Advances in Medicine, Psychology and Public Health (AMPPH)

Commentary in Cognitive Science

Learning with the Body: Embodied Cognition for Education

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Abstract

This article briefly examines the impact of embodied cognition (EC) in education, highlighting the role of the body in cognitive processes. It also explores how the integration of physical activities and sensory experiences in educational environments enhances learning effectiveness. Advanced applications such as virtual and augmented reality are investigated, simulating physical presence and interactivity to enhance learning. By applying EC principles, educators can create more effective learning experiences that improve educational outcomes. Embodied cognition is preferable to traditional methods because it directly involves the body in the learning process, thus improving student engagement and retention of information. However, teaching continues to adhere to traditional principles that separate the mind from the body.

The aim of this article is to present some practical applications of this approach and discuss its impact on the learning process, providing concrete examples of how learning environments can be designed. In addition, the article addresses the use of educational technologies that, by enhancing the sense of embodiment, could promote learning. In conclusion, the adoption of embodied cognition can revolutionize education, transforming it into a more dynamic and immersive process in which the body has a central role.

Keywords: Embodied Cognition; Learning; STEM disciplines; Virtual and Augmented Reality.

Cite this paper as: Re A, Bruno F. Learning with the Body: Embodied Cognition for Education. Adv Med Psychol Public Health. 2026;3(1):113-122. Doi:10.5281/zenodo.16763782

Received: 10 December 2024; Revised: 15 March 2025; Accepted: 30 April 2025; Published Online: 07 August 2025

INTRODUCTION

Embodied Cognition (EC) is a theoretical framework that highlights the importance of the body in cognitive processes. In this sense, cognition emerges not only from the brain, but from the dynamic interaction between brain,

body, and environment [1]. Embodied Cognition is based on the idea that many cognitive processes are realized through the body's control systems [2]. Furthermore, it emphasizes that perception, action, and cognition are not distinct domains but deeply interconnected. More specifically, this perspective emphasizes that motor skills, sensory systems, and physical interactions play a critical role in shaping our cognitive abilities [3,4]. The concept of Embodied Cognition represents a significant shift from classical cognitivism, which posited that cognitive processes were disembodied and independent of the physical body [5]. Since the concept of embodiment has entered the scientific discourse, the disembodied view of mind has shifted toward recognizing the constraints imposed by the body and the environment.

The idea of an embodied mind is also confirmed by the discovery of mirror neurons [6] that are activated both when a person performs an action, such as grasping an object, and when he or she observes someone else perform the same action, as long as it involves interaction with an object. Our understanding of others' actions would be based on embodied simulation mechanisms that allow an initial implicit and immediate understanding of actions [7].

This bodily role claim affected an extended domain of functions. These include language, progressively disengaged from the innatism postulated by Chomsky [8] and rooted in sensorimotor processes.
Research that has supported this thesis emphasizes, for example, that words are not abstracted from the body, as would be shown by the activation of sensorimotor brain areas during the reading of action words [9]. In addition, some studies of patients with brain lesions in the left inferior frontal cortex indicate impairment in comprehension of action verbs and images depicting actions [10].

More recently, the principles of EC have been extended to the field of education, based on the belief that its insights can also enhance learning. Despite the evidence supporting the role of the body in learning, educational settings have not yet created conditions to transformative change in this direction. Such change, which would begin with curriculum design, remains challenging. Schools often focus on the transmission of abstract knowledge, disconnected from real-world experiences [11]. The body remains largely invisible in schools [12], although research from several disciplines emphasizes its importance. The adoption of embodied cognition (EC) in the educational context requires a major reformulation of teaching strategies, emphasizing the importance of activities that use movement and gestures to increase student engagement and improve content memorization. This transformation should build on emerging evidence indicating that physical integration can significantly improve academic performance. Recent studies have demonstrated the positive impact that physical exercises integrated into the school curriculum have on student performance [8]. These teaching approaches not only promote better assimilation of knowledge, but also contribute to the development of skills such as problem solving, creativity and collaboration. In addition, regular physical activities during the school day improve students' concentration and mental health, providing benefits beyond simply improving academic performance [13]. To effectively implement these innovative methods, educators are encouraged to reconsider and adapt school facilities and schedules to accommodate dynamic activities that facilitate embodied learning. As research supporting the benefits of EC increases, growth in the adoption of these practices in schools is expected to lead to pedagogical changes in school settings.

