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Review

Significant Mirrorings in the Process of Teaching and Learning

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Abstract

The goal of the present paper is to propose a hypothesis of explanatory model of the processes of learning and education based on recent neuroscientific studies. We refer in particular to the researches developed around the properties of the system of mirror neurons. This idea was born from the belief that it is possible to transfer the results obtained from fMRI studies, relating to extremely simple motor and communicative actions, to the study of more complex actions such as those that occur in educational settings. The hypothesis is that, even in learning situations, it is exactly the possibility to automatically capture the concatenation of the intentional relation (mapped from mirrors) to initiate the understanding of the stimulus-situation (both in oral and written form). It is assumed that the level of comprehension depends on the level of *intentional attunement* that is created between internalized sensorimotor schemas and patterns perceived in the stimulus-situation, then by the involvement of a neurocognitive mechanism like the metaphor. To support this hypothesis, the contribution will initially present a concise summary of the neuroscientific results that have led to the current conception of cognitive functioning and to the paradigm change concerning the nature of knowledge. Finally, an idea of teaching/learning based on the concept of *significant mirroring* (SM) and some indications in order to foster it will be proposed.

Keywords: Mirror neurons, intentional attunement, shared representations, cognitive metaphor.

INTRODUCTION

Mirror neurons and the motor base of knowledge

After the discovery of mirror neurons (Rizzolatti et al. 1996) (For a discussion see: Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996), *Action recognition in the premotor cortex*; Rizzolatti, G. e Sinigaglia, C. (2006) the amount of research findings seem to have an unquestionable implication for educational science, given the involvement of the mirror system in the basic mechanisms of understanding and then of learning.

What is, shortly, the mirror mechanism, at first discovered in the premotor cortex of the macaque and then in humans? It turned out that we are endowed with a particular class of neurons which mirror that is "simulate" at motor level, the actions performed by others when we perceive them. If, when we observe an action, the same circuits that works when we are performing the same action are activated, it means that we use the same sensorimotor connections in order to understand an observed action without executing it.

Later, several fMRI studies (Fadiga et al., 1995; Buccino et al., 2001; Glenberg and Kashak, 2002; Tettamanti et al., 2005; Borghi and Nicoletti, 2005; Aziz-Zadeh et al., 2006; Aziz -Zadeh and Damasio, 2008) have shown that the same brain areas are activated, not only during the observation of actions with objects, but also while reading, or listening to a sentence, "as if" we were to perform the action which the phrase refers to.

The really surprising thing about this particular class of neurons is not only their activation, both during the execution of an action as well as during the perception of it, but rather the fact that their activation is regulated by the purpose of the action observed (Umiltà et al. 2001).

For example, looking at someone who grasps an apple to bring it to the mouth, or to put it in a container, activates different neurons because the purpose of the

action is different; on the contrary, cracking a peanut to eat it or picking an apple to bring it to the mouth, activates the same neurons because both actions are joined by the common purpose "to eat". (Fogassi et al, 2005).

It follows that, in order to "simulate" an action as if I were to do it myself, it is necessary to grasp the purpose, which is equivalent, in other words, to understand the intentionality underlying the observed behavior. It was this peculiarity to lead the researchers from Parma to attribute to the mirror neuron system (MNS) the understanding function of the action, conceived as an understanding of the purpose or intention of the action, in the form of predicting the outcome.

In contrast with the explanations given by classical cognitive science, the understanding of an action and the attribution of intentions to others, would not belong to different cognitive domains, because both would be the result of motor simulation resulting from the activation of logically related chains of mirror neurons (Gallese et al., 2006 b).

Gallese and Lakoff (2005) in their hypothesis of "neural exploitation" (see also Gallese 2000; Gallese, 2008b) argue that the architecture of the brain that controls the action, was later adapted as a new neuro-functional structure for thought and language, yet maintaining its original function, and suggest that the structure of information needed to characterize the conceptual structure is available at the neural level in the sensorimotor system.

It was also noticed that not only the transitive actions with objects, but also the communicative action, are understood and recognized by the observer to the extent that the sensorimotor chains on which they are based, are part of the his motor patterns repertoire (Buccino et al., 2004; Calvo-Merino et al. 2005). The implications of these findings for learning and educational science seem to be obvious.

Other experiments (Carr et al., 2003; Rizzolatti and Sinigaglia, 2006) have shown that mirror neurons, not only allow us to automatically capture the purpose or intentionality underlying the actions, but they make also possible the understanding of other people's emotions, the imitation and those situations that we call identification, sharing, empathy, thanks to which we are able to respond effectively to the behaviour of others.

