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Sezione *Brain Education Cognition*

Teaching Practices can Support the Natural Learning Brain Process: A Study on Students' Perceptions in Higher Education[1]

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1. Introduction

Today, in the era of social complexity, teaching can be considered as an intentional and interactive process for providing different opportunities for students to learn. It is important to be aware of teaching as the result of two interrelated assumptions. First, 'effective teaching is a complex, intellectually demanding, and socially challenging task' (Brown & Atkins, 2002, p.1). Second, effective teaching should be supported both by a set of methods and skills, and multidisciplinary knowledge. In fact, on one side, teachers should know deeply the subject they teach, analyze content, reflect on the characteristics of students, contexts and materials, on the appropriate approaches, on the selection of effective strategies and tasks for students. On the other side, they should know how their students learn, and therefore how other fields of research could inform practices and help them to create effective lessons and activities for students.

Brain-based research seems to have particular importance for learning (Cfr. Antonenko, Davis, Wang, & Celepkolu, 2019; Goswami, 2008; Zadina, 2015), offering evidence base for learning in which learning mechanisms can be understood. A direct application to the class of brain-based findings can't be taken in account, but we need to consider that all learning happens thanks to our brain. For long time the relationship between education and brain-based learning movement has been considered a 'bridge too far' (Bruer, 1997, p.4), because the practitioners were lacking in scientific knowledge. However, as brain research has played over 20 years of inferences into classroom practices, it could be the right time to start creating a constructive dialogue among different disciplines. This is a process that can promote the creation of a holistic teaching approach as the result of the combination of different knowledge.

The purpose of this study is to support the idea that brain research can help teachers to select strategies that better mirror their students' brain functioning, and their learning process as well. The following research questions (RQ) guided this study:

RQ1: What teaching strategies do students perceive supportive for their ways of learning?
RQ2: To what extent do students perceive their academic experience supportive for the internalization of their learning strategies?
RQ3: What representation do students have of their learning process?
RQ4: What relationship is there between students' ways of learning and mind-brain findings?

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2. Theoretical framework: an outline of the connection of mind-brain-based findings with learning process

Mind-brain based research has the potentiality to support our understandings of human learning through the combination of neuroimaging and cognitive psychology data.

Since birth most of neurons become progressively specialized thanks to the environmental stimulation. More stimulations the brain receives more connections creates, pruning those that are not used. In this sense, brain plasticity is biologically predetermined, and the characteristics of the environment has a strong impact on the related neural connections that depend on the experience, including educational experience (Goswami, 2008). Through the advances of fMRI, PET, and EEG brain imaging scientists have started to understand the way by which our brain processes new information, transferring it from short term to long term memory. The Reticular Activating System (RAS) is the structure of the brain that makes the first analysis of the sensory input with the task to get together different aspects of a sensory event. For example, a visual image has color, depth, structure, movement; all this represents some information that is processed by different cortical regions in an only event (Bell, 2017).

The research shows how 'working memory needs to change its content constantly and rapidly because problem solving abilities often require processing different types of information, swiftly switching from one to another cognitive task and simultaneously solving diverse problems' (Aries, Groot, & van den Brink, 2015, p.211). It means that more information is stored and manipulated more the reasoning abilities are improved; the repeated exposure to similar contexts, generating matched strategies, activates the meta-cognitive function of work memory that regulates pattern recognition of reasoning structures. Working memory training improves reasoning abilities (Aries et al., 2008). This phenomenon is confirmed also by the reading process: 'As reading skills are practiced, neurons send dendrites to other neurons, creating denser neural connections and possibly increasing myelination. The repetition of correctly performed skills building dendrites has implications for all the components of reading' (Bell, 2017, p.14): phonemic and phonic skills, vocabulary, fluency and comprehension. After the decoding process working memory is ready for the important comprehension process, that can be supported by students' prior knowledge and the use of strategies for breaking down the text (Bell, 2017).

