EMBODIED LEARNING IN KINDERGARTEN SCHOOL: PERSPECTIVES AND LIMITS

EMBODIED LEARNING NELLA SCUOLA DELL'INFANZIA: OPPORTUNITÀ E LIMITI

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ABSTRACT
Embodied Cognition emphasises the importance of the body in the learning process and promotes the use of bodily experience as an educational tool. The aim of this theoretical-argumentative study is to provide a descriptive overview of the educational applications of embodied learning, comparing studies and research that have explored its implementation in various disciplines of preschool education, and highlighting the opportunities and challenges that have emerged from recent experiments.

L'Embodied Cognition evidenzia l'importanza del corpo nel processo di apprendimento e promuove l'utilizzo dell'esperienza corporea come strumento educativo. Lo scopo di questo studio teorico-argomentativo è quello di fornire un quadro descrittivo delle applicazioni didattiche dell'embodied learning, confrontando studi e ricerche che hanno esplorato l'implementazione in varie discipline dell'educazione prescolare, sottolineando le opportunità e le sfide emerse dalle sperimentazioni recenti.

KEYWORDS
Educational neuroscience, embodied cognition approach, education, kindergarten, teaching and learning
Neuroscienze educative, approccio embodied cognition, educazione, scuola dell'infanzia, insegnamento e apprendimento

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Introduction: The importance of the Embodied approach in learning[1]

Learning is a multidimensional process that involves not only the mind but also the body. Recent discoveries in the psycho-educational and neuroscientific fields show that bodily involvement enhances learning, enriching the teaching and learning process (Gamelli, 2012). The body acts as a 'sixth sense' (Berthoz, 1998), enabling the individual to explore, learn about and interact with the world around him. Until recently, the role of the body in understanding, cognition and mental processes was often overlooked, and considered a secondary element. However, in the last ten years, this perspective has radically changed: more and more research is highlighting the crucial importance of the physical body in cognitive processes. A new theoretical view has emerged that emphasises how we interpret and understand expressions of natural language through the activation of specific brain areas dedicated primarily to perception, movement, and emotion.

This theory, known as *embodied cognition*, states that the cognitive process is closely linked to bodily characteristics, especially the sensory and motor systems.

Various empirical evidence (Gallese, 2003; Barsalou, 2008; Cottini & Rosati, 2008) has corroborated this hypothesis while highlighting the growing need for a deeper understanding of the link between teaching, bodily experience, cognitive process, and action. This has brought to light the importance of integrating new conceptual perspectives, enabling teachers to adopt a richer and more versatile approach in their pedagogical practice. In this perspective, an education focused on corporeity and movement assumes a crucial role in ensuring the effectiveness of individual education. Bodily education thus represents an opportunity to develop fundamental cognitive skills through sensory and motor experiences (Russo, 2011). The embodied approach maintains that cognition is embodied in our physical being and depends on our perceptual, motor, and emotional experiences. This enactive approach to education emphasises the cognitive component of the body and action, expanding the cultural and pedagogical consideration of corporeality. Through the body, we can understand and connect with others, facilitating

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Pasqualina Forte designed the methodology, wrote the results and discussion.
Chiara Gentilozzi wrote the introduction and conclusion paragraphs.
Elisa Pugliese wrote the abstract and edited the translation.
Pasqualina Forte and Lara Lucaccioni contributed to literature research and data collection.
Cristiana D'Anna supervised the study and reviewed the manuscript.
All authors have read and agreed to the published version of the manuscript.

emotional and relational synchronisation. Emotions and bodily well-being directly influence thinking, decision-making, and motivation, emphasising the importance of considering the body as an integral part of the cognitive process (Gomez Paloma & Damiani, 2021). Adequate body and movement education is fundamental to effective learning, as it allows for enriched understanding and experience through direct interaction with the physical and social world.

This theoretical-argumentative study aims to provide a descriptive framework, in terms of educational declinations of the embodied learning approach, through the analysis and comparison of studies and research that have tested its educational implementation in different disciplines (mathematics, second language, pre-reading skills, and word-reading skills) at pre-school age.

