BORN TO LEARN: NEUROSCIENCE AND EDUCATION IN DIALOGUE TO OVERCOME SPECIFIC LEARNING DISABILITIES

NATI PER APPRENDERE: NEUROSCIENZE ED EDUCAZIONE IN DIALOGO PER SUPERARE I DISTURBI SPECIFICI DI APPRENDIMENTO

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ABSTRACT

Can students with specific learning disabilities (SLD) benefit from the perspective of neuroscience in addressing challenges both inside and outside the classroom?
While pedagogy cannot fragment and multiply for each student in a classroom, it must channel its efforts towards the development of cognitive and emotional functions for all learners (Damiani et al., 2015).
A constructive dialogue between pedagogy and neuroscience can contribute to the development of inclusive teaching and the creation of a supportive environment that promotes the appreciation of the unique-diverse nature of individuals. The objective of this paper is to reflect on the opportunities offered by neuroscience to education to enhance the overall learning experience for all students, particularly those with SLD, thereby avoiding trauma from failure or the development of psychopathologies.

Gli studenti con disturbi specifici di apprendimento (DSA) possono trarre beneficio dalla prospettiva delle neuroscienze per affrontare le sfide in classe e fuori dalla classe?
La didattica, pur non potendosi frantumare e moltiplicare per il numero di allievi presenti in una classe, deve dirigere i suoi sforzi verso lo sviluppo delle funzioni cognitive ed emotive di tutti i discenti (Damiani et al., 2015).
Un costruttivo dialogo tra pedagogia e neuroscienze può contribuire allo sviluppo di una didattica inclusiva e alla creazione di un ambiente favorevole che promuova la valorizzazione dell'unicità-diversità delle persone. L'obiettivo del presente paper è una riflessione circa le opportunità offerte dalle neuroscienze alla didattica per migliorare l'apprendimento in generale di tutti gli studenti e in particolare di quelli con DSA, evitando traumi da fallimento o sviluppo di psicopatologie.

KEYWORDS
neuroscience, SLD, neuroeducation, Embodied Cognitive Science
neuroscienze, DSA, neurodidattica, cognizione incarnata

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Introduction

The process of acquiring reading, writing, and mathematical skills unfolds gradually and follows distinct phases. In the case of Specific Learning Disabilities (SLD), which are primarily categorized into four types, dyslexia, dysorthographia, dysgraphia, and dyscalculia, difficulties in reading, writing, and calculation manifest during the developmental age when these skills, for most children, become automated and require low concentration. The specificity of these disorders lies in the fact that they affect only certain learning abilities (reading, writing, calculation) and present comorbidities both within SLD (dysorthographia, dyscalculia, dyslexia) and with other neuropsychiatric disorders (behavioral disorders, anxiety disorders, mood disorders, ADHD). These conditions cannot be classified as pathologies but fall under the category of *neurodiversity*. The encountered difficulties do not stem from a low intelligence quotient, as evidenced by cases where individuals with SLD have IQs even above average[1]; this is exemplified by the fact that Albert Einstein and Leonardo da Vinci were dyslexic. Rather, the challenges arise from a different mode of learning that pedagogy often impedes rather than nurtures, failing to bring forth potentials and talents (Wolf, 2008).
Neuroscientific discoveries regarding brain plasticity, mirror neurons, the significant role of emotions in decision-making processes (Damasio, 1995), the synergistic link between body and brain in learning, and finally, the overcoming of the dichotomy between rationality and emotionality, open new horizons in the field of education. Pedagogy, tasked with designing actions for change and innovation aimed at addressing the educational needs of students by improving learning processes and psychophysical well-being, could gain greater efficacy if the insights into brain function provided by neuroimaging techniques were applied in educational contexts, fostering a dialogue with neuroscience.

Just as pedagogy can learn from neuroscience, neuroscience can learn from pedagogy, involving teachers in defining the research agenda of neuroscience (Geake, 2009, p.27, cited in Rivoltella, 2012, p. 45).

