NEUROEDUCATION AND LEARNING: TOWARDS AN INCLUSIVE AND FLEXIBLE TEACHING MODEL

NEUROEDUCAZIONE E APPRENDIMENTO: VERSO UN MODELLO DIDATTICO INCLUSIVO E FLESSIBILE

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ABSTRACT
Neuroscience studies brain processes involved in learning. Neuroeducation combines cognitive neuroscience, psychology, and educational practices to foster meaningful learning. This paper explores the link between educational and neuroscientific paradigms, highlighting Universal Design for Learning as a flexible, inclusive teaching model aligned with neuroscientific principles and special educational needs.

La neuroeducazione unisce neuroscienze cognitive, psicologia e didattica per analizzare i meccanismi dell'apprendimento. Il contributo esplora il rapporto tra paradigma educativo e neuroscientifico, attraverso le principali teorie di riferimento. L'Universal Design for Learning è proposto come modello di progettazione didattica flessibile e inclusiva, coerente con i principi neuroscientifici e i bisogni educativi.

KEYWORDS
Neuroeducation; learning; Universal Design of Learning
Neuroeducazione, apprendimento, Progettazione Universale per l'Apprendimento

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Introduction

Educational sciences, which have always been committed to defining effective strategies to promote learning, are progressively enriching themselves with the contribution of neuroscience, which proposes new interpretative and applicative models of cognitive and emotional processes, which are the basis of knowledge acquisition.

Recent acquisitions in the neuroscientific field are significantly redefining the understanding of the mechanisms that regulate learning, providing a more complex, dynamic and integrated vision (Frauenfelder, 2011). This approach allows us to overcome exclusively behaviourist or cognitivist perspectives, orienting pedagogical reflection towards greater attention to the neurobiological and affective dimension of the learning process (Immordino-Yang & Damasio, 2007; Tokuhama-Espinosa, 2011).

In this scenario, the synergy between educational sciences and neurosciences is configured as a fertile ground for the development of innovative teaching practices, based on scientific evidence, capable of responding to contemporary educational challenges. Neurosciences are profoundly transforming the understanding of learning processes, offering an innovative perspective on how the human brain structures and restructures its neural networks in response to environmental stimuli. The evidence emerging from the reference literature highlights the plastic nature of the brain, underlining how learning is the result of a constant neurobiological adaptation influenced by the interaction between experience, context and mental activity (Goswami, 2004; Dehaene, 2020). This new theoretical framework not only broadens the knowledge of the mechanisms underlying the acquisition of skills but also offers important implications for the design of more effective, inclusive and personalized educational environments. Neuroscience therefore offers a valuable perspective for training processes, becoming a necessary support for the design of effective and efficient educational interventions.

In this context, the Universal Design of Learning (UDL) design fits perfectly, a proactive psycho-pedagogical model that proposes educational personalization through a flexible approach, adequately responding to the neuroplasticity of the human brain, «according to the UDL model, flexibility is the factor that allows teachers and educators to adapt to the natural variability of their students and their learning preferences» (Baldassarre & Sasanelli, 2021, p. 161). Mitchell and

Sutherland (2014) consider UDL a construct that goes well beyond the concept of a mere strategy, defining it as a framework because it is able to integrate multiple components simultaneously and, thanks to its flexible nature, deal with the different aspects of the educational process

1. Brain, environment and learning: towards an integrated model

The beginning of the dialogue between pedagogy and biology, which has progressively taken the form of a comparison between pedagogy and neuroscience, until it merged into the recent constitution of bioeducational sciences, arises from the attempt to promote a broader narrative of the relationship between nature and culture (Frauenfelder, 2011). This new vision takes shape when it is understood that it is essential to overcome every form of simplification: it is no longer possible to believe that the human being is only a product of biology or only of education, «the conviction of a necessary broadening of the interpretation of this relationship matures, which can no longer be understood as a crude reductivism as an alternative to an equally crude culturalism» (p. 7). The new perspective that is being defined, of bioeducational sciences, seeks to go beyond this dualism in favour of an integration between what is biological and what is educational-environmental.