1. Methods

The study, through an argumentative theoretical approach, after a selection and analysis of studies based on the embodied learning approach (both quantitative and qualitative experimental studies) in the field of education, intends to reflect on the implemented interventions by highlighting their perspectives and limitations.

2. Analysis of scientific literature

Within the framework of neuroscientific studies on human movement, the concept of embodied cognition plays a relevant role, as it supports the idea that mind and cognitive processes should be examined within the context of mind-body interactions (Caruana & Borghi, 2013). The embodied approach indicates a theoretical and methodological approach hinged on the dependence of mental processes on the body (Palmiero, 2018).

The analysis of the link between teaching, corporeality, cognition and action is an important scientific foundation to promote the development of individual potential in education, outlining neurobiological mechanisms, psycho-methodologiespedagogical approaches and different existing teaching approaches. By virtue of this sudden evolution in neuroscience, it is necessary to enrich the knowledge of psycho-pedagogical theories, especially those related to corporeity, by integrating new concepts and knowledge that allow the teacher to acquire a new *forma mentis* in didactic methodology (Gomez Paloma, 2009). And this is even more fundamental if we are talking about pre-schools, where corporeity becomes the

subject of learning, *"the original substratum on which to base formative processes, the humus that facilitates the use and interaction of different intellectual forms"* (Gomez Paloma, 2004, p. 236).

Regarding the theoretical applications of embodied cognition in education, numerous scholars have suggested integration strategies and methodologies to illustrate how embodiment can influence teaching and learning contexts.

In the educational field, the most interesting aspect is represented by the fact that physical education, and therefore the body in movement, can become an extraordinary vehicle for the transmission of interdisciplinary knowledge and skills. A transversal educational program based on proposals aimed at playful learning and motor character, allows the child to find the motivational drive needed to know, experience, discover, and develop, the appropriate skills for harmonious psychophysical growth (Farnese, 2016).

A recent review by Forte et al. (2023) examined studies that identified and tested didactic approaches based on embodied cognition in the school context, aimed at fostering learning of other disciplines through movement and corporeality.

School-based interventions involving bodily movement have indeed been recognised as a possible strategy to reinforce school learning in children and adolescents (Álvarez-Bueno, 2017; Donnelly, 2016; Macdonald, 2018) and the scientific literature highlights how physical exercise and the use of materials, can facilitate the learning of complex skills in children such as mathematics and foreign language (Pouw, 2014; 2016).

The body, in accordance with the fundamental principles of perception and action outlined by the theory of embodied cognition, acts as a biological and cultural mediator in the learning process. This transcends it from its previous conception as a mere object of evaluation to a central entity of cognition. This renewed understanding of the body forms the basis for future research in the field of educational neuroscience (Ledoux, 2002).

Our cognitive activities are therefore not abstract, centralised, or confined to the purely mental sphere: they are deeply rooted in our motor and sensory processes. Recent studies and experimental applications have shown how the embodied cognition approach can aid and stimulate learning (Pesce, 2019). Indeed, bodily experience is a significant element in learning processes: physical actions and interactions with our surroundings can facilitate the understanding of concepts and imprint them in our minds in a deeper and more lasting way. Active engagement,

experiential learning, and other teaching methodologies involving the body promote better understanding, memorisation, and processing of information (Mavildi, 2021).

2.1. Effects of embodied learning on children's pre-reading and word reading skills

Sensory and motor experiences, which help children learn words, will also influence their future thinking and remembering of these concepts (Reggin, 2021). Embodied learning has been used to foster understanding of sounds and letters through motor and sensory activities, such as body movement while identifying letters and pronouncing the corresponding sounds. This approach enabled children to fully develop reading and writing skills.

The integration of movement into teaching sessions has been confirmed as an effective strategy for enhancing learning and improving reading skills (Mavilidi et al., 2020). Despite this, few studies have investigated the effects of body movement on speech recognition and spelling in children.