The relationship between work memory capacity and recall from long-term memory is determined by multiple strategies (effective strategy use, search efficiency, and monitoring abilities) related to encoding and retrieval: 'the relation between work memory capacity and long term memory recall is multifaceted in that a number of important strategic control factors are responsible for the relation' (Unsworth, 2016, p.57).

There is a functional link between the prefrontal executive processes and the emotional–motivational processes of the limbic system (Howard-Jones, 2014). Neuroimaging techniques have helped researchers to analyze the dynamic nature of cognition and emotion processing with influence on learning results (Immordino-Yang, 2016). In neuroscience context the evidence of emotional state is connected to the physiological response that interests all the activities of Central Neuron System and the Autonomic Neuron System (ANS) such as heart rate, body temperature and blood flow rate (Noa, Qijing & Zhijian, 2016). In learning settings, pressure and tension cause physiological and biological brain reactions, producing hormones with negative effects on students' concentration, short-long term memory (Vogel & Schwabe, 2016).

Empathy is another factor connected to learning process. Decety and Meyer (2008) states: "The psychological construct of empathy refers to an intersubjective induction process by which positive and negative emotions are shared, without losing sight of whose feelings belong to whom. Empathy can lead to personal distress or to empathic concern" (p. 1053). It is the precursor to feeling caring or distress, becoming the expression of emotional resonance, and involves our mirror-neuron system that is activated when we are experiencing what we are observing (Rizzolatti & Craighero, 2004). The discovery of mirror neurons has highlighted how the experience of the empathetic simulation is the result of the relationship between imitation and empathy. This means that vision, movement and body are connected with empathy and it in turn is generated from the experience of the body and movement of the person in relationship with others. This means that, our brain is 'a social organ […] and flourishes best within the context of social interaction' (Cozolino & Sprokay, 2006, p.13)

The factors above mentioned are connected to some key-factors of learning process. Specifically, the research focused on the environmental stimulation in supporting brain plasticity, on the importance to offer different sensory stimulations to facilitate the interpretation of the external information, to support short-long term memory through the learners' exposure to contexts where they can create easily matched strategies of retrieval and encoding, supporting reasoning skill and problem solving skills, thanks to the metacognitive function of work memory. From pedagogical point of view, the ability of instructors to create an emotional environment, and to develop an emphatic instructor-student relationship for and with learners is recognized as an important facilitating factor for learning process and learners' attention (Dirkx, 2008; Perry, 2006; Talmi, Lohnas, & Daw, 2019).

3. The study

The study is part of a wider research design in which have been involved students of two bachelor's degree courses of University of Padova and some brain's experts of different universities and countries. In this paper only the first part of the research was presented; it is focused on: (i) teaching strategies perceived by students as supportive for their learning; (ii) relationship between students' teaching strategies perceptions and mind-brain research findings.

3.1. Context of the study, participants and method

The study contexts were the two venues of Philosophy, Sociology, Pedagogy and Applied Psychology of university of Padova located in Padova and in Rovigo. Specifically, the students of two bachelor's degree courses in Educational and Training Science were involved.

The participants, voluntarily involved, attended the two different teaching courses 'Methodology of playing and animation' and 'Training and Development of Human Resources'. The authors agreed with the teachers of the courses where provided some invited lectures, presented the research project to students. A total of 74 students participated in the study: 5 were males and 69 females (Table 1).

Table 1. Participants

Gender	Educational science	Educational science - HR	Total
Male	1	4	5
Female	57	12	69
Total	58	16	74

Data collection was carried in November 2019, through a quantitative approach.

The study foreseen the development of a specific questionnaire taking in account the mind-brain research. It was created on the base of a 1-5 Likert scale. It was made of five sessions with a different number of items related to the following macro-areas: General information (4 items); Comprehension (7 items); Reasoning strategies (4 items); Memory strategies (7); Learning and emotion relationship (6 items).

At the end of the questionnaire three different questions were asked students: the first one asked them to explain their learning process through a metaphor, giving them the possibility to reflect and imagine their learning in a holistic way; the second one, asked them to rate at what extent their academic experience promoted their reflection on their learning strategies; the third one, asked them to rate at what extent learning strategies can be reinforced if oneself were aware of their own strategies.