In summary, according to the latest theories developed around the functioning of the system of mirror neurons, the understanding of the action (observed, heard, read or even imagined) would be triggered by the activation of the repertoire of motor acts available on a personal level; such trigger would give rise to the "simulation" of the perceived action, which would be understood because it is pre-represented in a motor level (synchronization of perception, action and cognition).

Therefore, in this perspective, the nature of understanding would be motor as it is initiated (not completed) by the processes of mirroring that originate in the motor area.

Since, as has been shown, the mirroring takes place to the extent that the motor repertoires of the observer (or learner) and of the observed (or the one who teaches) have similar patterns in common, the peculiarities of the mirror system refers to the concept of "zone of proximal development" (ZPD; Vygotskij; 1934) (Vygotskij introduces the concept of *zone of proximal development* (ZPD) to account for the relationship between the external aid and the resources gained by the child at a certain time of his learning process; it is defined as the distance between the current level of development and the level of potential development that can be achieved with the help of other more skilled people, adults or peers) that, from the second half of the twentieth century until today, has marked the history of pedagogy and psychology, and which will be discussed in the 4th paragraph of this contribution.

The new concept of mental functioning

Never before as in the last two decades have so quick and amazing results in knowledge of brain functioning followed, such as to produce a reversal in the conception of the brain architecture and in the explanation of cognitive functions related to it. The main studies will be briefly reported.

First of all, the experimental evidence of brain plasticity (modulated by the use), the studies on the epigenetic variability of brain connectivity, the researches on activation of cortical maps in preparation for the response, lead to abandon a simplistic view of the brain as a static organ, unable to regenerate and neatly divided into hierarchical modules.

It is now widely acknowledged by the scientific community that the information available to the mind-system is not contained in a single place (the memory), but is spread over a network, so that each response emerges from the structure given by the connection of many nodes, which are in turn activated in the representation of other entities (structural Connectionism).

In the new conception of mental functioning, the idea of "representation" is assuming a very different connotation from the explanation given by the classical cognitive science, according to which the reality representation is similar to an objective copy of what is out there, achievable in a computational code, independent from material support.

According to Gallese (2009) the "representation" would correspond to the simulation of a schema corresponding to a specific sensorimotor pragmatic interaction with the environment.

The linguistic-symbolic valence of representation would, instead, be a later acquisition and would occur by

the re-use of processes that already exist for another purpose, namely would descend from the processes that map the relationships of purpose with the world.

Therefore, while until a few years ago the motor system was considered as a simple movements controller/performer, currently the experimental results give us, instead, a motor system involved in the representation of motor acts (not simple movements) organized on the basis of the relation of purpose.

However it does not mean at all that the representational schemes do not exist, but that these patterns have a sensorimotor origin, and not symbolic, and that they refer, automatically, to underlying levels which resonate with the characteristics of the stimuli.

Therefore, there is a motor memory, pre-verbal and not semantic which may act in parallel to knowledge and verbal semantic memory.

In fact, the motor cortex is associated with the prefrontal lobe and the cingulate cortex, areas involved respectively in working memory and planning of actions, and in motivational and affective information processing. Therefore, there is an idea of memory intended as a "dynamic system property based on recategorization" (Edelman, 2007; p 55). According to Edelman, some synapses get stronger or weaker as a consequence of a repeated activation, and this would influence the involvement of some circuits at the expense of others.

Thus, the memory would not correspond to the archive of our history from which we retrieve what we need, but it would appear as the ability to select and combine, actively and creatively, resources available and distributed in various cortices, in conditions made possible by environment that directs them (attention) towards a single destination.

Regarding attention, Rizzolatti and colleagues (1987), on the basis of some behavioural experiments, argue that it is not necessary to assume the existence of two mechanisms of control, one for attention and one for action (as was thought up at the end of the 80s), because attention arises from the activation of cortical and subcortical neuronal circuits which transform the information into action (Premotor theory of attention). Not surprisingly, the selection and programming of a motor plan automatically produce a shift of the attention towards those regions in which the action must be performed.

In summary, the cognitive processes (perception, representation, language, memory, attention), which have always been considered belonging to distinct modules, appear actually much more intertwined and overlapped than one could understand so far. Studies on the properties of system of mirror neurons inform us that when we perceive, act, understand, speak, imagine and remember, we recruit the same neural circuit, which is then used for different purposes, as claimed by Gallese and Lakoff (2005) in their hypothesis of "neural exploitation."