Bara and Bonneton-Botté (2018) studied the effect of a six-week visuomotor intervention with six sessions of 45 minutes each on the learning of cursive writing in five-year-old children. They observed a significant improvement in letter recognition after the motor intervention compared to an intervention based solely on the visual component.

A study conducted by Botha and colleagues in 2020 investigated the effect of a perceptual-motor intervention on the correlation between motor skills and letter knowledge, with the aim of understanding which specific skills influence reading and writing skills in children. The intervention focused on the optimisation of perceptual-motor skills. During these activities, letters and shapes were introduced to facilitate letter recognition and learning. The study showed that this intervention significantly improved both fine and gross motor skills, as well as reading and spelling, indicating that integrating movement into academic activities is an effective method for promoting motor and learning skills in children. Furthermore, it was confirmed that the perceptual-motor intervention led to a significant improvement in reading and writing skills.

Similarly, research by Damsgaard (2020) on first-grade pupils investigated whether fine- or gross-motor enrichment during a letter 'b' and 'd' recognition session could improve performance compared to practice without movement. The aim was also to explore the children's motivation in tackling the assigned tasks. Participation in these motor activities increased their ability to recognise and differentiate the letters 'b' and 'd' in comparison to children who performed static tasks. In general, an advancement in letter recognition was observed with motor enrichment compared to the control group. Both fine- and gross-motor activities had a positive impact on the children's intrinsic motivation to complete the tasks (Damsgaard; 2022).

A study was conducted to explore the effects of embodied learning on pre-reading and reading skills in 5-6 year old children through the PLAYMORE programme, focusing on learning letterforms with the aim of evaluating the impact of two embodied teaching methods on reading skills, using movements with different motor modalities related to the teaching content.

2.2. Effects of embodied learning on mathematical concept

Learning mathematics is a complex and multifaceted process in which various components come into play. One form of numerical knowledge is constituted by children's motor and gestural experiences. Indeed, when they perform actions or games of movement, such as, for example, pointing, wiggling their fingers, or climbing stairs, they can integrate motor and gestural experience with linguistic, symbolic or non-symbolic modes of numerical representation, which constitutes an additional way of enriching mathematical skills (Bove, 2023). The importance of experience, the significant role of the body in the processing of mathematical thinking, and the variety of opportunities and ways of experiencing constitute three fundamental elements that have led both individuals and researchers to become interested in embodied mathematical cognition (Hall & Nemirovsky, 2012).

The use of manipulative materials and motor activities enhances children's learning of mathematical concepts. Indeed, through the use of tangible objects and the physical manipulation of numbers, children were able to better understand abstract concepts such as mathematical operations. A growing body of empirical evidence has demonstrated the importance of motor experience and manipulation of one's own body in supporting thinking while learning and performing mathematical tasks (Abrahamson, 2020).

Recent research has revealed interesting positive correlations between mathematical knowledge and motor functions in children between the ages of 3 and 10. These findings have been interpreted on the basis of the Decision Making theory, which emphasises the importance of prior analysis and decision-making in the execution of motor skills. Cognitive processes are closely linked to the interaction of the body with the environment, and a statistical analysis showed a positive link between learned mathematical concepts and motor skills, suggesting promising prospects for the development of an integrated teaching approach (Rio, Damiani & Paloma, 2015).

Goldin-Meadow and colleagues (2001) studied the effect of gestures during one task (where children had to describe the solution to a mathematical problem) on performance in another task (memorising words), showing that children (mean age 9.91 years) remembered more items when they gestured than when they did not.

A study by Have et al. (2016) investigated the impact of physical activity on the mathematical performance of seven-year-old children. The intervention involved a method of teaching mathematics that incorporated physical education in the classroom as a teaching aid. Secondary objectives included the evaluation of effects on executive function and the analysis of longitudinal correlations between physical activity and creativity, achievement in mathematics, executive function, body mass index and aerobic capacity. The results revealed that teaching mathematics with the integration of physical activity is more effective than the traditional method.