Students, after receiving a face-to face explanation of the purpose of the research, and after signing the informed consent related to data protection and the use of data collection, were invited to participate in an online questionnaire. This tool was created in advance through Google drive documents, and then the link was provided through the courses' Moodle platform for one group of students (58 students). The questionnaire was developed considering the individual anonymity. A paper questionnaire was administered to the students of 'Training and Development of Human Resources' course (16 students), because of the difficult wi-fi access in that university site. Only the students enrolled to the courses, and those who attended last class had the possibility to participate in the survey according to the specific time slot established by the researchers. In this way, the advantages were for both: for researchers, who collected data immediately; for participants, who had the possibility to complete the questionnaire through their mobile phone in the classroom or to fill in the paper questionnaire.

Quantitative descriptive statistics were used to analyze data collected. Findings related to the use of metaphor through which students represented their learning process were clustered according to their common meaning.

4. Findings

From mind-brain research only some factors have been analyzed in this paper; those ones that the authors have identified as important for students' learning processes and have connections with the mentioned theoretical pedagogical aspects.

4.1. RQ1: Teaching strategies perceived supportive by students for their ways of learning

According to students' point of view, if teachers would use some strategies, they could support them in the comprehension of lessons. Specifically, the combined use of visual aids (video, graph, pictures) (M= 4.36) and the use of maps (M=3.75) is perceived by students as the best strategies to support their comprehension. The mean of the only use of the graphs was the

lowest: 3.08; while the means of the other strategies (questions, predict, linkage among parts of the text) ranged from 3.22 to 3.38 (Table 2).

These findings, with the high item means (4) registered for mixed teaching strategies useful to support students' comprehension process fit with the idea that our brain can process different information at the same time. Changes in the classroom, activities and strategies catch the RAS's (Reticular Activating System) need for novelty (Willis, 2008). Also, during reading process "Fluent readers can decode, recognize, and comprehend the meaning of text at the same time, so their networks fire effectively and efficiently" (Willis, 2008, p.47).

Table 2. Teachers' strategies useful to support students' comprehension process

Items	Mean
Use of *visual aids* (video, graph, posters, pictures)	4.36
Use of t*raditional* elements (lectures, speeches, presentations)	3.31
Use of *questions*	3.27
Use of *predict* strategies	3.22
Use of *linkage*s among the parts of a text	3.38
Use of *maps*	3.75
Use of graphs	3.08

When asked participants to rate the reasoning strategies (RS) useful for their learning process, if teachers would use them at the end of their lesson, the mean of all RS ranged from 3.49 (comprehension-questions to analyze a topic or problem) to 4.09 (reflection questions on the difficulties that students meet) (Table 3). This shows that teacher shouldn't take for granted that students develop skills on their own, but that it is the teacher who explains how to solve problems to them, evaluate evidence, analyze topics and formulate hypotheses. This will allow them to approach various disciplines as experts (Weimer, 2013).

Table 3. Reasoning Strategies (RS)

Item	Mean
Reflection questions (on the difficulties that students can face)	4.09
Connection questions (related to the similarities and the differences between current problems/tasks and those solved in the past)	3.89
Strategic questions (on strategies/principles to adopt for solving a problem/ task)	3.99
Comprehension questions (to analyze a topic or a problem)	3.49

The memorization processes can be clustered in three categories: i) the first category includes the item means ranged from 4.04 to 4.39; it mirrors the student-centered approach used by teachers, where the focus was related to the strategy to create connections with past experience or picture associations, and students' involvement; ii) the second category includes the item means ranged from 3.27 to 3.66; it mirrors the personal ability of the students to cluster information in categories or to generate meaningful sentences; iii) the third category seemed to be more connected to rote memory, where the item means ranged from 2.41 to 2.86 (Table 4).

