



Hypotheses and study methods

Studying through movement: motor activities to improve performance in children with ADHD – A psychoeducational protocol

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ABSTRACT

In the psychoeducational field, identifying effective strategies to support the learning and development of children with Attention-Deficit/Hyperactivity Disorder is a key priority. An emerging approach involves integrating structured motor activities into the educational routine. This article examines the effectiveness of such activities as pedagogical tools for improving academic performance in children with Attention-Deficit/Hyperactivity Disorder, using a clearly defined intervention protocol. The study explores how different forms of physical activity can be strategically incorporated into educational contexts to facilitate homework completion and reduce anxiety and frustration associated with these tasks. In addition, it investigates how exercise may enhance cognitive functioning and foster a more inclusive and supportive learning environment. Various types of motor activities and their impact on academic performance and behavior are analyzed. The implementation of this psychoeducational protocol may provide new perspectives for educators, parents, and special education professionals, promoting a more dynamic, individualized, and integrated approach to learning.

Keywords

ADHD, Hyperactivity, Neuropsychomotor intervention.

ABSTRACT in ITALIANO

Nel campo psicopedagogico, l'individuazione di strategie efficaci per sostenere l'apprendimento e lo sviluppo dei bambini con Disturbo da Deficit di Attenzione/Iperattività rappresenta una priorità fondamentale. Un approccio emergente prevede l'integrazione di attività motorie strutturate nella routine educativa. Il presente articolo esamina l'efficacia di tali attività come strumenti pedagogici per migliorare il rendimento scolastico nei bambini con Disturbo da Deficit di Attenzione/Iperattività, attraverso l'utilizzo di un protocollo di intervento chiaramente definito.

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Lo studio esplora come diverse forme di attività fisica possano essere integrate strategicamente nei contesti educativi al fine di facilitare lo svolgimento dei compiti a casa e ridurre l'ansia e la frustrazione associate a tali attività. Inoltre, analizza come l'esercizio fisico possa potenziare il funzionamento cognitivo e favorire un ambiente di apprendimento più inclusivo e supportivo. Vengono esaminati diversi tipi di attività motorie e il loro impatto sul rendimento scolastico e sul comportamento.

L'implementazione di questo protocollo psicoeducativo può offrire nuove prospettive per insegnanti, genitori e professionisti dell'educazione speciale, promuovendo un approccio all'apprendimento più dinamico, individualizzato e integrato.

Parole chiave

ADHD, Iperattività, Intervento neuropsicomotorio.

INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD) is a neurobiological disorder that affects a person's ability to focus, control impulses, and maintain organized behavior. ADHD often appears in childhood, although symptoms may persist into adolescence and adulthood. Scientific literature indicates that the disorder is more prevalent in males than in females, with a ratio of approximately 2:1 in children and 1.6:1 in adults [1].

DHD is a multifactorial neurodevelopmental disorder, involving neurological, psychological, and educational components. Addressing it requires an integrated approach that considers all these aspects. Specifically, regarding neurobiological components, ADHD is thought to involve differences in brain functioning. It is associated with an imbalance in neurotransmitters such as dopamine and norepinephrine, which are crucial for attention, self-regulation, and emotional regulation. Abnormalities have also been observed in the functioning of the prefrontal cortex, a brain region involved in self-control, planning, and decision-making. Individuals with ADHD often show reduced activation in this area, which may explain difficulties in planning and impulse control. Recent research suggests that individuals with ADHD may exhibit differences in connectivity between various brain regions, particularly those involved in attention and motor control [2].

ADHD also significantly impacts psychological components, affecting emotions, motivation, and behavior. Individuals with ADHD may experience difficulty managing their emotions, which can result in challenges with self-regulation and emotional control. This includes impulsivity and difficulties controlling emotions, such as fru-

stration, anger, and anxiety. Such difficulties can create stress and tension in social interactions [3]. Due to the daily challenges associated with the disorder, individuals with ADHD may develop low self-esteem, particularly if they frequently feel incompetent or inadequate compared to peers or are often criticized. In addition to physical hyperactivity, many individuals with ADHD experience "mental hyperactivity," characterized by rapidly racing thoughts, difficulty sustaining attention on tasks, and constant distraction. ADHD is frequently associated with psychological comorbidities such as anxiety and depression, which may be exacerbated by difficulties in managing daily life [4].