The new research field intends human learning in a more articulated and integrated way, considering the biological modifiability and therefore the plasticity of the brain on the one hand, and environmental variability, that is, the differences in educational, cultural and social contexts, on the other. The construct of individual potential and learning that derives from it is therefore affected by the quality of this relationship, which takes place within an ever-changing and dynamic system, «consequently, new investigative paths are identified that are able to bring together two worlds traditionally considered distinct; so that the research work in each of the two sides tries to bring together, through a complex, systemic and interactive epistemological vision, interpretative dispositions that integrate different perspectives in the approach to thematic nuclei that are in some way shareable» (p.8). In this theoretical framework, the need to deepen the biological foundations of learning becomes increasingly evident; the brain system, as a fundamental structure underlying every cognitive and behavioural activity, represents the essential condition for understanding educational mechanisms (Immordino-Yang, 2016), consequently, the study of its morphological and functional characteristics assumes a central role in training models oriented towards mind-environment integration. Neural plasticity, or the brain's ability to modify its synaptic connections in response to external stimuli and significant experiences, is an essential biological property to explain the dynamics of behavioural change (Doidge, 2007; Kolb & Gibb, 2011). It represents the biological foundation of learning, making it possible for individuals to continuously adapt to educational and social contexts. Understanding the mechanisms that regulate plasticity not only allows us to build a more solid basis for pedagogical intervention but also opens new perspectives for educational planning aimed at personalizing training paths, respecting individual differences and the evolutionary potential of everyone (Tokuhama-Espinosa, 2010).

In this perspective, pedagogy is called to dialogue with neuroscience to build shared knowledge, capable of interpreting in a systemic and integrated way the relationships between brain structure, learning environment and skills development (Fischer, Goswami & Geake, 2010).

As Penrose (1992) highlights, the brain is not a static and immutable structure, but a dynamic system in which the connections between neurons, called synapses, are in continuous evolution. The emergence of the concept of brain plasticity has profoundly transformed the traditional vision of the brain, overcoming the idea that it represents a static and definitively structured organ; it is not a crystallized and immutable system, on the contrary, it is configured as a dynamic and adaptable structure, capable of reorganizing itself in response to environmental stimuli, learning and experiences lived by the individual throughout his or her life (Merzenich, 2013).

Neuroscience has highlighted how the neural system remains open to transformations since it is constantly subject to modulations and reconfigurations induced by both external factors and the organism's internal potential. Significant educational experiences, social relationships, cultural contexts and cognitive stimuli activate neural circuits that can be strengthened, restructured or even created ex novo (Draganski et al., 2006; Kolb & Gibb, 2009). This vision offers important implications on the pedagogical side, as it questions the idea that educational processes are effective only within a rigid time frame, that of developmental age to be clear. On the contrary, neuroscientific evidence shows that learning can continue to generate significant changes even in the later stages of life (Ansermet & Magistretti, 2008). Education, therefore, takes on the role of a transformative lever capable of promoting the growth and reorganization of cognitive and behavioural skills, provided that it is based on intentional, contextualized and significant experiences (Tokuhama-Espinosa, 2011; Thomas, 2013). Therefore, the cognitive activity of man is not determined only by genetic heritage but also reflects the exchange that he has with the reference environment, it is within this relationship that the processes of knowledge acquisition and training of the individual are defined. Learning is the result of a non-static process, but rather of a dynamic interaction between the environment and the individual, who thanks to the neural plasticity he enjoys is able to transform what surrounds him, to this logic Plessner (2006), also traces the concept of error that man makes, considering it not as a failure, but as the product of the elasticity and malleability of the human mind.