Educators are beginning to explore how the principles of Embodied Cognition can be applied to enhance and transform teaching strategies. For example, incorporating movement and physical engagement in lessons can help bridge the gap between abstract concepts and concrete understanding [14]. Integrating physical action and sensory perception into learning processes could not only increase the effectiveness of teaching but also make the educational experience more engaging for students [15,16]. Thus, the growing relevance of this theory provides new educational perspectives, suggesting that active learning, as opposed to direct instruction, enhances memory and the development of higher cognitive skills by leveraging mechanisms such as synaptic plasticity and the reinforcement learning circuit,

providing a neuroscientific perspective for the superior educational outcomes observed [17]. This paradigm shift encourages a reassessment of traditional educational practices and the development of innovative strategies that effectively integrate body and mind. This paper will explore the idea that the use of the body during the learning process can have effective results.

The use of immersive technologies in STEM will be briefly discussed as providing greater interactivity with complex scientific concepts, allowing students to have a sense of presence and agency in their learning experience.

DISCUSSION

The importance of the body in learning: An embodied perspective

In his work, Dewey [6] has often directed attention toward the practical opportunities of an active learning environment to foster knowledge acquisition. According to Dewey, children, if properly stimulated, can cultivate their activities and interests more actively. Their impulse to act is also expressed through play, movement and gestures, understood as forms of preparation for social life. Stimulating children's knowledge enables them to become self-aware and develop the characteristics that will enable them to adapt to society and its changes. The mechanistic view of the learning process is overcome; knowledge, in fact, should not simply be memorized, but each piece of information must be related to its context. In other words, what is learned must be learned with the whole body and this strategy promotes its internalization and memorization, integrating it into daily life. Information becomes a dynamic element, acquired simultaneously through all learning channels available to the student.

Today, there is increasing recognition of the importance of the body in education, in which more emphasis has been placed on movement, assigning greater value to motor skills for harmonious personal development.

From a strictly educational point of view, the introduction of motor behaviors and practices within individual disciplines has gained importance. In this context, the body is considered a component through which children can explore the world, relate to others and construct knowledge. Movement is considered a form of language, essential for the growth and development of mental functions. Through the body, we understand the world and interact with it. With this in mind, the teacher must be willing to engage, develop motor sensitivity, and cultivate appropriate body awareness. A body pedagogy oriented toward an attitude marked by discovery and interaction between bodies and environments. This new approach aims to affirm the principle that knowledge must be embodied, revisiting educational contexts that have traditionally neglected the body. A pedagogy of the body that transfers the basic principles of motor education processes to different educational contexts. In this sense, the reference to mirror neurons is particularly relevant. By studying mirror neurons, we have come to understand how the human brain and social behavior are closely linked. These neurons fire when we observe or perform an action, allowing us to imitate and understand what others do [18]. On this basis, it is easy to see how imitation processes can be encouraged in education. During the COVID-19 pandemic and the implementation of distance learning, the problems arising from mandatory distancing emerged. It became apparent how essential active experience and the body are in education. We realized that a central aspect of learning had been deprived of the importance it deserves. In some senses, technology limited physical contact with teachers, reducing these interactions to a purely visual aspect. However, the role of posture, body expressiveness, gaze, and other aspects of nonverbal communication in the educational relationship are fundamental. The teacher's body serves as a mediator of teaching, and the student's body acts as a mediator of learning [19].

Integrating the physical body into the educational process significantly enhances students' cognitive, motor, and academic performance, while also improving their motivation and emotional state. This approach, applied in both general and special education contexts, highlights the importance of incorporating movement into teaching practices to enrich learning and optimize outcomes in real classroom settings.[20]. The communicative body dimension is central

to this exploration: it contributes to students' attention, cognition, and classroom behavior, while promoting their physical, psychological, mental, and social well-being [21].

Thus, the mind cannot be separated from the body to the extent that cognition can be defined as a process in which the role of the agent also assumes fundamental importance. A characterization that can only extend to the way learning is understood and thought about, which is often still relegated to a passive and abstract dimension. Considering the body as an integral part of the learning process enables the development of more inclusive, dynamic, and person-centered pedagogical approaches [22].

The Congruent Gestural Interface Experiment by Segal investigated the impact of gestural versus traditional computer interfaces on elementary school children's math learning. The study compared learning outcomes between children using iPads with direct manipulation gestures and those using Macbook Pros with mouse-based interactions. This research focused on two types of mathematical tasks: discrete-change (counting and adding blocks) and continuous-change (estimating on a number line).