The disorder also significantly affects school functioning, particularly with regard to learning and interactions with teachers and peers. Children with ADHD struggle to sustain attention for long periods, follow instructions, and complete tasks. These challenges can result in poor academic performance, even though intellectual potential is often normal or above average. They may experience difficulties with planning and time management, which can lead to disorganization in school activities, such as forgetting homework, failing to prepare necessary materials for lessons, or misplacing materials. Consequently, impulsivity may lead to inappropriate actions during school activities, such as responding without thinking or acting before reflecting, which can result in social or disciplinary difficulties. ADHD often requires specific educational support, including curriculum modifications or personalized teaching techniques. Students may benefit from an individualized instructional plan (IDP), which includes remedial measures and compensatory tools to support academic achievement [5].

NEUROPSYCHOMOTOR SKILLS AND NEUROPSYCHOMOTOR TREATMENT

Neuropsychomotor skills are a discipline that focuses on the study and rehabilitation of an individual's psychomotor functions, integrating neurological, psychological, and motor aspects. This field examines the relationship between mind, body, and movement, emphasizing how the nervous system regulates and influences motor behavior and cognitive abilities [6].

Creating an integrated model in which physical exercise becomes an integral part of school and homework routines may help improve body awareness and self-regulation, offering a dual benefit of physical and mental activation. Neuropsychomotor therapy is a structured intervention aimed at developing an individual's motor, cognitive, and emotional skills, particularly in children with neurological or psychomotor disorders. This type of treatment can be applied to various conditions, including ADHD, movement disorders, behavioral disorders, and other difficulties related to the integration of motor and cognitive functions. Neuropsychomotor therapy integrates multiple practices and techniques to promote proper development and functional integration between body and mind. It addresses motor skills, cognitive abilities, executive functions, and emotional functions such as emotional regulation, frustration management, self-esteem, and socialization. It also supports sensory integration, enhancing the processing of and response to sensory stimuli. Overall, it aims to foster better integration between motor and psychological components, thereby improving quality of life, communication, relationships, and learning skills [7].

The motor intervention protocol we intend to implement may provide numerous benefits for learning, as it aims to stimulate and enhance the child's cognitive, motor, and emotional abilities in an integrated manner. When the body and mind work synergistically, learning becomes more effective and fluid. Among the main benefits, we hypothesize a significant improvement in motor coordination. Good coordination is essential for learning tasks that require precise movements, such as writing, drawing, or using tools.

Neuropsychomotor activities help develop fine motor skills (small, precise movements) and gross motor skills (larger movements), promoting greater confidence in everyday tasks and academic activities. These activities also

stimulate selective attention and concentration, which are critical for academic learning. They help children focus on a specific task, sustain attention for longer periods, and manage distractions. Furthermore, neuropsychomotor activities contribute to the development of executive functions, including planning, organization, working memory, and problem-solving. These skills are crucial for academic learning, as they enable children to tackle complex tasks, manage multiple steps of a process, and solve problems effectively. Among the expected outcomes, we also anticipate improved integration of sensory perception. Neuropsychomotor activities help children enhance body perception and spatial awareness, which are essential for many cognitive activities, such as reading and writing. Good sensory integration supports spatial orientation, shape and letter recognition, and the development of a sense of rhythm and sequence.

EVIDENCE FROM THE LITERATURE

The term ADHD has been used since the 1980s, although the characteristics of the disorder were previously described under various labels. The modern definition is based on diagnostic criteria established in manuals such as the DSM-5 (Diagnostic and Statistical Manual of Mental Disorders) [8] and the ICD-10 (International Classification of Diseases) [9].

The etiology of ADHD is complex and multifactorial, involving genetic, neurological, environmental, and social factors. When discussing ADHD, it is important to consider different epistemological approaches [10]. The psychobiological approach seeks to understand ADHD through biological and neural mechanisms, emphasizing empirical evidence and providing a biological basis for the disorder. The behavioral approach focuses on observable behaviors and environmental factors that influence children with ADHD, emphasizing behavior modification techniques and cognitive-behavioral therapy. The sociocultural approach recognizes that cultural and social factors affect the perception and treatment of ADHD, as cultural norms and expectations may influence how the disorder is diagnosed and managed.

