom learning

The neuroscience research (Francesconi et al., 2012; Ceciliani, 2018) has intensified in the most recent years, especially those concerning the correlation between brain, cognitive, and motor activities, which is more evident in younger subjects. The development of cognitive processes and representations influences the baby's movements in his first moments of life. Indeed, the kinaesthetic-bodily intelligence is manifested in a child through exploratory actions and the ability to reason in a certain situation, and it represents the first expression of learning to learn (life skill), a transversal competence expected by the European community in the training of citizens. This intelligence, among other things, is now supported by neuroscience, embodied cognition theories, and the consequent impact on embodied education, with an increasing focus on motor involvement in the development of the mind. Initial research on metacognition, that is, children's awareness of what they know and how they can use it and current research on Executive Functions highlight the importance of physical activity promotion (Bransford., 1999). Sports and motor activities provide the involvement of the totality of the individual by activating connections between consciousness and emotion, between the body and the surrounding environment. As a result, through this balance, the subject can govern his or her movements. As a consequence, cognition controls the emotion, so that the subject can choose which action to perform, making him move from input information to action (D'anna et al., 2023).

Many studies (Montagnoli et al., 2018) highlighted the vital role of the body in the learning process. Research about mathematics education showed that students are confronted with complex situations that hindered their reasoning and problem-solving skills. This increased the daily burden on teachers in managing their learning processes, administrative responsibilities, and their risk of failure. Mathematical knowledge, including oral counting, enumeration, and numerical representation, develops in parallel with motor skills. These latter seem to influence comprehension and interfere with the degree of mastery of learning mathematical concepts. Math learning, especially in primary school, should be perceptual-motor centered (Lakoff et al., 2005). Active observation allows the student to contextualize their learning according to the environment and the teacher to constantly grasp the different aspects and nuances of the various situations within the classroom. Another study showed positive learning outcomes by combining juggling exercises with multiplication tables (Van den Berg et al., 2019). Other studies have shown the role of gestures in learning mathematical concepts (Alibali et al., 2012). This beneficial effect of gestures' use in learning has been also demonstrated in other domains, like science, and foreign language education. Romano et al. (2000) have shown that playing and playful dimensions increase children's motivation, and attention, and improve their strategies of free discovery during learning. Literature also demonstrated that motor activity outside school was linked to better learning outcomes and that increasing the number of hours of physical education in school settings improved academic performance (Latino et al., 2020). Regardless of the effects of both modes of physical activity on cognition and academic achievement, it is widely recognized that they contribute to the healthy and better acquisition of motor skills in children.

Another classroom study (Have et al., 2018) implemented physical activity in the classroom as a facilitating tool for teaching mathematics, while analyzing the impact of this intervention on body mass index, aerobic fitness, and the level of physical activity. This research showed an improvement in academic performance in math after the integration of physical activity. In addition, this strategy helped maintain and consolidate a healthy lifestyle in students. Math symbolic writing difficulties and theoretical concept creation in children were facilitated by using gestures. Communication through touching objects, pointing towards them, and using fingers for counting were some of the practical gesture-based tools in body-centered learning approaches. This phenomenon shows how ideas are generated progressively through physical action. After recognizing external objects, children learn to connect the idea of the numbers of similar objects with the quantity without touching them and thus learn to simultaneously count "one, two, three, etc".

This body-environment interaction seems critical in learning (Soto-Johnson, 2018). There is a linear neural correlation between sensorimotor physical operations and arithmetic operations (Radford, 2011). In addition, an embedded spatial education can improve fundamental cognitive abilities, and spatial thinking, which are necessary for learning mathematics. Fostering the development of such skills from primary school seems also to contribute to a knock-on effect, increasing student interest and success in science-technology disciplines throughout education (Burte et al., 2017).