Results indicated that iPads, which allowed gestures that closely mirrored the tasks, significantly improved children's performance by reducing errors and encouraging advanced problem-solving strategies [23]. Text comprehension is also influenced by embodied cognition. A study has indicated that changes in narrative perspective can affect reading speed and recall by forcing readers to change their mental visualization of the scene [24]. Some researchers applied these principles to the effective teaching of reading comprehension. They found that children could improve comprehension and recollection of texts by physically reciting stories with toys [25]. An applied example of embodied learning comes from the field of physical education. Using graphical computer simulations that incorporate movement can help students understand complex systems. These simulations allow students to directly manipulate components, reinforcing their learning through sensory engagement. Gestural interface technology also exemplifies embodied cognition in learning [26]. Gestural interfaces are based on direct physical movements that provide opportunities to incorporate movement and tactile interaction into learning. For example, research has shown how gestural interfaces can improve student retention of learning materials, facilitating learning and enabling physical interaction with digital content. This compatibility between physical actions and cognitive tasks highlights the potential of embodied learning approaches to revolutionize educational practices.

Children's participation in artistic activities significantly contributes to the development of their cognitive abilities, enhancing skills such as critical thinking, creativity, and problem-solving. Children who regularly engage in these activities demonstrate greater capacity to analyze information, generate innovative ideas, and tackle complex problems compared to those not exposed to such experiences. Integrating artistic activities into educational programs can support academic performance and strengthen essential cognitive skills, while further studies are needed to explore the connection between arts and cognitive development [27].

Furthermore, engaging in physical activities and interacting with the body in space significantly enhances spatial awareness [28]. Hands-on experiences with physical manipulation further strengthen spatial skills, allowing individuals to physically interact with objects and understand spatial relationships. Research shows that bodily activities not only improve spatial reasoning [29] but also facilitate the understanding of abstract concepts, as seen in geometry[30] and mathematics [31]. The importance of bodily interaction is further supported by neuroscientific evidence, which reveals the activation of motor areas during mental rotation tasks [32]. Educational interventions based on physical manipulation, particularly during early childhood, demonstrate lasting effects on spatial and cognitive skills [33], fostering the development of essential competencies for STEM disciplines [34].

Virtual and augmented reality in education

Embodied Cognition focuses on experiential learning. The body in action becomes a facilitator of the educational learning process, a body that connects with itself, its surroundings, and other bodies. Knowledge must be experienced through the body and acquired through action. The physical sensation of movement and action is fundamental to learning. If we deny the sensation of an active body during the acquisition of new information/knowledge, the individual may develop negative feelings of lack of attention and motivation. Therefore, words should be seen as the language of the mind and movements as the language of the body. Although movement and thought use different channels, together they achieve the same result. Learners, by reproducing with the body what they acquire, internalize it more precisely and deeply. Undoubtedly, the use of the body as an "educator" is particularly effective for non-vocal individuals. There is a substantial difference between being nonvocal and nonverbal. Those who cannot speak can still use other methods to communicate. The body acts as a mediator, enabling us to reach where words or apparent difficulties create limits or obstacles. This process involves recognizing one's body and others' bodies as entities capable of embodying and transmitting knowledge.

The lack of direct physical interaction and shared contexts can significantly reduce the effectiveness of pedagogical approaches that rely on embodied cognition, which considers movement and sensory perception as integral parts of learning. When the body is involved in the learning process improves the results in terms of students' outcomes and this challenge has also opened numerous innovative opportunities to overcome these barriers. For example, the integration of technologies such as virtual and augmented reality can provide students with simulated bodily experiences that help maintain the effectiveness of embodied learning. For these reasons, the use of innovative digital technologies in the school context is an effective approach to encourage the acquisition of skills in scientific domains [35,36]. Recent research has explored the use of virtual reality to create immersive learning environments that allow students to explore and interact with educational spaces virtually as if they were physically present. Adapting to the needs of distance education also requires renewed attention to teacher training as emphasized and the development of specific skills for the effective use of educational technologies that support embodied learning at a distance [37].

An advantage is the opportunity to investigate aspects not easy to explore in the classroom, in particular in the teaching of STEM (Science, Technology, Engineering and Mathematics disciplines). Immersive technologies in STEM provide students a sense of agency in the learning experience [38] and offer the appropriate affordances to improve learning [39].

The benefits of embodied design for learning are linked with bodily interactions and this approach often involves hands-on activities, gestures to represent ideas and the use of physical or digital environments that respond to movement. In this sense, embodied design should be based on activities that enhance participants' body engagement by providing new opportunities for immersive body learning in digital environments that allow students to explore abstract concepts through physical experiences. In addition, virtual reality (VR) has also made rapid progress because of its ability to create a strong sense of presence. By immersing users in realistic environments, VR allows them to have a sense of being in a specific time or place.