What suggestions can be drawn from the evidence offered by the current cognitive neuroscience in terms of teaching and educational strategies?

In the 5th paragraph of this contribution, according to the paradigm just shown here, some strategies will be explained.

The embodied, pragmatic and intersubjective nature of knowledge

Previously some studies supporting the motor base of knowledge, attributing it to the presence of a neural mechanism of mirroring that involves the motor area of the brain were presented.

The mirroring mechanism, mapping our intentional relations with things and others, would acquire a fundamental role in our understanding of the world and in the way we react to it.

This way to interpret the genesis of knowledge accords well with the embodied cognition approach, which recognises the motor, and then embodied nature of comprehension. According to this approach, all cognitive activities depend on signals from the body to the brain and from the brain to the body, and on the fact that the body communicates and constantly moves in an environment creating an interaction of mutual influence.

In other words, according to this perspective, our concepts, our way of thinking and reasoning depends strictly on the potentiality related to the physical and motor characteristics of our body. The motor theory of knowledge and the embodied approach have, in turn, much in common with the enactive approach, initially developed by Maturana and Varela (1980) in cognitive biology and subsequently refined by Varela, Thompson and Rosch (1991).

In the enactive approach knowledge is thought as a result of the experience that comes from “having a body” with various sensorimotor capacities, and from the fact that these skills are placed in a broader biological and culture context in which the body interacts modifying it and from which is modified. According to Varela, whatever exists in the world (chairs and tables, people and faces) is entirely dependent on this constant sensorimotor interaction; an object can not be considered as something that independently exists 'out there'; the object takes shape as a result of our activity, so the object and we take form together. (Varela, 1999). This autopoietic circularity, linking perception and action, leads to the generation, or enaction of reality itself, on which it is based, or from which cognition emerges. Further, the discovery of mirror neurons strengthens this circularity and interdependence between perception, action and cognition, thus contributing to support the paradigm of embodied cognition, which implies the enactive approach and strengthens the pragmatic nature of knowledge.

According to the neuroscientific paradigm, if the mirror system organizes the comprehension on the intentional basis, i.e. around a purpose, the comprehension is equivalent to understanding the purpose of an action, or a behavior; in other words, it means grasping its usefulness or knowing what you can do with it (see Gibson, 1977 for the term *affordance*), which also involves the perception of the consequences of actions or the use of the given object.

Although several studies highlight the active engagement of the subject in the development of intersubjectivity (Trevarthen et al., 2001), in this paper it is assumed that intersubjectivity arises as an initial primer on the subpersonal level due to the mirroring mechanisms. This does not mean that intersubjectivity is restricted to this, nor does it mean that it is not subsequently and actively elaborated by the subject as a result of their physical and verbal interactions with the others (V. Fusaroli et al. 2013).

What the neurocognitive paradigm supports is that: a) intersubjectivity is rooted in intercorporeality; b) this condition stems from the activation of the circuits that map the intentional relations with the world that we share with the others (mirroring system); c) the activation of these circuits results in an immediate, direct and pre-verbal understanding of the others. In other words, the embodied simulation theory considers intersubjectivity as a result of the re-use of one's mental processes (in their physical form) to represent the condition of the others. The I and the YOU would be intertwined due to the sharing of intended purposes, which makes intercorporeality a privileged access to the world of the other (Amman and Welsh, 2014).

As far as the role of intersubjectivity in the context of human development is concerned, Zlatev et al. (2008) offer a complementary perspective to the conventional approach of the "theory of mind", albeit from a different level of analysis (social cognition). They suggest that the human mind is fundamentally based on intersubjectivity, meant as the sharing of intentional, cognitive and affective states between multiple parties, which occurs primarily in the early interaction structure, in imitation, and in gestural and verbal communication.

Even though it may sound absurd that a newborn is capable of intersubjectivity, Trevarthen (2011) points out that the contrary is shown in the neuroscientific research on how infants coordinate the rhythms of their movements and senses and how they interact with the purposes of the others. According to Trevarthen, such awareness involves the birth of a new psychology. Therefore, the current research in the field of social cognition recognizes the importance of investigating the embodied constituents of the intersubjective dynamics (Fusaroli et al. 2013), as well as the fact that the neuroscientific approach needs research on the processes of social construction of intersubjectivity to complete itself.

For example, Gallese et al. (2008a) believe that this intersubjective predisposition achieves its "full expression" by being mirrored by an appropriate (i.e. consistent and predictable) behavior of the adult who interacts with the baby.