The high item means registered for some memorization strategies such as 'connection of new information with previous knowledge', 'being involved in the activities' or 'association with known pictures' find connection with the pedagogical perspective of student-learning teaching, according to which teaching and learning processes should be built taking in account

both students' previous experience, and the use of active strategies useful to promote students' engagement and participation (Chi & Wilyie, 2014).

Table 4. Memorization Strategies (MS)

Items	**Mean**
I remember better when the new information when it can be connected with the *previous knowledge*	4.39
I remember better concepts/information creating *associations* with *pictures*	4.09
I remember better concepts/information creating some *categories*	3.66
I remember better concepts/information generating *sentences* (combining 2/3 words in a meaningful sentence)	3.27
I remember better when I *repeat* the new concept/information in the same way the teacher presented it	2.86
I remember better if I am *involved* in the activities actively	4.04
I remember better concepts/information if I *listen* teacher's explanation (without being involved in the activities)	2.41

The item means of relationship between context and learning processes ranged from 1.35 (stressful context) to 4.54 (positive classroom atmosphere). The high item means was registered also for empathy with teacher (M=4.01) and emotional memories (M=4.28); the item means for imitation of the activities and the use of active strategies were slightly lower (respectively 3.58; 3.86) (Table 5).

The positive classroom atmosphere and the emphatic relationship between students and teachers are other key components that support students' learning process. In fact, context and positive atmosphere are powerful influences for creating authentic learning experience and engaging a holistic teaching approach. They lead to memorable and lasting learning experiences (Iucu & Marin, 2014).

Table 5. Relationship between context and learning processes

Items	Mean
I learn better when I have the opportunity to *imitate* others while they are doing their activities	3.58
I learn better when the *empathy* (state of synchronicity and emotional relationship with another person) characterizes my relationship with teacher	4.01
At a long distance of time, I remember well concepts/information if I can connect them with *positive learning experiences*	4.28
If I am involved in the use of *active strategies* (e.g.: debates, role-play, groupwork, discussions, pictures, music, artifacts…) generates in myself a positive emotional state	3.86
I learn easier when in the context I perceive a *stressful atmosphere*	1.35
I learn easier when in the context I perceive a *positive atmosphere*	4.54

4.2. RQ2: At what extent students perceive their academic experience supportive for the internalization of their learning strategies

A comparison between the level of awareness of learning strategies and support received to reflect on them was investigated. When asked the participants at what extent the level of awareness of personal learning way to learn improve their strategies, they rated this component with a high score (M= 4.36); quite lower was the item mean related to the support received

during their academic experience in gaining awareness of their personal learning strategies through reflection (M=2.92) (Table 6).

Participants recognized a strong importance to be aware of their own learning strategies (M=4.36), but they perceived to not have received so much support for the development of it from their academic experience (M=2.92). To have the opportunity to reflect on their own cognitive function allow students to change them and to develop 'metacognitive' and 'executive function' skill (Goswami, 2008). These results on one side showed that students seem to know well how a high level of awareness of their learning strategies can support them in the effective selection of the right strategy in relation to the tasks or activities in which they are involved. They show a need of autonomy and self-directed approach (Knowles, 1980). On the other side, the results offer teachers an occasion to revision their teaching within the constructivism perspective, according to which students can participate actively in the construction of knowledge through sharing and exchanging processes (Duffy & Jonassen 1992).

Table 6. Comparison between awareness of learning strategies and support received to reflect on them

Items	Mean
To be aware of my own learning strategies makes me to reinforce them	4.36
During my academic experience, I was involved to reflect on my learning strategies	2.92

4.3.RQ3: Students' representations of their learning process

When asked participants to think of a metaphor that could better represent their own learning processes, they mentioned different meaningful pictures. To facilitate the analysis the metaphors were clustered according to their similar meaning in 11 categories: development/growing, connections, change, vision, organized construction, confusion, reflection, arduous path, linear path, emotional dimension, mental process. Five participants didn't give any answer (Table 7).