A study carried out in Italy by Ferrari et al. (2023) examined the early learning of numbers in five-year-olds, focusing on a specific approach with two types of materials: a long strip of paper with different coloured sections to represent a number line and the multi-touch iPad application, TouchCounts, which allows children to explore numbers in an expressive and relational manner. This free app is mainly used for counting, but also for subtraction and addition. Research has revealed children's engagement in early number learning.

2.3. Effects of embodied learning on the second language

In the field of foreign languages, embodied learning has been used to promote the learning of a second language by associating gestures and body movements with the words and sentences to be learned, demonstrating that this approach promotes the memorisation and application of language knowledge in practical contexts (Jusslin, 2022).

Over the years, scientific literature has investigated through multiple research, the use of gestures or hand movements, in addition to whole-body movements, can have positive effects in the learning process (Botha, 2020).

Mavilidi et al. (2015) showed that children aged 4-5 years who performed full-body movements while learning new foreign words achieved higher learning outcomes than children who used gestures or no-body movements. In particular, a study conducted by the same author (Mavilidi, 2018) involved 3-5-year-old children in learning a new language using gestures and physical exercises for 4 weeks. The results showed that the use of gestures and physical exercise, especially when integrated into the learning task, had beneficial effects on learning new words, supporting the importance of incorporating movement into learning activities to improve learning outcomes.

The 2015 study by Toumpaniari, Loyens, Mavilidi and Paas analysed the effect of combining gestures and physical activities in the classroom on learning foreign language vocabulary in pre-school children. This educational approach proved effective for several reasons. Firstly, it helps to improve recall of events, making the mnemonic traces more complex and distinctive, facilitating their retrieval. Secondly, physical activity has a positive impact on the brain's executive functions, probably due to increased blood flow and oxygenation as well as optimised neuronal processes (Hillman, Castelli & Buck, 2005). Finally, this method of teaching is able to significantly motivate children, as it is fun, playful and positively affectively connoted learning (Sibley & Etnier, 2003). This study contributes to the understanding of the learning experience and suggests that the combination of gestures and physical activities can be an effective educational strategy for learning vocabulary in pre-school children.

3. Perspectives and limits

Body movement is a complex concept and the mechanisms that influence cognition and learning vary widely depending on the characteristics of the physical activity. It is therefore crucial, when studying the relationship between bodily movement and school performance, to distinguish between different types of motor activities (Hillman, 2008; Moreau, 2018). In recent years, numerous researches have explored the link between physical activity, cognitive functions and school learning (Tomporowski, 2008; 2015).

Experimental research has revealed that executive functions, crucial for the development of spelling and language skills, can benefit from a single session of

physical activity. Physiological mechanisms responsible for the immediate effects of exercise on cognition include a temporary increase in levels of catecholamines (Skriver, 2014), steroid hormones, and growth factors (Budde, 2010), as well as changes in brain oxygenation and blood circulation (Endo, 2013).

Despite growing evidence of a link between physical activity (PA) or fitness and cognitive performance (Chaddock, 2015), few high-quality longitudinal studies have examined the effect of physical activity on school performance (rather than cognitive control or other educational outcomes) (Tomporowski, 2015; Hillman, 2014). Few studies have investigated the academic outcomes of integrating physical activity in the classroom. A US study of primary school children showed that those who participated in 90 minutes of moderate to intense physical activity per week during school hours for three years experienced greater academic improvement than controls (Donnelly, 2011). These results, however, were secondary and based on a small subset of the study sample. Another small randomised trial in the USA on third graders showed mixed results on academic improvement with the supplementation of 30 minutes of PA three times a week for three months, compared to controls (Reed, 2010). Finally, a more recent study showed that academic lessons that included physical activity significantly improved primary school students' performance in mathematics and spelling (Have et al., 2016).