2. Neurocentric didactis

The development of neuroscience in the last thirty years has led to a significant epistemological evolution in knowledge related to cognitive processes, evolution and the nature of the human being. All this has had a significant impact on the understanding of the neural mechanisms underlying cognitive functions that have given rise to a new descriptive model of learning, in which the central role of cerebral motor acts has been reconsidered and reformulated, paving the way for a more dynamic vision of the educational process (Longo, 2011; Olivieri, 2011; Rivoltella, 2012). Considering current knowledge, educational neuroscience can offer important contributions to learning processes. A school that consciously integrates the results of neuroscientific research into its didactic approaches can not only improve the effectiveness of teaching but also offer teachers more refined tools to understand and support the cognitive and emotional development of students. The dialogue between neuroscience and educational practice opens promising perspectives for mutual collaboration: on the one hand, neuroscientific research can guide pedagogical innovation through empirical evidence; on the other, the school environment represents a privileged context to validate and enrich such evidence, thanks to the direct and systematic observation of learning processes. It is therefore necessary to promote the inclusion of neuroscience in the school landscape, so that teaching can evolve in tune with the most recent discoveries on the functioning of the human brain (Frauenfelder & Santoianni, 2003; Goswami, 2004; Fischer, 2009; Geake, 2009). Neuroscience is expected to «contribute to improving the academic results of the most disadvantaged students, but also make education even more effective for the best, guiding everyone towards a better way of learning. It is above all towards teachers that the actual indications of this discipline are addressed. It is by teaching differently, taking advantage of a supply of more adequate teaching tools, that students will learn better and feel better at school» (Berthier, et al., 2018, p. 49).

From the neuro-cognitive research stream come today numerous contributions useful for educational processes, we mention in this contribution only two lines of address, without however any claim of exhaustiveness, referring to the numerous contributions present in the context of educational neuroscience.

A line of address that is progressively emerging is that of *brain-based learning*, or a set of teaching approaches based on evidence from neuroscience and cognitive psychology, which investigate the mechanisms through which the brain processes, stores and re-elaborates information (Trinchero, 2015). The assumption of this orientation is that truly effective didactics cannot ignore an in-depth understanding of the neurobiological processes that regulate learning. Integrating this knowledge in educational planning means promoting environments and teaching strategies that are more consistent with brain functioning, favouring the development of students' cognitive and emotional potential (Slavkin, 2004; Caine, et al., 2005). Teaching inspired by the principles of brain-based learning should, therefore, be based on these theoretical assumptions to design educational interventions capable of activating and fully enhancing the individual potential of learners. This implies the development of intentional teaching practices, oriented towards the development of cognitive and emotional skills, structured in such a way as to be consistent with the ways in which the human brain functions.

Another orientation that is being defined in recent years, which radically changes its point of view, is the *teaching brain*, which clearly no longer has as a reference the learner as in brain-based learning, but rather the educator, specifically his mind (Rodriguez, 2013; Rodriguez & Solis 2013; Rodriguez & Fitzpatrick, 2014; Rodriguez, & Mascio, 2018). In this paradigm, researchers underline how the teacher's brain can process information centered on the student, thus understanding the cognitive processes of students and what they are able to learn (Gola, 2020). Teachers can therefore use this model to guide not only what students think and know, but also what they are capable of, their potential, all this by virtue of a multiple vision that the teacher possesses: awareness of himself, of the learner, of relational interaction, of teaching practice and of the context (Rodriguez & Fitzpatrick, 2014).

The recognition of the leading role of neuroscience in educational processes requires a reinterpretation of teaching in a neurocentric way, in which knowledge of brain mechanisms becomes an essential condition for effective, conscious and inclusive teaching. However, for the principles of neurodidactics to be effectively translated into daily and sustainable practices, it is necessary to have a pedagogical model capable of integrating them in a structured and flexible way within educational planning. From this perspective, the UDL framework is configured as a privileged tool to make the theoretical assumptions of neuroeducation operational, offering a teaching system based on the concepts of flexibility, adaptability and accessibility.

3. Universal Design for Learning for Flexible Teaching

Planning[1], with the consequent adaptation of the school curriculum, can be considered as the first inclusive action in which the foundations are laid for a flexible teaching action aimed at the active participation of all students, with their diversity and differences (d'Alonzo, 2017; Cottini, 2017).