This capability has become increasingly valuable in educational environments, where VR is transforming the way people learn and interact with information. In education, VR enables students to engage more deeply with complex topics by providing experiences and practices that promote understanding and memorization. When it comes to exploring scientific concepts, VR makes learning more interactive, emotional and impactful, creating an environment where knowledge is experienced rather than simply observed. Furthermore, VR is used to enhance the sense of embodiment [40] and offers several advantages. Moreover, using controllers in virtual reality (VR) environments allows users to interact with objects and perform actions and gestures that can improve educational outcomes [41]. Research

by Alshammari has shown that the use of technologies that simulate immersive experiences can increase the effectiveness of learning, providing almost real experiences that stimulate both observation and action in controlled and safe contexts [42]. In addition, the use of tangible, embodied interfaces have been shown to be effective in fostering spatial cognition. These technologies, which allow physical interaction with digital content, make learning more engaging and accessible to students.

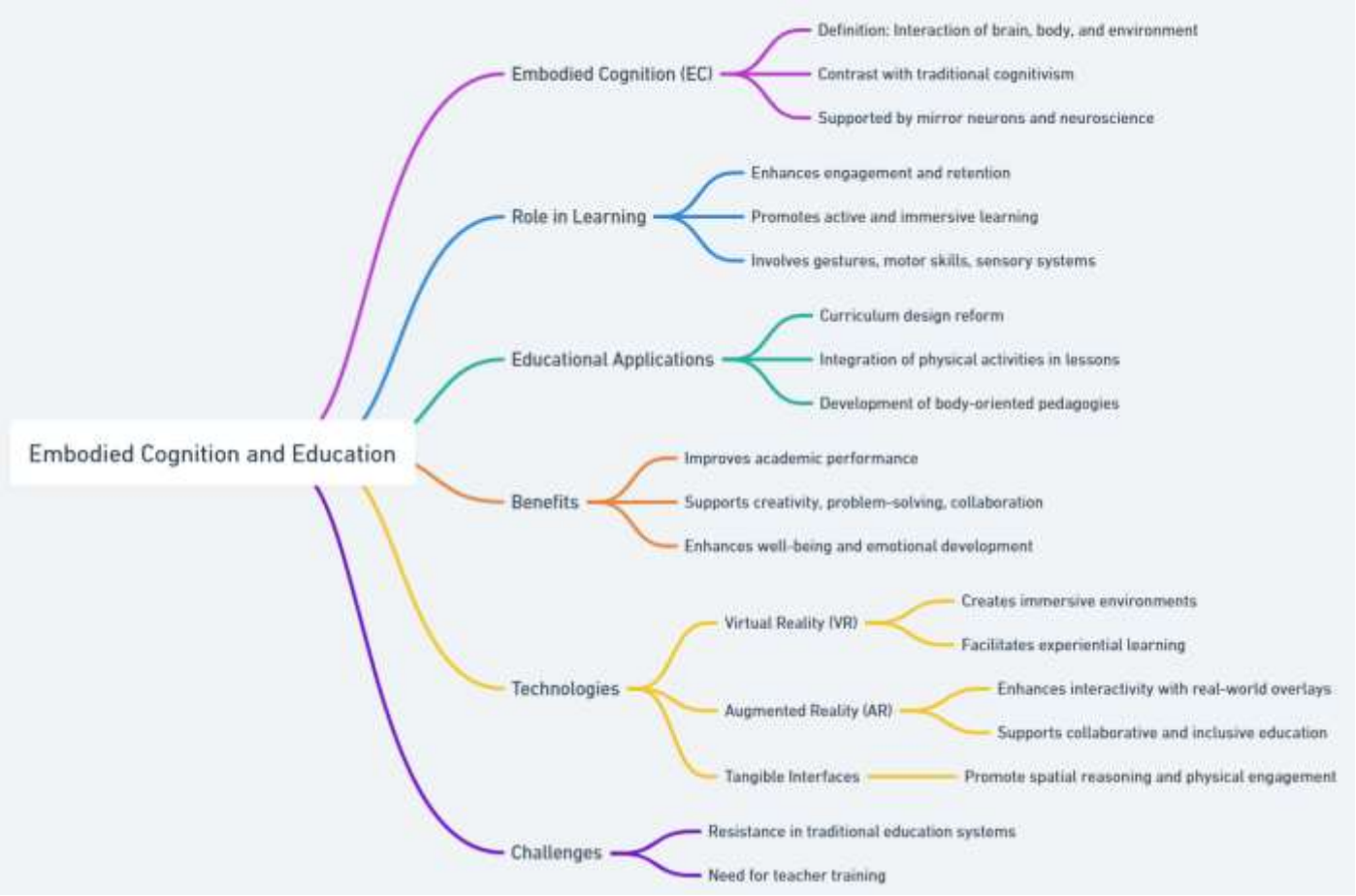
A study [43] focused on early spatial learning in children aged 2 to 4 years through the use of a tangible user interface, the effectiveness of which is based on the embodied nature of tactile interactions and movement. A tangible user interface represents an innovative mode of interaction between the user and the digital world, in which physical objects are used to manipulate virtual information. Unlike traditional graphical user interfaces, which rely on screens and mouse or keyboard input, this type of interface involves the body and allows users to act on physical objects. The haptic feedback generated by interacting with this type of interface enables a concrete and stimulating learning experience, promoting new spatial problem-solving strategies.