Specifically, it is easier to find experiments that assess learning almost exclusively from a motor perspective. This is supported by a study conducted by Komaini and colleagues (2021), which aimed to design and implement instruments for measuring motor learning that exploit sensor technology in preschool education to assess children's fundamental movements such as running, walking, and jumping. This study aims to demonstrate that learning requires a dynamic interaction between motor and cognitive skills. The effectiveness of learning should not be limited to cognitive functions alone, but should also consider the importance of experience and physical involvement. Neuroscientific research indicates that physical activity and environmental interaction enhance neuroplasticity and that experiential learning leads to superior outcomes. The embedded learning approach could be expanded and applied in education to foster deeper and more stimulating learning for preschool children. The scientific literature is generally based on psychological and docimological parameters. It would indeed be interesting to monitor physiological parameters that could provide important indications on the level of children's involvement and stress during learning (cortisol, glutamate, heart rate, respiratory acts, etc.).

A study conducted by Geršak and colleagues in 2020 investigated the relationship between physical activity and learning outcomes in a school context through the use of wearable devices. These devices allowed the researchers to monitor various physical and physiological parameters as well as the behaviour of the children. The research involved two groups of seven-year-old children from a primary school, comparing and analysing their physical and cognitive activity during geometry lessons.

The contributions of neurophysiology with the help of new technologies provide important information underlying learning mechanisms. An extremely interesting study conducted in Italy in 2015 by Gomez Paloma et al. scientifically analysed the potential consequences of learning of two different teaching methodologies: innovative and traditional. The study focused on various aspects of school learning, such as learning environments based on the multisensory experience, the reprocessing and memorisation of information, the cortisol level of students, and its possible repercussions on learning. Research has shown that the adoption of experimental didactics leads to an improvement in students' academic performance, with a greater increase in long-term assessments, confirming the effectiveness of innovative didactics on memorisation processes. Furthermore, it has been observed that the learning benefits of introducing new teaching methods are manifested in those students with not excessively high cortisol levels. In other words, an excessively high cortisol level, indicative of excessive stress, can have a negative influence on learning and student performance.

Conclusions

Studies in the field of education investigating the correlation between embodied learning and embodied teaching from a qualitative perspective are manifold. It is difficult to design and conduct research protocols that use neurobiological parameters to better analyse and investigate human behaviour during a learning process. Memory, attention, perception, action, learning, etc. are some of the processes to be studied thanks to this progressively developing field of research (Gallese, 2003; 2005). However, it is evident how crucial the role of the body is in learning processes and how the paradigm of embodied cognition, promoting a holistic view of the educational experience, is valuable in educational contexts to understand how the mind-body interaction influences the way we learn and store information. The embodied cognition approach reveals that cognitive activities are closely intertwined with motor and sensory processes, and the studies presented confirm that bodily experience fosters deeper and longer-lasting learning,

facilitating cognitive performance, understanding of concepts, memorisation and information processing, offering the possibility of a more cohesive and dynamic educational methodology (Gomez Paloma & Damiani, 2021).

Despite the fact that there are still limitations in understanding the lasting impact of embodied learning on school performance over time, as well as the correlation between physical activity, executive functions and school success, as outlined above, it is crucial that the collaboration between neurophysiology educational psychology and pedagogy continue to dialogue and explore through research how deep and engaging learning can be facilitated for pupils, and that these studies are disseminated in the educational sphere among those working in schools so that a real change in vision and teaching approach can take place, less and less based on lectures and more and more on active lessons where students have the opportunity to learn in a meaningful way (Sweller, Chandler, 1991).

References

Abrahamson, D., Nathan, M. J., Williams-Pierce, C., Walkington, C., Ottmar, E. R., Soto, H., & Alibali, M. W. (2020, August). The future of embodied design for mathematics teaching and learning. In *Frontiers in Education* (Vol. 5, p. 147). Frontiers Media SA.

Álvarez-Bueno, C., Pesce, C., Cavero-Redondo, I., Sánchez-López, M., Garrido-Miguel, M., & Martínez-Vizcaíno, V. (2017). Academic achievement and physical activity: a meta-analysis. *Pediatrics*, *140*(6).

