

Bio-education, simplicity, neuroscience and enactivism

A new paradigm?

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Abstract: *Four lines of research, which are present in Italian context, have been compared in the present paper, they share a common origin within the bio-educational studies. This paper analyses the elements of proximity amongst the four perspectives. The reflection captures the possibility of a new paradigm that provides new potential educational research and teaching leads. The topics covered include: the centrality of action, the relationship between body and knowledge, the notions of simplicity and enactivism.*

Riassunto: *Nel contributo si sono confrontate quattro linee di ricerca presenti nel contesto italiano della ricerca che, aprendosi al dialogo, hanno ritrovato la loro comune matrice negli studi sulla bio-educazione. Il contributo analizza gli elementi di tangenza tra le quattro prospettive e coglie la possibilità di un nuovo paradigma che offra nuove potenzialità alla ricerca pedagogica e didattica. Gli argomenti trattati riguardano: la centralità dell'azione, la relazione tra corpo e conoscenza, gli input delle ricerche nel settore delle neuroscienze cognitive per l'educativo e i concetti di semplicità ed enattivismo.*

Keywords: *Bio-education, Simplicity, Enactivism, Knowledge.*

Introduction

“Non-linear Trajectories in Research. New Interdisciplinary Scenarios” was a day of studies, held in Salerno, Italy on 8th and 9th November 2012. In this context, four lines of research, present for a long time on the Italian pedagogy and didactic panorama, were compared and, after open discussion, rediscovered common origins in the bio-educational studies.

Eliana Frauenfelder, opening the works, proposed the suggestive metaphor of the four-leaved clover to refer to the four lines of research represented in the debate. The intervention pointed to their convergence within an emerging paradigm that is making itself known in the present socio-cultural context, inside and outside pedagogy.

Here is a brief note of the four leaves (to follow the metaphor).

Eliana Frauenfelder introduced the issue of Bio-education in the final decades of the last century and perhaps it is the one (of the four lines) that has the longest history. It highlights the need for studies in education to have a reference to the biological processes that have an impact on the learning mode, and on the results of it (Frauenfelder, 1994). Bio-educational research, originated from Eliana Frauenfelder's studies on learning as "the multiplicative converging centre, to which the contributions of all those disciplines whose competence is always intertwined with a specifically pedagogical one can be brought back" (Frauenfelder, Santoianni, 2002, 39). Specifically, bio-education paved the way to the scientific establishment of the principle *educability*, creating "an alliance" between biology and pedagogy "as a result of sharing some degrees of epistemological compatibility and of partial reflection" (de Mennato, 2006, 49).

A second leaf is *Simplexity*. *Simplexity* is a property of living organisms: "life has found solutions to simplify complexity. Nor does it evoke the utterly remarkable ability of living creatures to create borders delimiting closed spaces, such as the cell and the body itself. These solutions are indeed simplifying principles that reduce the number or the complexity of processes.

They make it possible to rapidly analyze information or situations, taking into account past experience and anticipating the future-which helps to grasp intention-all the while respecting the complexity of reality" (Berthoz, 2011, X-XI). The research team of the University of Salerno, led by Maurizio Sibilio, is investigating, analogically and biologically, the possible didactical use of *simplexity's* properties and principles shown by the physiologist of perception, Alain Berthoz.

The third leaf is the one of *Neurodidactic* and its contribution in the analysis of the processes that governs learning production (especially now that access to knowledge is significantly marked by the mediation of digital technologies) and the strategies that they require. The studies of Pier Cesare Rivoltella and his research team (2012) at CREMIT, University of Milan, showed the importance of picking the effects of cognitive neurosciences in the educational context to develop innovative and sustainable didactics on the learning level.

Finally, the fourth leaf is the one of *Enactivism* that starting from Varela's studies, it analyses complex systems, showing the circularity of action and knowledge and the brain-body-artifact-world sequence. Pier

Giuseppe Rossi research team (2011) is analysing the fall out of Varela's systemic method in the didactic field.

Many elements of tangency present in these researches and in possible synergies of research, pose questions about the existence of a paradigmatic perspective shared by all of them.

The paper picks up elements of contact in this direction and suggests working avenues, fully acknowledging that research today presents liquid qualities that do not allow conclusive analysis.

New realism and post-modernity. The centrality of action

Recently, there has been a heated debate, in philosophy, between new-realism and post-modernism. Ferraris "opened the dances" with the *Manifest of new realism* on the *Repubblica*, Italian newspaper, issued on 8 august 2011. During spring 2012, Gabriel (in Bonn) and Bojanić (in Belgrade) organised the meeting "New Realism" with the participation of Boghossian, Eco and Searle. Central to Ferraris is the unavoidability of a reality and of a friction of reality that we all confront every day or, as Eco would say, the need to deal with the "hard clog" of reality.

Since the start of the millennium there have been various signs of a turnaround, also underlined by Berthoz who speaks about a "return to reality" (2011, 162). If in the 90s the constructivist trend played the main role, that made some cognitivist like Reigeluth (1999), and Merrill (2002) sustain the presence of a new paradigm, characterised by personalisation, autonomy with responsibility, cooperative relations, initiative, diversity, web, holistic structure and oriented to processes, client's centrality (Reigeluth, 1999, 17), however, from the start of the millennium something began to squeak.

The concept of embodiment is put at the centre by various externalist views (Rowdinds, 2003) both in its phenomenologist shape (Jackson e Pettit, Dretske, Lycan), and in its semantic one, while dialoguing with the most recent studies in the neuroscientific field. Radical externalism (Rocwell, Honderich, Manzotti) discusses the "*Fossato Galileiano*" and proposes overtures where knowledge and experience intertwine.