Evaluating the effectiveness of teaching and learning is a crucial moment for enhancing the quality of education and the methods employed, especially when educational institutions face significant challenges such as learning difficulties, aiming to promote the harmonious growth and development of individuals. It is crucial, in this regard, to focus on adequate teacher training in the use of

[1] Some studies demonstrate a higher prevalence of *gifted* individuals among those with SLD (Toffalini et al., 2017).

compensatory tools and in identifying students' difficulties, ensuring that specific interventions are implemented early on to reduce them (Stella, 2010).
In the field of education, research based on feedback from teachers and students is underutilized or nonexistent. This stands in contrast to most businesses that assess the quality of products or services through customer experiences and use them for improvement.
In today's knowledge society, lifelong learning is considered a fundamental and indispensable aspect of individuals' lives, born to learn. Inadequate learning during the educational journey risks compromising the professional and personal development of individuals in adulthood (Reffieuna, 2011).
Deepening knowledge about the processes through which the mind learns, overcoming "distrust or lack of confidence in the results of psychological and neuropsychological research means, for school professionals, building a school and teaching environment friendly to dyslexics so that no intelligence goes to waste" (Damiani, 2012, p.368-369).

Improving student learning by transferring research findings into educational practices requires collaboration between researchers and teachers. This becomes even more crucial when addressing learning difficulties, posing the risk of leaving someone behind (Fischer, 2009). At the end of the 20th century, the *Mind, Brain, and Education movement* emerged almost simultaneously in Paris, Tokyo, Cambridge, and Harvard. This movement asserts that "effective teaching cannot ignore a deep understanding of the brain processes underlying learning (Trinchero, 2015, p.53)" and aims to enhance knowledge of learning and teaching processes through equal collaboration between neuroscience research and educational institutions. The brain-based approach to pedagogy, connecting neuroscience and education, starts from the idea that effective learning arises from the brain's ability to transform itself when learning.

The human brain exhibits plasticity throughout the entire lifespan, undergoing a series of changes influenced by what is learned. These changes can underlie an increase in intelligence, defined as the capacity to respond effectively and efficiently to stimuli requiring the interpretation of a situation, decision-making, subsequent action, reflection on one's interpretations and actions, and their alteration when necessary (Ibidem).

Learning and research programs designed for teachers and researchers inspired by neuroscience consider knowledge as a process that is actively constructed (Singer, 1995) through relationships with the world, in line with Piaget's cognitive theory, in which cognitive development is an active process of adaptation to information and experiences in the world that are progressively acquired.

We are, therefore, facing a predominantly educational process (engagement and action toward an external environment) not linked to the mere spontaneous maturation of internal structures. Without external stimuli, the brain does not develop (Capurso, 2015, p.51).

In Italy, significant impetus toward the affirmation of bioeducational sciences and the overcoming of *biological reductionism* has been provided by the research work of Elisa Frauenfelder and Flavia Santoianni[2].

The interaction between education and neuroscience is feasible and offers various opportunities for development in training, monitoring, and comparing the effects of different teaching models on learning. It extends to a generalized attention to individual differences in learning and how to address them, a focus that can become specific in approaching special educational needs (Santoianni, 2019, p. 47).

1. Pedagogically Effective Learning Environments for Students with SLD

In Italy, students with Specific Learning Disabilities (SLD) are protected by Law 170/2010, and their well-being at school should be supported by compensatory tools and dispensatory measures adopted in the Individualized Educational Plan (IEP). However, despite the extreme variability in how these disorders manifest, the IEP is often applied in a generic and inappropriate manner, disregarding the actual educational needs of students. There is a risk of emphasizing the difficulties of these students when, for example, teachers demand performances that they cannot execute. Such situations create frustration, decrease self-efficacy, and increase the discomfort of these students, who may reject schooling due to feeling different from their classmates.

The Individualized Plan, which should serve as both a logbook and a witness to a teacher's research process regarding strategies that protect the student's right to learn, enhance their resources, and discover their specific learning methods, often becomes a legal tool or imposition of poorly personalized measures. Importantly, it

[2] Professor Santoianni is the director of a research laboratory, the BEC Lab, at the University of Naples Federico II, and also oversees a journal established in 2014, Research Trends in Humanities (RTH), which includes a section dedicated to bioeducational sciences.

is not accepted by the student, who is not involved in this challenging research process (Lampugnani, 2017, pp. 371-372).