In the context of pedagogical orientations that address the issue of educational and teaching planning in an inclusive way, a systematic proposal is offered by the UDL construct, developed by the *Center for Applied Special Technology* (CAST, 2011) of the University of Northern California. UDL appears as one of the educational approaches «most capable of addressing in a stimulating way some of the greatest challenges of teaching such as the valorisation of diversity and inclusive education» (Montanari & Ruzzante, 2021, p. 72). In the Departmental Decree n. 479 of 2017 states «the framework offered by the Universal Design for Learning (UDL) […] defines useful guidelines for a "plural" teaching design, rich in strategies for learning in its various phases. The UDL can be a useful reference for the construction of the inclusive curriculum[2] so that what is necessary for some becomes useful for all» (pp. 5-6).

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[1] Planning, although considered equivalent to the term programming, presents different characteristics. «The term programming indicates a logical and rational procedure of identified intentions and subsequently pursued with the collaboration of all the operators involved in a certain public or private sector» (Marzano, 2013, p.106). If programming is the responsibility of the client and does not directly involve teachers, planning «directly involves school operators, the professionalism of teachers/trainers who, starting from the indications outlined in the programming phase, interpret and adapt them to the needs and reality of the subjects in training: therefore it has a more markedly pedagogical function and of adapting the programmatic lines and decisions to the context» (Tammaro, 2018, p.59).

[2] «The curriculum is the planning and implementation of a school educational path at class and institute level, which is usually included in a national program (conceivable both in terms of contents to be transmitted and objectives to be achieved)» (Frabboni, 1992, p. 101). The term of Anglo-Saxon origin «generally indicates the plan of educational activities

Universal Design (UD), with its related variant *Design for All*[3], is a philosophy that had its first applications in the field of urban planning and construction where, inspired by a vision of the world without barriers and obstacles, it aims to create facilitating contexts. Universal Design is a term coined by the American architect Ronald Mace in collaboration with the University of North Carolina (Mace, 1985; Story, Mace & Mueller, 1998) to designate the construct of universal design of physical environments, products and services that are without boundaries, that is, universally accessible and usable, and therefore usable by the greatest number of people, regardless of their biological, social and psychological characteristics. This philosophy has been operationalized by the Center for Universal Design (CUD) through the identification of seven principles such as: equitable use; flexibility in use; simple and intuitive use; perceptible information; tolerance for error; low physical effort; size and space for approach and use[4].

The main idea behind this movement is that it is more "convenient" to design spaces and environments by considering in advance the diversity of the people who could inhabit, live and frequent them rather than having to act later by applying adaptations to the accessibility difficulties perceived by individuals, for example with a disability (Mangiatordi, 2017). The UD movement, therefore, does not aim to solve a problem for a single individual, but starts from the observation that it is more appropriate to design buildings and objects by thinking in advance about the diversity that distinguishes each person, eliminating possible barriers before they manifest themselves as such. Universal Design emerged from the broader movement of accessibility and adaptive and assistive technology, based on the pioneering concepts of barrier-free.

This original perspective subsequently launched its challenge to education with the idea of universal learning design according to the psycho-pedagogical approach of Universal Design for Learning (UDL). This framework is based on the learning

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implemented by a school institute to achieve the educational goals established by law or by the institute itself» (Barbieri, 1997, p.2).

[3] The philosophy of Design for all, in Italian Universal Design or designing for all, proposes an inclusive model that is attentive to everyone's needs and can be applied to communication systems, environments, public services and consumer products, which the entire population can use. «Accessible design is a person-centered design, certainly not on the categorization of individuals according to the logic of one size fits all, which takes into account the needs, even unexpressed ones, and the expectations of each person, both with and without disabilities» (Montanari & Ruzzante, 2021, p. 72).