Bara, F., & Bonneton-Botté, N. (2018). Learning letters with the whole body: Visuomotor versus visual teaching in kindergarten. *Perceptual and motor skills*, *125*(1), 190-207.

Barsalou, L. W. (2008). Grounded cognition. *Annu. Rev. Psychol.*, *59*, 617-645.

Berthoz, A., & Dal Pra, E. (1998). *Il senso del movimento*. McGraw-Hill.

Botha, S., & Africa, E. K. (2020). The effect of a perceptual-motor intervention on the relationship between motor proficiency and letter knowledge. *Early Childhood Education Journal*, *48*(6), 727-737.

Bove, B., Doz, E., Cuder, A., Pellizzoni, S., & Passolunghi, M. C. (2023). Empowering mathematical learning with the new digital device "MagiCal": a pilot study.

Budde, H., Voelcker-Rehage, C., Pietrassyk-Kendziorra, S., Machado, S., Ribeiro, P., & Arafat, A. M. (2010). Steroid hormones in the saliva of adolescents after different exercise intensities and their influence on working memory in a school setting. *Psychoneuroendocrinology*, *35*(3), 382-391.

Caruana, F., & Borghi, A. M. (2013). Embodied Cognition: una nuova psicologia. *Giornale italiano di psicologia*, *40*(1), 23-48.

Chaddock-Heyman, L., Erickson, K. I., Kienzler, C., King, M., Pontifex, M. B., Raine, L. B., ... & Kramer, A. F. (2015). The role of aerobic fitness in cortical thickness and mathematics achievement in preadolescent children. *PloS one*, *10*(8), e0134115.

Cottini, L. & Rosati, L. (2008). *Per una didattica speciale di qualità: dalla conoscenza del deficit all'intervento inclusivo*. Morlacchi Editore.

Damsgaard, L., Elleby, S. R., Gejl, A. K., Malling, A. S. B., Bugge, A., Lundbye-Jensen, J., ... & Wienecke, J. (2020). Motor-enriched encoding can improve children's early letter recognition. *Frontiers in Psychology*, *11*, 520681.

Damsgaard, L., Nielsen, A. M. V., Gejl, A. K., Malling, A. S. B., Jensen, S. K., & Wienecke, J. (2022). Effects of 8 weeks with embodied learning on 5–6-year-old Danish children's pre-reading skills and word reading skills: The PLAYMORE project, DK. *Educational Psychology Review*, *34*(3), 1709-1737.

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., ... & Szabo-Reed, A. N. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: a systematic review. *Medicine and science in sports and exercise*, *48*(6), 1197.

Donnelly, J. E., Hillman, C. H., Greene, J. L., Hansen, D. M., Gibson, C. A., Sullivan, D. K., ... & Washburn, R. A. (2017). Physical activity and academic achievement across the curriculum: Results from a 3-year cluster-randomized trial. *Preventive medicine*, *99*, 140-145.

Donnelly, J.E., Lambourne, K. (2011). Classroom-based physical activity, cognition, and academic achievement. *Prev Med*. ;52: S36–42.

Endo, K., Matsukawa, K., Liang, N., Nakatsuka, C., Tsuchimochi, H., Okamura, H., & Hamaoka, T. (2013). Dynamic exercise improves cognitive function in association with increased prefrontal oxygenation. *The Journal of Physiological Sciences*, *63*, 287-298.

Farnese, A. (2016). *Mente in movimento. 99 giochi per l'educazione fisica, l'apprendimento e l'interdisciplinarietà.* Editore: Calzetti Mariucci.

Ferrara, F., & Ferrari, G. (2023). Kindergarten children and early learning of number: Embodied and material encounters within the classroom. *Digital Experiences in Mathematics Education*, *9*(3), 401-419.

Forte, P., Pugliese, E., Ambretti, A., & D'Anna, C. (2023). Physical Education and Embodied Learning: A Review. *Sport Mont*, *21*(3).