Emotional-relational components play a crucial role in both the personal well-being and educational success of students with SLD, as demonstrated by numerous studies (Buonomo et al., 2017; Maughan & Carroll, 2006; Lackaye et al., 2006), describing their difficulties in adapting to school environments, low self-esteem, and confidence in their abilities.
While identifying the clinical aspects of SLD is crucial for recognizing and defining the presence, specificity, and severity of the disorder, such as dyslexia or dyscalculia, other aspects, such as emotional difficulties and problems in social skills, also need attention. These, although involving a different domain, ultimately impact the learning sphere (Molisso et al., 2019, p. 47).

Neuroscientific studies demonstrate an interaction between emotions and rational learning. Negative emotions, such as fear, hinder or impede learning in general for all students. However, students with SLD are more exposed to a sense of inadequacy and a more pronounced predisposition to depression (Maughan et al., 2003). The educational success of students is influenced not only by biological aspects but also by environmental factors (Calder et al., 2000; Zeman et al., 2006). A study conducted in schools in Leon, Spain (Garcia & De Caso, 2004), showed that students with writing-related SLD who simultaneously followed a course of writing lessons and a motivational program achieved better results than those who exclusively attended the writing course. This highlights the need to create inclusive, empowering, and motivating learning environments that do not generate stress, anxiety (Nelson & Harwood, 2013), and learned helplessness behaviors among students with SLD. The individual in learning environments must be considered in "all the dimensions that constitute them: social, cognitive, emotional, but also biological" (Reffieuna, 2011, p.10).
Learning techniques to regulate one's emotions through cognitive processing, especially when negative emotions like frustration, anger, fear, and sadness are involved, can be very useful, especially for students with SLD (Fischer & Bidell, 2006), to address challenges both inside and outside the classroom.
An interesting testimony regarding the adoption of methodologies and teaching practices inspired by neuroscientific discoveries comes from the Westmark private school in California, which caters to children and adolescents from the second to the twelfth grade with SLD. The curricular design, starting from the concept of neuroplasticity as the possibility of adaptation and structural change in the brain in

response to received stimuli, offers students activities that promote the creation of new neural circuits. This stems from the understanding that

if brain plasticity does not cease, childhood and adolescence are extensive periods of brain plasticity where learning can mature, periods of particular cognitive sensitivity where ideas and judgments can mature and configure very quickly (Minello, 2020, p.33).

Implementing effective and early teaching interventions on basic skills in school-aged students with SLD, modifying the brain's structure through the creation, enhancement, and elimination of existing synapses, profoundly influences both the future development of cognitive functions and the "construction of healthy identities and personalities" (Damiani, 2012, p.375).

To meet the specific needs of students with SLD, the California school has adopted teaching and learning models that leverage multiple sensory channels. An example is the production of a news program, the Westmark News Network, to which students can contribute in their preferred way: videos, texts, images, or sounds. Following a news program that uses visual, auditory, and tactile stimuli simultaneously facilitates faster information processing compared to written pages and improves the learning of students with SLD (Nijakowska, 2008) by creating stronger connections between information and the brain.

Thematic and integrated teaching allows the development of knowledge previously acquired by students. The integration of disciplines such as mathematics, literature, and social studies through cooking lessons, home economics, or sewing workshops is functional for acquiring and consolidating skills such as comparison and measurement between magnitudes. The assessment process occurs through multiple modalities, prioritizing those that allow students to better express their skills. The serene and non-competitive relational climate created during these activities, respectful of different cognitive styles and learning rhythms, also contributes to improving the cognitive level of students, making them resilient and capable of facing increasingly important challenges (Wagmeister & Shifrin, 2000). According to Caine & Caine (1994), while challenges develop learning, threats hinder it.