[4] For further information: http://universaldesign.ie/What-is-Universal-Design/The-7-Principles/

sciences and suggests setting up flexible educational environments, capable of adapting to individual differences, of each one (Rose, & Meyer, 2002; Rose, Meyer, & Hitchcock, 2005; Rose & Meyer, 2006; Hall, Meyer, & Rose, 2012; Calvani, 2012). The main ambition is to build educational paths that are flexible and accessible to the greatest possible number of students from the beginning, avoiding the need for later adaptations and thus ensuring equal learning opportunities (Sen, 1980; 2012).

The UDL paradigm was born in 1984 in the United States from the work of Rose and Meyer, founders of the Center for Applied Special Technology (CAST), a research organization based in Massachusetts, aimed at identifying innovative strategies, mediated by digital technologies, to support the learning of students with disabilities. Starting from the assumption that diversity is the norm, and in light of technological progress with its relative diffusion in all areas of life, CAST has broadened its horizon of investigation aiming to identify intervention actions that lead to the design of a flexible and plural educational offer, thanks to the adoption of methods, tools and strategies accessible to all students from the beginning, without the need to make changes during the educational path. The resulting psycho-pedagogical approach aims to convergently address three major challenges such as diversity, inclusive education and technology by implementing the principle of personalisation in curricular planning and eliminating any possible label (H, ADHD, SEN etc.) which in fact nullifies the concept of inclusion and universal right to education and instruction (Savia, 2015).

The inclusive teaching vision proposed by UDL reverses the perspective regarding the elements to be considered deficient in training practice: it is no longer the person who is labelled as “missing” or “different” but rather the curriculum traditionally designed with respect to an ideal of student and context, which is ineffective in «guaranteeing equal learning opportunities and understanding the real needs of students with abilities, motivations and behaviours that deviate from the average» (Iannella, 2020, p. 95).

The UDL proposes a set of key principles and guidelines useful for building educational paths that offer all individuals the same learning opportunities. The model suggests the formulation of educational objectives, methods, materials and assessments that are not calibrated on a one-size-fits-all basis. On the contrary, a flexible and personalized approach is promoted, suitable for recognizing individual needs starting from the identification of personal needs and abilities, to encourage participation, involvement and promote the learning potential of everyone. In this perspective, the goal of the school is not to transmit knowledge but, rather, to promote and support all students, regardless of the presence or absence of difficulties, in the process of growth of their knowledge and skills. In the language of the UDL, we do not speak of students with disabilities but of *disabled curricula* (CAST, 2011; Aquario, Ghedin & Pais, 2017). The reversal of perspective means that the aim is not to adapt curricula to the individual variability of a few, but to structure a curriculum that is accessible and usable by all students, with heterogeneous abilities and different backgrounds (Montesano, Carchidi & Valenti, 2019).

The theoretical principles underlying this pedagogical approach can be found in the cognitive psychology of Piaget (1967; 1977), Bloom (1956; 1957; 1986), Bruner (1967; 1987; 1992; 1996), Vygotskij (1934; 1974; 1978), as well as in the neuroscientific literature referred to in the first part of the contribution.

The "plural" teaching design proposed by UDL is based on three key teaching principles (Fig. 1):

Principle I. Provide multiple means of representation (the "what" of learning): everyone perceives and understands information differently, therefore, there is no ideal and uniform representation for all students, but it is necessary to adopt multiple forms of representation (visual, auditory, graphic, digital, etc.) that allow accessibility to knowledge.

Principle II. Provide multiple means of action and expression (the "how" of learning): each student expresses his or her knowledge in a personal way and to do so can favour various means and/or modes of expression, for example, those with linguistic difficulties may prefer written production and not oral questions and, vice versa, those with difficulties in executive functions may prefer oral questions. There is no optimal solution that is valid for all students, for this reason it is necessary to provide a range of modes of expression.

Principle III. Provide multiple means of engagement (the "why" of learning): engagement and motivation are crucial elements of learning and students differ significantly in this respect. Individual affectivity can be influenced by countless aspects: physiological, sociocultural, psychological, cognitive; there are students who prefer novelty and spontaneity, others routine patterns, or working individually and others, instead, to collaborate with classmates. There is no right or wrong way, therefore it is essential to provide multiple options for engagement (CAST, 2011).