Students, through the use of metaphors, showed to have a different but clear representation of their way to learn. In fact, most of them connected their own learning process to the idea of transformation related to the categories of development/growing and change: this is an idea of vertical and incremental development. For some others learning is a well-organized structure and it seems to be a horizontal development process. If for a very small group pf students (3) learning is an easy process, for a group of eight students is difficult, and for few others appears as an involving experience or on the contrary as just a mental process. These findings mirror student/learner centered perspective according to which individuals are unique people, and instructors' task coincides with the creation of a learning environment where students can be engaged in personalized paths (Schweisfurth, 2015; Schuh, 2015; Weimer, 2013).

Table 7. Metaphors of students' learning processes

Categories of meaning	Metaphors used by students	Number
Development /growing	Tree/plant/flower	20
Connections	Puzzle/Pollock's picture as a group of an only picture/linkage among information	6
Change	Evolution/permanent building renovation/ spiral	3
Vision	Map/visual pictures	10

Organized construction	Organized desk/house made of bricks/house with foundations/brick after brick	7
Confusion	Caos	2
Reflection	Snail/maze	6
Arduous path	Ladder without some steps/ mountain/swing/ seasons/ steps forward and backward/sun and rain/uncertain trip/sailing trip	8
Linear path	Continuous line/a way to go/easy way/path with steps	3
Emotional dimension	Positive emotions/ book of fairy tales	2
Mental process	Group of information/abstract	2
No answers		5
Total		74

All the metaphors mentioned have a positive connotation except the 'caos' metaphor that shows that some students are experimenting a difficult learning process.

4.4. RQ4: Relationship between students' teaching strategies perceptions and mind-brain findings.

Data analysis process allowed the researchers to identify many critical points of connections students' teaching strategies perceptions and mind-brain findings (Table 8).

Table 8: Relationship between teaching strategies and mind-brain findings

Students' perceptions on teaching strategies		**Mind-brain findings**
Comprehension	Mixed strategies support comprehension process	Our brain is a parallel processor (Aries et al., 2015; Caine & Caine, 1991) Reticular Activating System (RAS) analyzes the different aspects of sensory event at one time (Bell, 2017; Garcia-Hill et al., 2013; Willis, 2008). Learning is multi-sensory (Goswami, 2008)
Reasoning strategies (RS)	Participants recognized the importance of receiving support for their reasoning strategies development. They support their learning process	Working memory (WM)plays a crucial role in developing reasoning skills involving logical reasoning and problem solving (Klingberg et al., 2002). WM stores and manipulates information during complex cognitive activities, such as reasoning (Klingberg, 2009). The manipulation of information, the re-use of the strategies, and the activation of metacognitive function of work memory strengths RS (Aries et al., 2008; Jaeggy et al., 2008)
Memorization strategies (MS)	Students recognized as the most effective memorization strategies those that consider their previous experience, association, engagement.	The long and term memory systems influence each other their performance (Mathy & Feldman, 2012; Norris, 2017)
Learning context	Students connected a learning context made of possibility to imitate others, to create connections with positive learning experience, to have empathy with teachers, to be emotionally	Context, situations, experience, simulation, imitation, empathy, positive atmosphere activate brain circuits and allow: to create our mental representation thanks to mirror neurons (Rizzolatti & Sinigaglia, 2006), to

	involved as key elements of their learning	activate our 'emotional thoughts' (Immordino-Yang & Damasio, 2007) The synaptogenesis is 'experience dependent' (Goswami, 2008, p. 382)
Reflective support on learning strategies	The possibility to reflect on their own learning strategies help students to internalize them.	The reflective process helps individuals to change their own cognitive functioning by developing 'metacognitive' and 'executive function' skills (Goswami, 2008). The brain-awareness-mind cycle is the natural course of human reflection (Iran-Nejad & Gregg, 2001)

A variety of teaching strategies is perceived supportive by students for their comprehension process. This mirrors the biological functioning of our brain. It can process different information at one time. When we live an experience our brain generates thoughts, emotions, imagination, and predispositions simultaneously and interact with the information that we have already stored in our long-term memory (Caine & Caine,1991). Our Reticular Activating System (RAS) analyzes the external input and collect the different aspects of a sensory event, providing the essential stream of information for the formulation of many of our actions (Bell, 2017; Garcia-Hill et al., 2013). For instance, involving different cortical regions in an only event, individuals are able to decode, recognize, and comprehend the meaning of a text at the same (Willis, 2008). This suggests teachers shouldn't foresee lecturing exclusively, but the use of lecture combined with visuals resources that allow students to develop open-ended representations and sharing information in a way they feel most comfortable as long as they cover the topic.