The opportunity to achieve educational success is also linked to the acquisition of the ability to manage failure and control one's anxiety and attention, especially when interaction occurs in highly competitive learning environments.

The technologies of Universal Design for Learning (UDL), widely adopted in the United States, have been designed based on the results of neuroscientific research on learning and cognitive processes to overcome differences in student learning

and the difficulties associated with them. These are complex processes that occur through the interconnection of three neural networks: the recognition network, the strategic network, and the affective network (Rose & Strangeman, 2007). The recognition network receives information from the sensory sphere and transforms it into knowledge, defining the object of knowledge. The strategic network concerns the mode of learning and the goals intended to be achieved, while the affective network involves the emotional factors that motivate learning.
The differences in students' learning are central to the UDL curricular approach, which uses digital tools to replace textbooks, creating innovative learning environments and stimulating the three neural networks whose interconnection makes meaningful learning possible. The main characteristic of UDL information technologies concerns the content and its mode of use, which varies according to the needs of the students. The use of speech synthesis, the ability to change the format or language of the text, and integrate it with hypertext links suggest its extreme adaptability and accessibility for students with learning disabilities (DSA). UDL technologies also provide personalized support to students in difficulty through feedback messages, a virtual tutor, or a help page, making the learning experience extremely interactive.
However, it is important to specify that the use of educational technologies cannot improve the quality of learning for students with DSA if it falls within the scope of obsolete and inadequate methodologies and teaching methods. The validity of UDL lies in having developed personalized and flexible teaching strategies that guarantee all students the possibility of achieving a common goal using different tools and skills.

2. **Embodied Cognitive Science and SLD**

The application of neuroscientific discoveries and knowledge to teaching has high innovative potential for schools characterized, as Damiani et al. (2015) state, increasingly by the complexity and special educational needs of its classes. It is necessary, therefore,

to rethink teaching in terms of the best possible teaching. The best teaching is good teaching that can reach the most fragile student while simultaneously enhancing the more capable student (Damiani et al., 2015, p. 85).

In general, neuroscientific knowledge suggests that to achieve educational success, one must focus on a real task.

It is necessary, therefore, to minimize passive listening and the uncertain memorization of abstract conceptual representations and to invest in the pragmatic experimentation of knowledge through lived experience (Gomez Paloma et al., 2015 p.159).

Embodied Cognitive Science (ECS), an interdisciplinary field (neuroscience, philosophy), surpassing the Cartesian mind-body dualism, is based on the idea that the body plays an active role in the learning process and that even the most abstract knowledge originates from the processing of bodily experiences. "Cognitive processes depend on the sensory-motor system, and the consequence is that the central role of the body has allowed it to be understood as an additional resource for task resolution, so that the subject does not make his mind the only tool of action" (Pastena et al., 2015, p.264).

ECS represents a valid paradigm for programming specific educational interventions that, by valuing corporeality, limit the impact of DSA on learning, well-being, and the realization of personal life projects.

Mirror neurons, an important neuroscientific discovery of the 1990s, activate when performing an action or observing someone perform an action, allowing for the mental simulation of that action. According to Rizzolatti (2010), the Italian neuroscientist whose name is associated with the discovery of mirror neurons, "basic actions such as observing others, imitating them, repeating essential gestures many times, constitute the foundation of learning and socialization processes (Damiani et al., 2013, pp.1214-1215)." This neural mechanism through learning by imitation can facilitate the acquisition of new skills and promote school inclusion. Simple repeated movements or object manipulation can enhance learning; words do not tell the whole story.

A recent study (Lodi et al., 2018) illustrates how an experimental group of students using finger counting as support for solving math exercises or mimicking the gestures of an experimenter to solve problems achieved better results in exercises than the control group that did not use such strategies. The acquisition and improvement of calculation skills, therefore, derive greater benefits from finger counting than from the use of calculators, which are often chosen by teachers as a compensatory tool for students with dyscalculia.

According to the study, which also investigates the effects of motor activity aimed at learning in students with SLD, there are

analogies between linguistic and motor skills. Speaking involves body movement, reading uses visuo-motor coordination, moving is designing an action in the form of a sequential organization, so it seems plausible that similar procedural functions can improve the ability to tackle linguistic or mathematical tasks (Lodi et al., 2018, p.337).