Based on empirical evidence from educational and neuroscientific research (Rose & Meyer, 2002; Rose, Meyer & Hitchcock, 2005), the fundamental principles presented can be traced back to three different brain networks, interconnected with each other and implicated in learning processes (Ausubel, 1988; Israel, Ribuffo & Smith, 2014; Della Sala, 2016): the *recognition network* (what of learning), the *strategic network* (how of learning) and the *affective network* (why of learning).

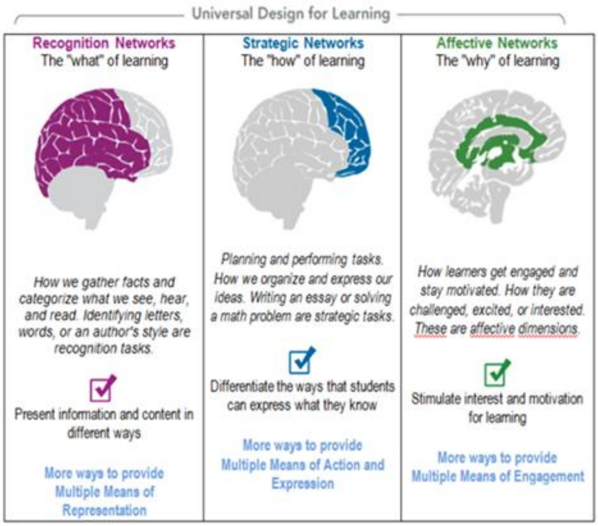

Figure 1. UDL teaching principles (Savia, 2015, p.54)

The recognition network, in the posterior area of the cortex, is activated in the processes of acquisition and first processing of information received through the senses to extrapolate its meanings. It is the network that deals with the "what of learning" and recognizing what we perceive to make it available to our memory and the other two main systems (Baldassarre & Sasanelli, 2021). The strategic network, in the frontal area of the cortex, is activated in the processes of processing and construction of knowledge, it is responsible for how we introduce information into the environment around us, allowing us to provide answers to complex problems through reasoning; this network represents the "how of learning". Finally, the affective network, in the median area of the nervous system, is implicated in emotional involvement and in the attribution of personal meaning to the information processed by learners. This network represents the "why of learning": the student's commitment that supports learning by connecting information to emotions, in accordance with the objectives to be achieved (Schoenbaum & Roesch, 2005; Mangiatordi, 2017; 2019).

Designing curricula based on UDL principles allows teachers to eliminate potential barriers to the teaching process and at the same time helps students master learning by becoming experts, that is, “well-informed and resourceful; strategic and goal-oriented; determined and motivated” students (CAST, 2011, p. 7).

The three founding principles have been operationalized and transformed into practical examples through the identification of nine Guidelines (CAST, 2011) to support teachers in their daily practice in the classroom to guide the initial planning, the choice of objectives, tools, methodologies, materials, and evaluation methods. The guidelines, starting from the recognition of the vastness of individual differences, offer a series of suggestions that can be implemented in all school subjects, to guarantee students access to knowledge and learning. Below is a detailed diagram (Fig. 2) of the Guidelines extracted from the CAST website (www.cast.org).