Students stated that their learning process is supported by development of their reasoning strategies. This finds connection with the research on work memory, according to which contexts and situations where students can play constantly their problem solving and metacognitive skills allow them to internalize reasoning structures (Aries et al., 2008; Jaeggy et al., 2008; Klingberg, 2009).

Students stated that the teaching strategies that create connection or association with their previous knowledge facilitate their memorization process. That finds relations with the interrelated functions of short-long term memory systems.

> Long-term learning of novel words or digit sequences depends on STM, and performance in STM tasks is influenced by information in LTM. Even under the view that there are separate short and long-term storage systems, the two systems should operate in concert. […] Although STM is predominantly phonological, performance in STM tasks is nevertheless influenced by lexical or semantic factors, or by other information stored in LTM (Norris, 2017, p. 994).

LTM is the storage system of previous knowledge and past experience. This means that to facilitate the memorization process teachers should create situations and use strategies that support students' association with their previous experience. In fact, for example, we usually recall better words than nonwords (Hulme, Maughan, & Brown, 1991), and lists of familiar sequences better than the lists composed of unfamiliar sequences (Mathy & Feldman, 2012). At the same time, memory performance is better when context states at encoding and at retrieval are more similar to each other (Smith &Vela, 2001). These are all aspects connected to the

value of learners' experience and the idea of learning as a situated process (Lave &Wenger 1991), where the context is an important factor of learning. In turn, the context includes the use of artifacts, interactions with others, generating the social construction of knowledge. In this sense, our brain is a processor of experiential learning (Caine & Caine, 2006). These findings match with a constructivist perspective (Duffy & Jonassen 1992).

Meaningful are also the findings related to the relationship between the context and the learning process. In fact, *empathy, positive atmosphere, positive learning experience, active learning strategies*, and the opportunity to *imitate* the others' activities are recognized by students as key-factors of a learning environment. These results find their roots in the body and movement experience of the individuals who are in relationship with other people. Mirror neurons represent the neuronal system of our ability to imitate and to create mental representations and empathetic simulation (Rizzolatti & Sinigaglia, 2006), thanks to the involvement of different brain circuits. However, the relationships and their emotional quality can facilitate or inhibit the integration of the different representations, visual, bodily, playing impact on the way by which we interpret the reality. Interpersonal relationships have an experiential dimension that allows us to understand the sense of people's action and emotions (Gallese, 2012), and to create an internal simulation of actions. It means that both the visual and the motor systems are involved, developing our ability to understand and interpret the reality through our body, and moving from procedural learning to verbal and complex learning. Once again, the experiential and relational learning is in alignment with the constructive paradigm and situated learning (Lave & Wenger,1991)

Also, the *positive atmosphere*, as factor that support learning, recalls the interdependence between emotion and cognition, termed 'emotional thought' (Immordino-Yang & Damasio, 2007), involves learning processes, memory, decision making and creativity, becoming part of cognitive skills and showing how cognition without them has less support (Immordino-Yang, 2016). When individuals perceive a threatening situation can lose the attention useful to solve problem or face situations. It means that our brain uses emotions to guide actions, choosing positive situations and avoiding negative ones.