As a result, the characteristics of the proposed models are vital for the influence they will have in the learning process. Such a construct is consistent with Bandura's *theory of social learning* (1977), in particular with the concept of *modeling.* The author, a prominent figure in social cognition, characterizes the identification that develops between model and modeled as a fundamental feature of observational learning. The identification is based on similar characteristics: the higher it is, the better the learning effect will be on the behavior of the modeled.

In conclusion, in the wake of the mentioned studies that highlight the embodied, pragmatic and intersubjective nature of knowledge, we wonder whether the science of learning and education is researching the impact that these new pieces of evidence have on teaching methods and means. For example, we may wonder: if the brain organizes comprehension around a purpose, does our mind use the same criterion for learning? How important is the perception of the purposes linking the different teaching actions (or several concepts) in facilitating learning? What are the devices that the educational relationship can implement in respect to the motor and intersubjective nature of knowledge? In the 5th paragraph of this paper we will offer suggestions to make the teaching and learning process more in tune with the brain/mind functioning.

The ideas proposed mainly come from the latest research in neuroscience, cognitive linguistics (which contemplates the metaphor as a cognitive mechanism), the Vygotskij construct of ZPD (1934) and social cognition.

The understanding of intentionality in the learning process

Based on the recent findings and research in neuroscience, the hypothesis proposed here is that even in learning situations it is precisely the ability to grasp the "intentionality" of the action (or of what is to be learned) to make it meaningful "for me", and then to create the conditions "to move towards the action"(motivation). The ability to capture the intentionality of the action, or the information, is not here referring to grasping "the educational intentionality" of the proposed action but to understanding the purpose relations that connect different concepts.

The intentionality thus understood would emerge from the activation of a concatenation of motor actions towards-one-purpose, previously mapped as a result of our interactions with the others and the world (Gallese et al.; 2006 b). As explained in Section 2, the paradigm of

the ES claims that the understanding of the purpose/intention of an action performed by the others (such as a sentence or an emotion expressed by the others), derives from the activation (neural, therefore unconscious) of the same circuits that allow the viewer to perform the same action (simulation), or to experience the same emotion. Iacoboni et al. (2005) showed that it is necessary that the observer understands the intention included in the observed concatenation of acts in order for the same circuits (shared representations) (Gallagher and Zahavi introduced the term "shared representations" in *La mente fenomenologica* (2008) to show that agents and observers simultaneously use the same circuits which simultaneously make the action, the observation, the imagination and the imitation possible) to be activated.

If the glimpsed direction of purpose was different, other chains (other representations) would be activated while the selected one would not; consequently, since the circuit carrying the same intentional relation in both subjects is not activated, the mirroring or "simulation" (basis of understanding) would not occur. Results like these have led researchers of the ES to conceive understanding in terms of understanding-of-purpose, or intentional action.

The concept of "shared intentionality", which Tomasello develops by considering the origins of human communication (2008), is consistent with the implications of the mirroring functioning. According to Tomasello, the natural tendency of the human species towards collaboration, clearly visible in the newborn, would create a "common background" for the realization of the "shared attention" between mother and child, which is useful to understand the intentions of maternal actions and the use of objects.

The results of Dimitrova's studies (2013) on the origin of intentional communication have the same outcome. The author believes that effective mother-child communication is made possible by the common understanding of the usage of objects (purpose). Therefore, even though the studies start from different levels of analysis, it seems that their results show that the interactions with the others and the world are organized on the basis of intentionality / shared purpose.

This article intends to show that the comprehension of the structure of a topic is also possible in educational contexts thanks to the ability of the teacher and the pupil to share the purpose relations that link together several concepts. Consequently, the greater the repertoire of schemas possessed by the student, the higher the chance for the "shared representations" of a concept (or *significant mirrorings*; SM) and its understanding to happen.