Gallese, V. (2003). The manifold nature of interpersonal relations: The quest for a common mechanism. *Philosophical Transactions of the Royal Society of London B*, 358 (1431), 517-528.

Gallese.V. (2005). Embodied simulation: From neurons to phenomenal experience. *Phenomenology and the Cognitive Sciences*, 4 (1).

Gamelli, I. (2012). *Ma di che corpo parliamo?.* Franco Angeli.

Gejl, A. K., Malling, A. S. B., Damsgaard, L., Veber-Nielsen, A. M., & Wienecke, J. (2021). Motor-enriched learning for improving pre-reading and word recognition skills in preschool children aged 5–6 years–study protocol for the PLAYMORE randomized controlled trial. *BMC pediatrics*, *21*, 1-18.

Geršak, V., Vitulić, H. S., Prosen, S., Starc, G., Humar, I., & Geršak, G. (2020). Use of wearable devices to study activity of children in classroom; Case study—Learning geometry using movement. *Computer communications*, *150*, 581-588.

Goldin-Meadow, S., Nusbaum, H., Kelly, S. D., & Wagner, S. (2001). Explaining math: Gesturing lightens the load. *Psychological science*, *12*(6), 516-522.

Gomez Paloma, F. & Damiani, P. (2015). *Cognizione corporea, competenze integrate e formazione dei docenti.* I tre volti dell'Embodied Cognitive Science per una scuola inclusiva. Trento: Centro Studi Erickson.

Gomez Paloma, F. (2004). *Corporeità ed emozioni. Una didattica psicomotoria per la costruzione del saper… essere*. Napoli: Alfredo Guida Editore.

Gomez Paloma, F. (2009). *Corporeità, didattica e apprendimento. Le nuove neuroscienze dell'educazione*. Salerno: Edisud.

Gomez Paloma, F., & Damiani, P. (2021). *Manuale delle Scuole ECS. The Neuroeducational Approach. La sfida del cambiamento educativo per il benessere e l'apprendimento.* Brescia: Editrice Morcelliana.

Have, M., Nielsen, J. H., Gejl, A. K., Thomsen Ernst, M., Fredens, K., Støckel, J. T., ... & Kristensen, P. L. (2016). Rationale and design of a randomized controlled trial examining the effect of classroom-based physical activity on math achievement. *BMC public health*, *16*, 1-11.

Hall, R., & Nemirovsky, R. (2012). Introduction to the special issue: Modalities of body engagement in mathematical activity and learning. *Journal of the Learning Sciences*, 21(2), 207-215.

Hillman, C. H., Pontifex, M. B., Castelli, D. M., Khan, N. A., Raine, L. B., Scudder, M. R., ... & Kamijo, K. (2014). Effects of the FITKids randomized controlled trial on executive control and brain function. *Pediatrics*, *134*(4), e1063-e1071.

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature reviews neuroscience*, *9*(1), 58-65.

Jusslin, S., Korpinen, K., Lilja, N., Martin, R., Lehtinen-Schnabel, J., & Anttila, E. (2022). Embodied learning and teaching approaches in language education: A mixed studies review. *Educational Research Review*, *37*, 100480.

Komaini, A., Hidayat, H., Kiram, Y., & Mario, D. T. (2021). Motor Learning Measuring Tools: A Design and Implementation Using Sensor Technology for Preschool Education. *International Journal of Interactive Mobile Technologies*, *15*(17).

LeDoux, J. (2002). Il sé sinaptico. *Milano: Raffaello Cortina Editore*.

Macdonald, K., Milne, N., Orr, R., & Pope, R. (2018). Relationships between motor proficiency and academic performance in mathematics and reading in school-aged children and adolescents: A systematic review. *International journal of environmental research and public health*, *15*(8), 1603.

Mavilidi, M. F., Lubans, D. R., Eather, N., Morgan, P. J., & Riley, N. (2018). Preliminary efficacy and feasibility of "Thinking While Moving in English": A program with physical activity integrated into primary school English lessons. *Children*, *5*(8), 109.