ADHD, as a neurodevelopmental disorder, may be influenced by genetic factors. Barkley [11] suggests that the disorder has a significant heritable component. Family members of children with ADHD are more likely to have the disorder, and genetic variants related to

neurotransmitters, particularly dopamine, have been associated with ADHD. Neurological factors and neuroimaging research have revealed differences in brain architecture and functioning in individuals with ADHD. Specific areas of the brain involved in regulating attention, behavior, and impulse control, such as the frontal lobe, may exhibit abnormalities. Environmental factors, including exposure to toxic substances (e.g., lead) during pregnancy or early life, psychosocial factors (e.g., adverse family conditions), and nutrition (some studies suggest a link between food additives and ADHD symptoms), may influence the development of the disorder. Prenatal factors, such as complications during pregnancy, premature birth, small birth size, and substance use during pregnancy (e.g., alcohol and nicotine), are also associated with a higher risk of developing ADHD [11].

Various methodologies are used to improve cognitive, social, and emotional skills in children with ADHD. Many children with ADHD experience difficulties processing and responding appropriately to sensory stimuli. Interventions based on sensory integration aim to improve their ability to process sensory information (visual, tactile, auditory) and respond more appropriately to the environment, thereby reducing hyperactive and disorganized behavior. Another methodology focuses on improving cognitive skills, such as working memory, planning, and attention. Cognitive enhancement interventions aim to strengthen executive functions. These include activities that support working memory, such as exercises requiring the maintenance and manipulation of information, including memory games, mental calculation exercises, or repeating number sequences. Activities that teach self-control, such as turn-taking games or “stimulus-response” exercises, require children to pause and think before acting. Games that stimulate cognitive flexibility, such as puzzles, logic games, role-playing, or activities in which the rules change during play, also promote adaptive cognitive strategies [12]. Behavioral approaches are commonly used to teach children strategies to manage impulsivity and improve attention. The ABA (Applied Behavior Analysis) methodology is based on analyzing and modifying behavior. Although primarily used for children with autism spectrum disorder (ASD), ABA may also be effective for children with ADHD. ABA focuses on behavior modification through reinforcement of desirable behaviors, which can be adapted to manage ADHD symptoms, including inattention, impulsivity, and hyperactivity. Positive

reinforcement, a key tool of ABA, is particularly effective for children with ADHD, who may become easily demotivated or distracted. Immediate reinforcement after desirable behaviors encourages their repetition. ABA can improve attention management, self-control, motivation, and social skills. However, treatment should be personalized and combined with complementary therapeutic approaches to address ADHD comprehensively [13].

In recent years, mindfulness has become an increasingly popular therapeutic approach for children, particularly those with ADHD. It helps develop self-awareness and improve emotional and behavioral self-regulation, both of which are often challenging. Children with ADHD often struggle to maintain attention on tasks for prolonged periods. Mindfulness teaches them to focus on the present moment, whether it involves an activity, a sensory experience, or their own emotions. Regular mindfulness practice improves the ability to sustain attention and return to tasks when distracted. It also helps children observe emotions without being overwhelmed, learning to recognize anger, frustration, or anxiety as they arise and respond in a calm and deliberate manner. Mindfulness encourages children to pause before acting, reflect on their reactions, and consciously choose how to respond [14]. This approach can be particularly useful for reducing impulsive behaviors. Mindfulness can be taught through age-appropriate, playful methods, such as games that stimulate body and sensory awareness. Examples include “listening activities” or the “silence game,” in which children remain still for a few minutes.

Neuropsychomotor skills

Neuropsychomotor sciences are an interdisciplinary field that studies the interaction between cognitive, emotional, and motor processes, with a particular focus on childhood development. The evolution of this field has been influenced by various epistemological perspectives and by research on the etiology of psychomotor disorders. The roots of the discipline can be traced to developmental psychology, psychomotor sciences, and neuroscience.