Peppler (2017) has recently described how counting originated in the real world: We count sheep by observing them. If our eyes are shut or the sheep are not where we are, we retrieve a concrete image of the animals to count them. We don't think of abstract living beings. Instead, we visualize sheep and not dogs the way we have experienced them. Furthermore, during counting, we use the body to support the cognitive task by counting on our fingers. We explain math basic operations (addition, subtraction, division, and multiplication) to children by putting real-world things together, taking them apart from each other, cutting them, and so on. All this, we do use our bodies. Even illiterate persons who cannot read or write numbers can perform the operations by referencing the task to real-world objects.

In two experiments by Crollen and Noël (2015), 5 to 9-year-old children had to accomplish one-target, two-target counting tasks, and additions. While doing this, participants had no constraints, interfering hand movements, and interfering foot movements to deal with. Hand movements disrupted counting more than foot movements. These results suggest a connection between our fingers and counting. Considering that in childhood the acquisition of numerical skills is tightly connected with finger counting, these results do not surprise. In an fMRI study, Tschentscher et al. (2012) presented adults' digits from 1 to 9 only visually while they lay quietly in the scanner. Depending on the participants' counting habits (left- or right-starters), hemodynamic activity in the contralateral motor cortex was observed when the numbers were presented. This neuroscientific evidence supports the view of embodied mathematical knowledge. The connection between motor activity in the brain and counting with fingers is connected to Hebbian learning mechanisms. They apply during learning and connect cognitive mathematical operations with finger movements performed while counting (Sato et al., 2008).

Advances in cognitive neuroscience research explaining the role of brain-body interaction and its role in learning

In recent years, psychological and neuroscientific research (Fischer et al.,2007) has shown that cognitive functions depended on action and perception and thus were experience-based. The body and its movement can through senses like vision, touch, and hearing internalize conscious concepts and representations of the body and identity; these can also serve in learning, intelligent behavior, and stimulating memory and emotional intelligence (Fischer et al.,2007). From this perspective, embodied cognitive research can have important implications for education because it highlights an approach to learning that passes through whole-body engagement (Gallagher et al., 2015).

Research (Dini, 2022) on learning through playing shows that sensorimotor stimulation is essential in promoting learning. Motricity in children contributes to learning through instinctive and innate representations that they tend to have with the world and their surroundings. These representations are incorporated by their senses and the concepts change depending on the constantly variable environmental motion-based elements. This can explain how representations of numbers, letters, and geometric shapes can occur by using the body and various environmental instruments, such as beams, balls, clubs, and musical tools. And how students are more likely able to solve arithmetic tasks with body-centered teaching approaches (Magistro et al., 2022; Lovecchio, 2022). Embedded learning is configured as an effective teaching mode that can involve all participants: embodied cognition as a "modus" can help build students' knowledge and shape their educational success (Paloma et al., 2016).

The central role of experience, the importance of the body acting in mathematical thought, and the multiple possibilities and modes related to experience are three key aspects that have brought the individual, and the researchers, closer to embodied mathematical cognition (Hall et al.,2012). There is little research on how physical activity interferes with learning. Some studies (Alibabi et al.,2012; Cook et al., 2016) associated math and geometry education with physical gameful activity and concluded that this combination resulted in better geometric acquisition skills of right angles, rectangles, and squares. This observation demonstrates a synergy between the cognitive and motor components within the nervous system in modulation and shaping behavior. Learning is a holistic process and is not just limited to memorization and thinking. Embodiment in learning depends on coordinating, cognitive, emotional, perceptual, and motor skills to guide and enrich our interaction with the environment and society (Pesce et al., 2019). Applying body-centered teaching methods can facilitate the acquisition of cognitive tools students may require in educational subjects based on conceptualization and critical thinking (Hraste et al., 2018).

The observations in this study highlight the importance of early implementation of motor activity education and shaping school curricula to use body-centered approaches (Donnelly, 2016). Recent research showed a positive correlation between mathematical knowledge and motor functions in children aged between 3 and 10 years old; this association was justified in previous studies by the theory of decision-making (Iannello et al., 2007). This theory implies that the execution of motor skills requires ahead-of-action and analysis-oriented decision-making reasoning. A statistical analysis of learning mathematical concepts and motor skills showed positive outcomes embedded in teaching on development (Rio et al., 2015), highlighting again that cognitive processes are deeply rooted in the interaction of the body with the world.