Mavilidi, M. F., Okely, A. D., Chandler, P., Cliff, D. P., & Paas, F. (2015). Effects of integrated physical exercises and gestures on preschool children's foreign language vocabulary learning. *Educational psychology review*, *27*, 413-426.

Mavilidi, M. F., Drew, R., Morgan, P. J., Lubans, D. R., Schmidt, M., & Riley, N. (2020). Effects of different types of classroom physical activity breaks on children's on-task

behaviour, academic achievement and cognition. *Acta paediatrica*, *109*(1), 158-165.

Mavilidi, M. F., Ouwehand, K., Schmidt, M., Pesce, C., Tomporowski, P. D., Okely, A., & Paas, F. (2021). Embodiment as a pedagogical tool to enhance learning. In *The Body, Embodiment, and Education* (pp. 183-203). Routledge.

Moreau, D., & Tomporowski, P. D. (2018). 10 complex motor activities to enhance cognition. In M. L. Cappuccio (Ed.), *Handbook of embodied cognition and sport psychology*, 273. MIT Press.

Palmiero, M., Borsellino, M. C., (2018). *Embodied cognition: Comprendere la mente incarnata.* Edizioni Aras.

Pesce, C., Croce, R., Ben-Soussan, T. D., Vazou, S., McCullick, B., Tomporowski, P. D., & Horvat, M. (2019). Variability of practice as an interface between motor and cognitive development. *International Journal of Sport and Exercise Psychology*, 17(2), 133-152.

Pouw, W. T., De Nooijer, J. A., Van Gog, T., Zwaan, R. A., & Paas, F. (2014). Toward a more embedded/extended perspective on the cognitive function of gestures. *Frontiers in Psychology*, 5, 359.

Pouw, W. T., Mavilidi, M. F., Van Gog, T., & Paas, F. (2016). Gesturing during mental problem solving reduces eye movements, especially for individuals with lower visual working memory capacity. *Cognitive Processing*, 17(3), 269-277.

Reed, J. A., Einstein, G., Hahn, E., Hooker, S. P., Gross, V. P., & Kravitz, J. (2010). Examining the impact of integrating physical activity on fluid intelligence and academic performance in an elementary school setting: a preliminary investigation. *Journal of Physical Activity and Health*, *7*(3), 343-351.

Reggin, L. D., & Pexman, P. M. (2021). New insights from embodied cognition about children's learning of language and concepts. *Early Childhood Education*, *47*(1), 17.

Rio, L., Damiani, P., & Paloma F. G. (2015). Embodied processes between maths and gross-motor skills. *Procedia-Social and Behavioral Sciences,* 174, 3805-3809.

Russo, P. (2011). Note su sensorialità, corporeità, sessualità nel gruppo. *Funzione Gamma*, *26*.

Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: a meta-analysis. *Pediatric exercise science*, *15*(3), 243-256.

Skriver, K., Roig, M., Lundbye-Jensen, J., Pingel, J., Helge, J. W., Kiens, B., & Nielsen, J. B. (2014). Acute exercise improves motor memory: exploring potential biomarkers. *Neurobiology of learning and memory*, *116*, 46-58.

Sweller, J., & Chandler, P. (1991). Evidence for cognitive load theory. *Cognition and instruction*, *8*(4), 351-362.

Tomporowski, P. D., McCullick, B., Pendleton, D. M., & Pesce, C. (2015). Exercise and children's cognition: The role of exercise characteristics and a place for metacognition. *Journal of Sport and Health Science*, *4*(1), 47-55.

Tomporowski, P.D., Davis, C.L., Miller, P.H., & Naglieri, J.A. (2008). Exercise and children's intelligence, cognition, and academic achievement. *Educational Psychology Review*, 20, 111–131.

Toumpaniari, K., Loyens, S., Mavilidi, M.-F., & Paas, F. (2015). Preschool Children's foreign language vocabulary learning by embodying words through physical activity and gesturing. *Educational Psychology Review*, 27(3), 445–456.