Neuropsychomotor sciences integrate knowledge from psychology, medicine, neurology, and pedagogy, allowing for a holistic view of childhood in which body, mind, and emotions are interconnected. Theoretical models, such as constructivism and the systems

approach, recognize that learning and development do not occur in isolation but result from dynamic interactions between individuals and their environment [15]. Neuropsychomotor therapy focuses on structured interventions that use movement as a therapeutic tool. Through play and physical activity, professionals help children develop motor, cognitive, and emotional skills [15]. This therapy addresses a range of developmental issues, including movement disorders, learning disabilities, attention deficit disorders, and behavioral disorders. These difficulties may have multifactorial etiologies, involving genetic, neurological, and environmental factors. A child's environment plays a crucial role in development. Stressful situations, emotional deprivation, or socioeconomic challenges may negatively impact neuropsychomotor development, whereas enriched or stimulating environments can foster the harmonious growth of motor and cognitive skills. Alterations in neurological processes can influence motor behavior and psychomotor development. Modern neuroscience suggests that early experiences may shape neural connections and influence cognitive and emotional development.

STUDY HYPOTHESIS

Creating a motor protocol for children with hyperactivity, such as those with Attention-Deficit/Hyperactivity Disorder (ADHD), is important for several reasons. One key reason is channeling energy, as hyperactive children often struggle to manage excess energy. A targeted motor protocol may help children direct this energy constructively, improving concentration and reducing impulsiveness. The development of motor skills is fundamental for children with hyperactivity, who may experience difficulties coordinating movements and developing fine and gross motor skills [16]. A structured motor protocol can improve coordination, balance, and overall motor control. Improving the management of impulsiveness through physical exercise and structured games helps children learn to respect rules, timing, and turn-taking. These activities also support the development of self-regulation by promoting control over impulsive behaviors. Physical exercise may enhance attention span and memory while stimulating neuroplasticity. A well-designed and targeted motor protocol can promote greater concentration, even during school activities [17].

Methodology

Integrating physical exercise into teaching strategies for children, particularly those with hyperactivity, may significantly improve learning outcomes and classroom behavior [18]. The combined movement-and-teaching approach allows children to harness their need for movement while enhancing their ability to concentrate. The protocol we propose includes two main components, each focused on improving specific aspects of children's behavior and learning. These components aim to help channel excess energy, improve concentration, reduce impulsivity, and promote emotional self-regulation [19]. Specifically, the first component involves physical exercises that stimulate motor coordination and behavior regulation. These exercises may improve self-control and help manage impulsive behaviors. The second component consists of movement strategies designed to enhance concentration and self-regulation, thereby promoting emotional self-regulation and increasing attention span.

Integrating Physical Exercise into Pedagogical Strategies with “Active Breaks”

Integrating physical exercise into pedagogical strategies through active breaks can be a highly effective method to improve learning, concentration, and students' psychophysiological well-being.

Active breaks, or short periods during which a sedentary activity is interrupted to perform light but purposeful physical activity that stimulates both body and mind. These breaks may serve as pedagogical tools to increase student engagement, enhance attention, and promote positive classroom behavior [20].

Practical Example: Strategic “Active Breaks” during homework

Imagine a classroom or home environment where children with ADHD are completing homework. The teacher or parent introduces the concept of “active breaks,” short periods dedicated to physical activity. These breaks are specifically designed to improve concentration and reduce restlessness. This approach may be implemented as follows.

Breaking tasks into blocks: Tasks are divided into 15-20 minute segments. After each block, the child takes a 5-minute active break.

Type of motor activity: Active breaks may include exercises that stimulate the vestibular system and increase alertness. Examples include jumping jacks, short runs along a defined path, ball games, or light obstacle courses. These exercises can help release excess energy and refocus attention.

Calm-down activities: After more intense exercises, a brief period of deep breathing or light stretching can help promote calm and prepare for the next study cycle.

Monitoring and adaptation: Each child can select from a range of activities during breaks, allowing the intervention to be tailored to their needs and interests. This personalization may increase motivation and engagement. Progress can be monitored through a diary or a shared feedback sheet among therapists, teachers, and parents.

Practical Exercise Examples

Coordinated Jumps

Equipment: Hoops on the floor or circles drawn with chalk.

Activity: Children are instructed to jump from one hoop to another, following a predetermined path. Variations may include hopping on one foot, performing two consecutive jumps within one hoop and one in the next, or jumping laterally.

Objective: To foster concentration, strengthen self-regulation through brief structured physical activities, and enhance motor coordination and attentional control by requiring the execution of precisely sequenced movements.