Future directions

In the scientific panorama, specifically educational neuroscience, are an emerging area bringing together researchers in cognitive and developmental neuroscience, education psychology, education theory, and other related disciplines to explore the interactions between biological and educational processes. This is a recognized field of research that makes transdisciplinarity its specific episteme, which tends to combine the principles of research evidence and recognized scientific rigor, with ecological paradigms such as classroom situations in which students and teachers act (Gola et al.,2023).

Motor activity to bring health benefits and development of executive functions such as attention, perception, decision-making, and problem-solving must be regularly practiced given the close link between body activity and cognitive processes (Paloma, 2013). t is necessary to adopt, during the hours of Physical Education, teaching that involves a dual approach, qualitative and quantitative, engaging children in recreational contexts with activities of moderate intensity and vigorous. The qualitative aspect favors, in the child, the acquisition of active lifestyles and healthy eating habits that allow for to prevention of numerous health problems while, the quantitative, consolidates the idea that physical activity is fundamental in everyday life (Ceciliani, 2018).

Osgood-Campbell (2015) states that future research should show evidence of the link between sensorimotor action and cognition in classroom activities and, specifically, should examine the improvement of specific academic skills such as language comprehension, mathematics, and scientific thinking. More so, future work should investigate the impact of sensory-motor abilities on language acquisition and comprehension (Willems et al., 2012). Studies should focus on teaching and learning investigating how designers can build new understandings of embodied mathematical cognition in learning environments (Hall et al., 2012).

The practical didactic applications of the embodied cognition theory, applied to motor activity and movement, can influence positively the development of cognitive functions above all through aerobic exercise with high coordination and mental commitment (Best, 2010). This approach should be used both in school and out of school it can be an excellent methodology to bring children closer to sport through cognitive involvement and motivation (Tosi, 2022).

Conclusion

In this paper, it is highlighted how learning requires a dynamic interaction of motor and cognitive skills. The efficacy of learning should not only focus on cognitive functions but also the role of experience and body involvement and its potentiality. Neuroscience research on the developing brain shows that physical activity and interaction with the environment are linked to better neuroplasticity and that experiences, and participatory learning leads to better learning outcomes. It is necessary to overcome the current idea that closed classroom school designs are necessary for promoting efficient learning, since they often exclude social and body-centered environmental interactions. Effective learning requires involving the student in doing by generating dual mental and physical stimulation. New educational cultures setting the student as a protagonist of his knowledge and encouraging his/her active participation in educational curricula seems necessary. The theory of embedded learning presented in this paper can be translated into educational research by combining theoretical knowledge with motor skills. Starting from experience to achieve skills and knowledge favors body-centered learning investigations. And can also help decipher the individual differences in interaction with the environment in generating cognition and thinking processes. The fundamental innovative aspect is the role of action in learning, understood not only as a simple execution of a movement but as an articulated interaction with the surrounding world capable of capturing and collecting as much information as possible.

Future research can focus lay the foundations for the construction of touchscreen tablets, and related applications, able to create opportunities for students to solve problems of motor action designed specifically to give rise to targeted protocols that in turn can help the reflective side. In short, touchscreen applications have the potential to be meeting places for action, perception, and cognition (Duijzer et al., 2017). Currently, there is no defined protocol to be able to implement an embodied and effective teaching about learning mathematical concepts, however, it is clear that it is necessary to become aware of the role that the body plays in learning. In general, these studies concluded that physically active learning improved results in mathematics. The applications of Embodied Cognition in this field of teaching allow this theory to be taken as a theoretical lens, since it allows the use of gestures as a demonstration of evidence, as, through the latter, students learn linear algebra, differential equations, complex variables, and more. The activation of what is involved in embodied knowledge is in itself indicative of a high, in some way conscious, elaboration of what is happening in the surrounding environment (Tosi, 2022).

Although there is little scientific evidence, the picture outlined highlights a strong interest on the part of educational research for the experimentation of protocols and teaching models that can amplify learning in terms of generalization and memorization.

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Conflict of Interest
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