The idea moves from a research about the involvement of simulative and metaphorical processes in the understanding of the text (Mario D., 2013) (On a phenomenological level, the research (Mario D., 2013; *Se immagino capisco: Il ruolo dei processi simulativi e metaforici nella comprensione del testo*. PhD thesis, PhD in Cognitive and Educational Science, Ca' Foscari University of Venice) aimed at identifying the role of the imagination (as a result of "simulation" in neuroscientific terms) in the understanding of a text. Based on Varela's neurophenomenological approach, the results highlighted the close relationship that exists between the understanding of the text, meant as the understanding of its purpose, and the degree of "intentional attunement" created, on a metaphorical basis, between the gestalt imagined by the reader and the structure of relationships contained in the text) based on an analysis of one hundred phenomenological reports in "first person". The study supports the hypothesis that the grade of *intentional attunement (*With *intentional attunement*, Gallese (2006a) means the state of dynamic reciprocity that is established between the subjective and objective pole of the interpersonal relationship, as a result of simulation or mirroring processes) (which allows the realization of shared representations) that is created between the sensorimotor patterns available in the reader's experiential repertoire and the structure of relations perceived in the text , makes possible mirroring processes that lead to "grasp" the meaning of the text (as a "grasping" intentional relations implicit in it).

The idea is that this mechanisms are involved even when a student listens to a lesson or studies a topic. As far as learning situations are concerned, the suggestion proposed is that the understanding of the stimuli employed is possible by glimpsing at the "direction" taken by the conceptual flow triggered by such stimuli.

In this perspective, the understanding comes from the presence of shared representations between the two poles of the educational relationship. These representations would be started, but not concluded, by the simulation or mirroring processes of the MNS. By allowing the recognition of the proposed concepts, and thus their "significance", this sharing would create the generative tuned status that leads to new learning.

Gallese hypothesizes that the attunement level, able to produce learning processes or "adjustment of neurophysiological states", is realized in "small steps" over against a minimum difference of mutual pre-representations, and differences above a certain threshold do not lead to learning because do not drag toward change (Gallese, 2006a, p.21).

The conceptual similarity between the idea of Gallese of "adjustment of neurophysiological states" that takes place in front of a minimum difference of reciprocal pre-representations, and the concept of "zone of proximal development" by Vygotskij (1934) seems to be clear; similarity recognized by Gallese himself (Gallese, 2006c, p.563). The concept was introduced, indeed, by Vygotskij to explain the distance between the level of

current development and the level of potential development that can be achieved with “the help” of efficient mediators (human or tools).

According to Vygotskij, the educator, to act within the "zone of proximal development", enabling the understanding and internalization of content to learn, should propose to the children problems (or situations) at one level a little higher than his current skills, but simple enough to be to him recognizable.

In this intersubjective dynamic the concept of "mediated action" proposed by Werstch (1998) becomes important. With this construct the author intends to emphasize the role of the educator as a mediator in order to adapt the cultural content and the means/tools employed (agency) to the resources present in the learner (agent). Werstch supports the idea that focusing on what happens in the intersubjective relationship is more useful than analyzing separately the characteristics of the subject (knowledge, skills, etc.) and the external conditions (mediator/means of mediation/cultural tools). This is confirmed by the results of recent studies in neuroscience that lead to the overcoming of internal/external dualism.

Intersubjectivity would become the "shared space" (on the sub-personal, cognitive and interpersonal level) where the "semiotic mediation" is placed, which in turn realizes the intersubjective condition.

How to encourage the *significant mirrorings* in the process of teaching and learning

The hypothesis of *significant mirroring* (SM), introduced here, looks at the concept of ZPD and "shared representations" and gets a glimpse of a theoretical framework which is suitable to identify the useful conditions that make the realization of the state of intentional attunement possible and that would provide the basic prerequisite for an effective "mediated action".

How to realize the "attunement intentional" state when the distance between subjects’s basic motor patterns is such as not to allow the mutual mirroring?

It is assumed that the understanding is facilitated by a mechanism similar to the one that we call metaphor. The metaphor would guide the selection of motor patterns useful to accommodate the new concepts "in terms of another" (see the conceptual metaphor theory by Lakoff and Johnson 1980; Gallese and Lakoff, 2005).

The conceptual metaphor theory is supported by several behavioral (V. Ackerman et al., 2010; Boot and Pescher, 2012; Gibbs and Matlock, 2008), neuroimaging and electrophysiology studies that found an involvement of the sensorimotor system in the figurative uses of language (Cuccio et al. 2013). The metaphor allows us to grasp the similarities in the two domains of reference and understand the new concept on the basis of the structural overlapping created by the similarity of the recalled patterns.

Edelman (2006) speaks about the metaphor in terms of cognitive mechanism as well. The winner of the Nobel Prize believes that at the beginning the brain (both phylogenetically and ontogenetically) recognizes configurations (conceived here as patterns of action) before recognizing the logic. Furthermore, given the huge variety and associativity of brain networks, the brain uses a mechanism similar to a metaphor to categorize stimuli and situations that maintain the same structure (i.e. the same patterns of action), though belonging to very different contexts and events.