The reflection phase is another important aspect of students' learning process. Learning is usually seen as internalization of external knowledge through a constructive elaboration. According to bio-functional perspective, that expands the functional theory, understanding our brain is an important condition for understanding the interaction process of mind with the external world. "The mind has no direct access to the outside world- only the brain does" (Iran-Nejad & Gregg, 2001, p.874). For this reason, it is important to know how the nervous system works, how the mind interact with brain, and how it uses the brain and the body sub-systems to interact with the world. This interactive process is known as brain-mind cycle of reflection during which the brain creates through a dynamic process the brain creates an intuitive self-awareness for the mind. The awareness represents the conversational language between the brain and the mind. In fact, in turn, the mind reflects and acts on the awareness that the brain creates (Iran-Nejad & Gregg, 2001). In this sense, the brain-awareness-mind cycle is a natural path of human reflection. It is supported not only by are the knowledge, but also by imagination, insight, suspense, curiosity interest, approach, avoidance. These components show the importance to create a learning context where the stimuli promote meaningful learning experience and changes in the students' cognitive functioning (Goswami, 2008).

5. Implications

This study showed some important practical implications for teachers. In the current complex society, as practitioners of teaching they should be aware of the way to learn of students to provide them different strategies of teaching that better fit with their 'mental system functioning'. Findings of this study showed that mind-brain research can indirectly inform teaching practices reinforcing some methods and avoiding the use of others. In fact, the relationship that exists between the memorization process and the individuals' previous knowledge, between reasoning strategies, memorization process, context and learning process, highlights a strong combination with the principles of learner-centered perspective and mind brain findings. According to them a learning environment should be a safe and meaningful context:

- where the holistic involvement of students with their experience and their knowledge, body and mind should be considered as a milestone of the teaching process.
- where the teacher-student relationship would be the result of an empathetic approach and an emotional atmosphere.
- where all the strategies used by teachers should motivate and promote students' involvement and participation.
- where the teacher well knows the representation that students have of their learning process (use of metaphors). It is an opportunity for teachers to know better their students, and for students to reflect on their ways to learn.
- where the reflection learning strategies can be a habitus of teaching and learning processes.

They are components that were identified in this study in relation with natural course of brain-mind functioning. In this sense, teachers need to think about themselves and be ready to cross disciplinary boundaries and to build new form of dialogue with different knowledge and research fields. At the same time, new paths of interdisciplinary professional development should be thought for them, in order to support their teaching choices with brain and mind in their hands.

6. Discussion and conclusions

In the last decades the subject of the relationship between mind-brain research and teaching has become central for some researchers, both for those who support it and for those who are against it. Also, in Italy the interest for this kind of partnership is growing with attention on the connection of the biological functioning of memory and emotions to learning process (Damiani, Santaniello, Paloma, 2015); on the *enactivism* as circularity among action and knowledge and the brain-body-world sequence (Rossi, 2011). These are research dimensions that enhance professionals' reflection on the opportunity to cross disciplinary boundaries with the aim to improve practices in formal and informal contexts, avoiding the division of mind from body and the separation of students from context. Findings showed that learning involves the whole body: we receive stimuli from the context, and through the processes of our brain and mind the information is decoded, analyzed, interpreted, compared with the stored knowledge; if our emotional thought is positive, we conceptualized it in a new form of knowledge and move to the actions thanks to motor systems. In this sense, providing effective context and learning experiences foresee the implementation of teaching practices that better mirror the natural way of human learning and reflection.

In this perspective, this study showed that the key-concepts of experience, context, strategies (combined strategies/MS/RS), empathy, emotions, memory, and reflection, create linkages between pedagogical principles and mind-brain research, inspiring a holistic bio-psycho-social approach (Geake & Cooper, 2003), on the base of the idea that "learning is social", because our "brains evolved to flourish in complex social environments" (Goswami, 2008, p. 391) and "most environmental experiences are multisensory, and therefore fibre connections between modalities are ubiquitous (Goswami, 2008, p. 389).

In conclusion, this study suggests possible future research paths: (i) In which way can experts of different disciplines create a fruitful collaboration? (ii) How can the different knowledge' boundary crossing be managed? And through what boundary objects? (iii) What new shared language needs to be developed among the different experts? Crossing knowledge boundaries, it is a process that cannot be taken for granted, but it needs to be built with the active participation of all the experts. It is a 'bridge' that can be built by properly trained "engineers" (Zadina, 2015, p.75).

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