Pedagogical objective: This activity not only supports students' physical and psychophysiological well-being but also contributes to improved academic performance and enhanced learning quality. When structured physical activities are systematically integrated into the educational curriculum, students may benefit from increased energy levels, sustained attention, intrinsic motivation, and improved peer interaction, thereby fostering a more stimulating and productive learning environment [20].

Ball Throwing and Catching

Equipment: Soft or foam balls

Activity: Children perform the activity in pairs or individually against a wall. The child throws the ball and catches it. The type of

throw can be varied (two-handed, one-handed, high, or low throws).

Objective: To improve hand-eye coordination and concentration. Gradually increase the complexity of the motor task to maintain engagement.

Pedagogical objective: This activity aims to improve attention span and task endurance while keeping children highly engaged. When integrated into the routine as an active break, it helps children with ADHD manage hyperactivity and sustain concentration [21].

Exercise Integration and Mind-Body Techniques Combination

The concept of "mind-body" refers to the connection between cognitive processes and physical well-being. The relationship between mind and body is a fundamental topic in many disciplines, including psychology, medicine, philosophy, and neuroscience. It is widely recognized that mental and physical health are closely interconnected: thoughts, emotions, and psychological experiences influence physical health, and vice versa.

The mind-body connection is particularly relevant in the treatment and management of ADHD [22]. Since ADHD primarily affects attention, self-control, and information processing, integrating strategies that engage both mind and body may be highly effective for improving symptoms and promoting better functioning across contexts. One possible example is "mindful movement" for academic tasks. This approach combines physical exercise with mindfulness practices, such as yoga or Tai Chi, to help children with ADHD develop greater awareness of their bodies and emotions. These activities can promote a balance between physical activation and mental regulation.

"Mindful Movement" routine

Before starting homework, the child participates in a short, 10–15-minute mindful movement session. This session may include the following components:

- Simple yoga poses: Such as Child's Pose (Balasana), Downward-Facing Dog (Adho Mukha Svanasana), and Tree Pose (Vrksasana), which combine balance, strength, and breath awareness [23].

- Breathing and coordination exercises: While holding yoga poses, children are guided to focus on their breathing, following a slow, deep rhythm. The teacher or parent may guide a count of four seconds for inhalation and four seconds for exhalation.
- Slow and controlled transitions: Exercises such as Tai Chi or slow stretching movements, in which the child moves deliberately from one pose to the next. The focus is on maintaining balance and sensing each movement.
- Visualization exercises: During these movements, the teacher may guide a brief visualization. For example, children imagine themselves as a tree rooted in the earth for stability, yet gently swaying in the wind for flexibility. This approach helps children connect with their bodies and achieve calm.
- Conclusion with a “resting pose”: After the active and mindful movements, children conclude with a brief relaxation period in Savasana (corpse pose), focusing on their breathing and releasing tension [24].

Practical example of exercise

Start: Breathing exercises or light stretching (2-3 minutes).

Activity: After completing the circuit once, it is important to include an active break to recover. During the break, children can perform deep-breathing exercises (e.g., inhale for 4 seconds, hold for 4 seconds, and exhale for 4 seconds) or light stretching exercises.

Objective: To promote relaxation and emotional self-regulation, preparing children to resume their routine or engage in new activities.

Pedagogical objective: This approach supports the development of self-regulation and body awareness, may reduce stress, and may improve concentration and homework management. Mind-body techniques can provide children with practical tools to manage hyperactivity, impulsivity, and anxiety, making learning a more balanced and calm experience.

These examples demonstrate how physical exercise and mindfulness techniques can be creatively integrated into educational settings to support children with ADHD during homework [25].

Below is a summary table comparing the activities of the active break protocol and the mind-body approach for children with ADHD. Both protocols aim to enhance concentration, self-control, and psychophysiological well-being, but they employ different methods to achieve these outcomes.

Both modalities can be combined to create a pedagogical program that may enhance not only learning but also the child’s overall psychophysiological well-being. Active breaks emphasize short physical activities, providing a quick “reset” that can improve concentration, energy levels, and behavioral regulation in children with ADHD. The mind-body approach focuses on the integration of mind and body. It can support children in developing self-awareness, reducing stress, and promoting more balanced emotional and energy regulation [26].