Therefore, starting from the outlined framework and according to the views expressed here, to assist the mirroring process in the learning contexts, teachers should become aware of the basic mechanisms of our knowledge and our way to represent the world. Moreover, they should also realize that learning, like human nature, is a construction exquisitely relational and intersubjective at neural level.

On top of that, they should never forget that, to realize the mirroring processes, during learning, students can mainly draw from their sensorimotor repertoire. Therefore, if the context of teaching does not allow the activation of the mapped chains during their interactions with the environment, students may not understand new concepts.

A tool that would facilitate the identification or selection of neuro-conceptual maps and would be useful to “grasp” the new concepts, is the use of a “perceptual-motor” language based on the use of words and verbs able to reactivate the experience related to the interaction with objects and others (such as big / little, over / under, near / far, break, climb, descend ...); words also able to reactivate the sensorial, motor and emotional experience associated with them (see Lakoff and Johnson, 1998).

Moreover, if it is true that understanding involves grasping "the intentionality of action" (according to the neuroscientific paradigm), it follows that the teacher should predispose the conditions to catch the "intentional relations" that connect the concepts and the "directionality" (in the sense of purpose) of the proposed activities and attitudes that accompany them.

Neuroimaging studies show that understanding the purpose or what you can do with the object is crucial to understand something (in terms of *affordances*; Gibson, 1977).

To this end, the use of diagrams or maps to highlight "the structure of intentional relations" which organizes an argument (something different from the concept maps in use) turns out to be of fundamental importance so that it is precisely the structure to be perceived by students (See also the concept of "structure" of Bruner, 1966).

However, when the presented configuration is not in tune with the pre-representations in the learner's

repertoire (that is to say, "outside" from the *zone of proximal development*), the learning process is not triggered because there is no activation of any circuits that can start the mirroring.

In such cases, the use of a "good metaphor" would favor the creation of new connections and thus new acquisitions, allowing to talk about something abstract (of which you do not have the structure yet) in terms of another more concrete thing (because it is related to your actions).

Finally, it is fundamental that teacher assumes, in the course of educational interaction, consistent and predictable behaviors to encourage, in the students, the perception of the direction toward which the teacher tends (the whole purpose that gives meaning to teacher's overall action) in order to allow the full expression of the intersubjective predisposition within each of us.

CONCLUSIONS

It seems to be clear that the investigation of learning, and issues related to training, currently cannot neglect the brain.

If psychology and the educational sciences did not base their epistemology on the brain (Edelman, 2006) they would remain incomplete sciences and would no longer be able to offer an effective response to their interest problems. However, there is not the intention to claim that every mental phenomenon, or educational practice, is reducible to the neural mechanisms of motor patterns. The aim of the present paper is to point out that the brain function sets the conditions for the emergence of surprising mental complexity of which we are aware.

The extraordinary and still largely mysterious connection linking the mind, the brain and the body together is conceptualized here in its intentional dimension. This condition makes the human being the Heideggerian "being in the world" and "what-how" (V. Garza and Smith, 2009).

Although much about the processes that make possible the emergence of the mind from the body remains to be understood, today we have enough evidence to assume that the language has played a decisive role in this "passage", and also that it founds its roots in the motor area of the brain, through reusing circuits that map our constant interactions with objects and other people (MNS functionality).

By being consistent with these starting points, this paper tried to highlight the advantage, for both educational and learning sciences, to exploit the intersubjective and motor nature of knowledge, and the role of metaphorical language in the conceptual comprehension.

The hypothesis proposed is that since comprehension is closely linked to the sensorimotor repertoire, it implies the realization of the state of intentional attunement (between teacher and student) in learning contexts as well, which is generated by the sharing of the reciprocal sensorimotor pre-representations.

It is proposed that when the pre-representations are not shared, or partially shared, understanding is made possible thanks to a neuro-cognitive mechanism like metaphor that, allowing to grasp a concept in terms of another one, provides the conditions to realize the state of attunement that makes what you learn significant or recognizable and then understandable (hypothesis MS). Although the focus of the argument was centered on neural aspects (which trigger more complex cognitive processes), we believe that the state of attunement discussed here is consistent with the concept of ZSP Vygotskij and with Bandura's modeling concept.

On the basis of this assumptions, some useful indications to teachers to act in conformity with the motor, pragmatic and intersubjective nature of learning are offered, which also satisfy the requirement of "learning to learn" because it retrieves the relationship with things and other people, as well as the meaning and the utility of them.

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