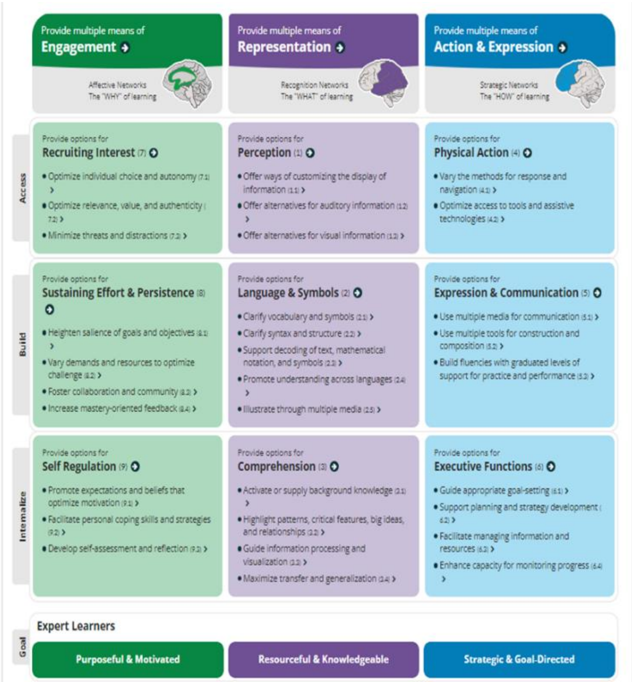

Figure 2. UDL structural model (https://udlguidelines.cast.org/)

The figure n.2 can be read in both vertical and horizontal mode. Vertically, the guidelines individually analyse the three different principles underlying the educational framework (providing multiple means of representation; providing multiple means of action and expression; providing multiple means of involvement). From a horizontal point of view, instead, the analysis of the objectives is offered with respect to the three different criteria such as access, development, and enhancement. The lower part of the figure also highlights the objectives that are set for each individual principle so that students can call themselves experts, that is, initiative-taking and motivated students, full of resources and knowledge, strategic and oriented towards educational goals.

Conclusions

The neuroscientific and design perspectives described propose arguments that are connected to some of the traits that qualify and guide teaching action: the plurality of methods and flexibility (Laneve, 2017).

For a long time now, the expansion of the social base of those who learn has made it difficult to use a single method to communicate-transmit-teach. The inadequacy of a single teaching method is attested by a typical indicator of unease and ineffectiveness of the training system: the increase in school dropout rates that reaches high percentages in the most disadvantaged territorial and social contexts. Alongside this macroscopic and quantifiable dispersion, «a less visible form of dispersion, but no less serious and worrying: the dispersion of cognitive potential» (Laneve, 2017, p. 138). In fact, many students complete their educational path with a wealth of knowledge and skills far below their own capabilities, lacking basic skills, unable to read cultural alphabets, demotivated and frustrated by studying. This considerable loss of human resources, and the consequent emergence of new forms of illiteracy, directly calls into question the responsibility of educational institutions. Faced with a teaching traditionally incapable of recognizing and identifying differences in cognitive styles, motivational structures, methods of acquiring knowledge, communicative forms, and socio-affective aspects, the synergy between neurocentric teaching and UDL planning can concretely contribute to renewing the pedagogical paradigm of inclusion.

To succeed in this direction, we must first understand how people are, how they were trained, what their interests, potential abilities, and independent learning skills are, and calibrate the teaching interventions on them, thus enhancing the cognitive, emotional, social and human potential of each person. Just as to sew a dress it is necessary to take meticulous measurements, so to create “tailored” learning paths it is necessary to take measurements, that is, to collect qualitative and quantitative data that help to describe and understand analytically and accurately the characteristics of each person.

In this sense, recalling the other principle stated by Laneve (2017), didactic flexibility is expressed in the aversion to “any form of crystallization, routinization, standardization” (p. 140), not only of methods, objectives, but also of contents, evaluation approaches, translating, instead, into the willingness to seek new solutions. Recent acquisitions in the neuroscientific field applied to inclusive planning allow us to reveal the full potential of didactic flexibility which translates into rejecting pre-packaged teaching and preferring teaching that recognizes the importance of the relativity of each training intervention based on the broader cultural, educational, psychological, social and situational problem that concretely conditions the validity and usefulness of its implementation.

Author contributions

- The paragraph entitled *Introduction* is the result of a joint collaboration by the authors: Calenda & Tiso
- Paragraphs *1. Brain, environment and learning: towards an integrated model* and *2. Neurocentric didactis* are attributed to Maria Tiso.
- Paragraphs *3. Universal Design for Learning for Flexible Teaching* and *Conclusions* are attributed to Marika Calenda.

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