EXPECTED OUTCOMES AND DISCUSSION

The implementation of physical activity for educational purposes in hyperactive children, including those with Attention-Deficit/Hyperactivity Disorder (ADHD), may lead to significant outcomes across multiple domains. Applying the protocol can be expected to result in:

- Improved attention and concentration: Regular physical activity may enhance children’s ability to maintain focus for longer periods, both in school and daily life.
- Reduction in impulsive and hyperactive behavior: Physical activity may help decrease excessively impulsive or hyperactive behaviors, supporting improved bodily and emotional self-regulation.
- Enhanced social skills: Through group games and structured activities, children may develop better peer interaction, cooperation, respect for rules, and conflict management skills.
- Increased motivation and well-being: Physical activity stimulates endorphin production, which may improve and reduce anxiety, potentially enhancing motivation in academic and social contexts.
- Improved motor skills: Alongside behavioral benefits, physical activity may enhance motor coordination, balance, and the development of fine and gross motor skills.
- Integration and inclusion: Group-based physical activity can promote social integration of children with ADHD, reducing potential exclusion and supporting inclusive educational environments [26].

This study supports the notion that physical activity provides not only physiological benefits but also educational and behavioral advantages. Movement can become a powerful tool to enhance learning outcomes and psychophysiological well-being in children with ADHD.

In summary, structured physical activity represents a highly promising educational

Table 1. Overview of the activities included in the active break protocol and the mind–body approach for children with ADHD.

PROTOCOLS/ ACTIVITIES	ACTIVE BREAKS	MIND-BODY
Main objective	Promote concentration and improve self-regulation through brief structured physical activities.	Promote mind-body integration by enhancing emotional regulation, body awareness, and stress management.
Duration	Approximately 5 minutes of physical activity, distributed throughout learning sessions.	Longer sessions, generally lasting 10 to 15 minutes and typically implemented prior to learning activities.
Type of activity	Brief, dynamic exercises such as jumping, walking, throwing a ball, and motor activities designed to stimulate energy levels.	Techniques combining slow, controlled movements with breathing and focused awareness, such as yoga, stretching, and meditation.
Methodology	Structured active breaks that promote physical movement as a form of cognitive “reset”.	Relaxation and mindful movement techniques, such as tai chi or guided breathing, to improve mind-body balance.
Tools used	Minimal equipment, such as free space in the classroom and small materials like balls or hoops.	Yoga mats, calming music, meditation guides or images to support relaxation and attentional focus.
Benefits used	Facilitates the release of excess energy, thereby improving concentration and reducing impulsivity.	Enhances body awareness and emotional regulation, contributing to reduced anxiety and improved self-regulation.
Psychological impact	May stimulate endorphin production, contributing to improved mood, reduced stress, and increased classroom engagement.	Reduces anxiety, supports emotional regulation and promotes inner calm and sustained self-regulation.

intervention for managing and supporting children with ADHD. It may improve both quality of life and academic achievement.

CONCLUSIONS

Physical exercise constitutes a valuable educational resource for supporting the development and learning of children and adolescents with ADHD. Incorporating targeted physical activities into school and family routines may improve attention, self-control, and executive functioning, while fostering social skills such as collaboration and respect for rules. Through structured exercise, children with ADHD can learn to manage energy and impulsivity in positive ways, transforming potentially disruptive behaviors into opportunities for active learning. Educators and fami-

lies may integrate physical activity into daily routines as a supportive tool to strengthen self-esteem, resilience, and a sense of belonging, leveraging each child’s strengths. Physical activity can help release excess energy constructively, reduce hyperactive and impulsive behaviors, and improve attention management and motor control. Therefore, promoting the inclusion of physical exercise in educational programs not only strengthens cognitive and behavioral skills but also represents a holistic pedagogical approach. This approach considers the individual as a whole, encouraging balanced development and addressing each student’s specific needs with ADHD.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

AUTHORS' CONTRIBUTION

Lorena Vincenza Perrone: Conceptualization; Writing – original draft (abstract, study hypothesis); Writing – review & editing; Supervision; Integration of techniques and strategies. Antonietta Gambino: Writing – original draft (introduction; neuropsychomotricity; psychomotor treatment); Investigation. Giulia Imperiale: Methodology; Writing – original draft (pedagogical strategies); Formal analysis. Gaia Vangelista: Methodology; Writing – original draft (pedagogical strategies); Formal analysis. All authors have read and agreed to the published version of the manuscript.

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