It is possible, therefore, to prevent and counteract the functional effects of SLD through motor activities that activate

the skills that are prerequisites for reading-writing processes and mathematical operations, activating different brain districts that, in turn, induce the birth of new neural connections Lodi et al., p.336).

Students with SLD (8-13 years) who underwent a targeted training program with stimulation achieved significant improvements in reading, writing, and calculation skills after 5 months. This demonstrates that "learning difficulties are intrinsically linked to praxic-motor disorganization (Ivi p.338)." Often, SLD is accompanied by problems in the motor area and can be successfully addressed through the practice of appropriate exercises and play-sports activities.

Conclusions

The importance of creating a space for reflection and comparison between neuroscience and pedagogy arises from the dual need to apply and experiment with neuroscientific discoveries in educational contexts to avoid them remaining mere "theoretical knowledge accumulated in laboratories (Damiani, 2012, p.369)" and to promote innovation in schools, which must be guided by teachers through the design of appropriate educational interventions for all students, with particular attention to students with SLD.

The connection between neuroscience research and teaching practice can be fruitful using various tools and strategies such as the design of specific teaching materials and educational software, the production of television broadcasts, the use of educational robotics (Damiani et al., 2013), sports practice, creative workshops of manual activities, or games-based learning. Competences, according to the theory of skills (Fischer et al., 2007), can be acquired through countless and diversified modalities. The important thing is to create pedagogically effective learning environments that adapt to different learning styles and student needs through diverse approaches to knowledge and activities and paths that produce multisensory stimuli.

The use of educational technologies and software does not guarantee adequate learning for all students if it is not characterized by flexible and customizable curricula that provide students with different and alternative ways to acquire

knowledge and languages and that offer support in moments of difficulty by involving and motivating students in learning.
Emotions and feelings stimulate the body and mind to learn, and, together with the social and cultural contexts in which people are situated and with which they confront, influence decision-making processes (Immordino-Yang, 2011) regarding action and thought. The educational success of students with SLD is influenced, in particular, by the psycho-emotional aspects and the relational climate of learning environments. It is therefore essential that they convey trust and security while respecting diversities.
Learning processes, according to the discoveries and knowledge of neuroscience, are dynamic and develop gradually. Therefore, to improve them, it is important to focus attention on the progress and learning needs of students. Limiting assessment to final performances does not favor the development of metacognitive skills.
Regularly conducting formative assessment allows students to improve, and teachers to monitor their progress and difficulties to plan targeted interventions using the most suitable teaching strategies and methods (OECD, 2005). The assessment process must also be compatible with the difficulties associated with DSA and occur in ways through which the student with SLD expresses their competences best.
A significant role falls to the in-service professional development of teachers, which, if successful in integrating neuroscience into teaching, would manage to step into

those areas traditionally left uncovered by teacher training paths and ordinary teaching practices (body and emotions). These areas constitute key aspects of human development and, at the same time, essential prerequisites for school learning. The goal is to highlight relationships and build bridges between the evolutionary dimension and the didactic dimension, in a continuous interconnection between research, teaching, and innovation (Damiani et al., 2015, p.85).
It is, therefore, important that school professionals, despite being burdened by an increasing and complex workload, in the face of limited social and economic recognition of their role, commit to planning flexible teaching paths and innovative methodologies that promote the growth and maturation of students, leveraging the contributions of neuroscientific discoveries and transdisciplinary dialogue. This involves overcoming the “historical subordination of schools to medical and psychological paradigms (Damiani, 2012, p.369)”. The challenge ahead is complex and requires reconciling neuroscientific discoveries with established pedagogical

theories and educational practices to assess their impact on learning and teaching processes. However, it is an essential step to ensure that the inclusivity of the Italian school system does not remain a utopia and that individuals with SLD are not at risk of social exclusion but can bring out and valorize their own potential and talents, much like Einstein and Leonardo da Vinci.

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