Augmented reality, by integrating digital elements into the user's real environment, allows students to interact with educational materials in ways that emphasize bodily experience. This type of technology can transform a standard virtual classroom into an immersive experience, where students can touch and manipulate virtual objects, improving understanding and memorization through direct experience and interaction. For example, research by Carter has shown that augmented reality can improve the learning of complex concepts in sciences and mathematics, allowing students to visualize and manipulate three-dimensional models that represent abstract structures or dynamic processes [44].

Additionally, these technologies can be used to facilitate collaborative learning, even at a distance. By implementing augmented reality, groups of students in different locations can work together as if they were in the same room, discussing and building projects in a virtually shared environment. Professional training also benefits from the application of augmented reality, as illustrated in the study by Herron, which describes how augmented reality simulations better prepare medical students for surgical procedures, offering them the opportunity to practice in scenarios that faithfully mimic reality, without the risks associated with early experiences on real patients [45].

Parallelly, the integration of the performing arts into the educational curriculum, such as theater and dance, is another example of innovative approaches that use the body to facilitate learning. These art forms not only allow students to express themselves creatively but also to better understand and memorize educational material through bodily experience. Lessons that incorporate elements of dance and acting can improve students' long-term memory and problem-solving abilities. The use of augmented reality (AR) in academic education not only actively engages students but also enhances their ability to understand complex concepts by making them tangible and directly interactive [46,47]. The combination of these technologies and teaching methods represents an exciting frontier for education in which the learning environment extends beyond the traditional boundaries of the classroom. With the addition of recent developments in neuro-education that have studied the impact of neuroplasticity on learning strategies, it is clear that the possibilities based on virtual and augmented reality are just beginning to be fully exploited [48].

Figure 1. This map illustrates the core concepts linking *Embodied Cognition* and *Education*, highlighting how bodily interaction enhances learning through movement, sensory experience, and immersive technologies like VR and AR. It also outlines educational benefits, practical applications, and current challenges in implementing embodied approaches.



CONCLUSIONS

The Embodied Cognition (EC) approach represents a paradigm shift in education that has the potential to revolutionize both teaching methodologies and students' learning experiences, particularly in STEM disciplines. By incorporating EC principles, educators can employ strategies that prioritize bodily experiences, such as movement, gestures, and sensory engagement, to facilitate learning. This approach not only enhances understanding but also encourages interaction, participation, and motivation in the classroom. In addition, EC supports the use of immersive technologies, such as virtual and augmented reality, to create multi-sensory and dynamic educational environments. Augmented Reality (AR) and Virtual Reality (VR) technologies are being increasingly integrated into educational settings, observing a positive impact on student engagement and participation. These technologies allow for the creation of immersive experiences that can significantly improve comprehension and retention by enabling students to visualize and interact with the subject matter in a more engaging and intuitive manner.

Furthermore, the use of VR and AR extends beyond simply enhancing engagement; it can fundamentally transform the learning process by providing a platform for experiential learning where theoretical knowledge is applied in practical, realistic scenarios. The sensory-rich environments created by these technologies ensure that learning is not

just observed but also experienced [49] making abstract concepts more tangible and relatable. The combination of embodied cognition and advanced technological tools like VR and AR represents a significant advancement in educational practices [50-55]. It supports a learning approach in which cognitive, physical, and emotional aspects of learning are integrated. For future research, it will be crucial for educational institutions to continue to explore these innovative approaches and technologies, ensuring that teaching methods evolve in tandem with advances in cognitive science and technology.

Author Contributions: Writing—original draft preparation: A.R: Writing—review and editing: F.B. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: None

Conflicts of Interest: The authors declare no conflict of interest.

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