However, the new millennium's return to realism cannot deny the role of the subjects that did not only mark constructivism, but also the physics of the 1900s. It hints on overcoming the contrast between realism and

constructivism, giving to action the central role. In philosophy emerged the term post-constructivism to indicate the dichotomy between representational, realism and the classical socio-constructivism (Rouse, 1996, 2002a, 2002b; Joas, 2001; Asdal, 2005; Wehling, 2006; Solé, 2011). Knowledge “is not to be comprehended as simply the mental «possession» of a knower, non-knowledge is not merely the lack thereof but an (unrecognised) implication of materially and socially situated research practices” (Wehling, 2006, 81).

Rouse proposes “a shift from thinking about a putative object that a concept could describe, to thinking about the practices in which the concept is used” (Rouse 1996, 199), while Wehling sustains that “knowledge is not to be understood (and “reified”) as an independent and coherent entity or object which is discovered by science and thus explains and justifies scientific practices” (Wehling, 2006).

Two texts were published about the actions and practices of 2001, in two contexts: the French speaking and the English speaking ones, that seem to be concerned by similar topics. They are: *Théories de l'action en education* edited by Baudouin and Friedrich, and *The Practice Turn in Contemporary Theory* by Schatzki, Knorr Cetina and Von Savigny. Action is doubly connected and in a recurring mode with knowledge. It does not consider the computational model that is the algorithmic consideration of processes as built on the linear sequence information-processing-action.

The central point becomes the situated practice, in which knowledge is embodied, and the reflective processes.

The studies on action turn toward Aristotelian theorisations, expressed especially in Nichomachean Ethics, with some significant changes brought by the reception of those theories against a background marked by neo-pragmatism, from sociolinguistics to hermeneutic. Contemporary researches monitor the presence of qualifying elements such as reflection, intention, awareness and self-interpretation that unites words with actions (Baudouin, Friedrich, 2001; Schatzki *et al.*, 2001). At the same time, they move away from Aristotle on three points:

- there can not be a relation of mechanical dependency on means and ends: in a complex scenario, the end can not be seen as an absolute and abstract to which action should turn to, because the “unemendability” of the real” (Ferraris, 2012) requires a continuous and recursive review of the ends during the action;
- in the action there is a structural coupling among subjects, it causes a

co-specification process with the other subject, this is why a subject cannot be autonomous from the others, and from the context;

– to set action in the forefront brings the necessity to take a holistic vision of the person: in action the person performs in all his entirety. In particular, there is a reevaluation of the body role, not just in action, but also in the process of knowledge, a body that acts in interchange with the world (Joas, 2001, 29).

An approach based on action has at the same time an ontological value, as the constructed world is always real and testable; epistemological, as action converses in a recursive mode with knowledge; axiological, as man is not only a detached observer anymore in a world that follows autonomous processes, totally independent from him. Man is also an actor who interacts continuously with the world while transforming it, and becomes responsible for directions that he gives.

The action and the four-leaved clover

In the educational field too, the approach based on action raised to an interesting role that depends both on the general elements of the present socio-cultural context, and on the peculiarities of educational acting.

Is it possible, helped by the magnifying lens of action, to see the link between the four leaves of the clover mentioned at the beginning of the contribution?

Body and knowledge

The first effect of the centrality of action is to consider didactical acting in its various dimensions, and to fully exploit the relational modes of interaction between the teacher and the classroom. Communication requires also non-verbal channels. Each teacher has his way to live the lesson, because of his way to act it physically, because of his way to “move around the classroom”.

Once the Cartesian distinction of *res estensa* and *res cogitans* is left behind (a distinction marked by the non-communicability of the two dimensions and their belonging to ontologically different plans), the body stops being a useless instrument or the simple tool through which information

reach the mind that elaborates them sending executive orders to the body. A thinking body emerges, a body where there is a constant circulation between perception and action. Perception is in itself an action derived from a previous decision:

la perception est en fait non seulement une action simulée mais aussi et essentiellement une décision. Percevoir, ce n'est pas seulement combiner, pondérer, c'est sélectionner. C'est, dans la masse des informations disponibles, choisir celles qui sont pertinentes par rapport à l'action envisagée. C'est lever des ambiguïtés, c'est donc décider (Berthoz, 2003, 10).

Since the development of physics in the 1900's emerges the active role of observation that denies the researchers' classical and scientific approach where the observer should have been neutral, unable to pollute the context. Interpretations on the function of waves in the analysis of quantum objects show, after Heisenberg, how it is just the measure or the interaction between observer and observed, to establish that among many probable futures it builds up a *hic et nunc*. After each event the system takes an unpredictable direction or, better, not entirely predictable before the junction. Something similar happens in the educational context: the interaction between the system and the event acknowledges the relationship between subjects and system.

The role of the body obtains three different focuses: in classroom interactions it processes learning and teaching (1), in the psychomotor approach (Lapierre and Aucouturier, Le Boulch, Pierre Vayer) that has corporality as the meeting place of the cognitive, socio-affective and relational dimensions in constitutive processes (2), the teaching processes show the function of the teacher's bodily communication in the classroom (3).

It is worth to return to the repetitiveness in action between acting and learning that refers to a knowing body, a body that actively participate in the learning processes. In this view the analysis of Merleau-Ponty should be recovered, it examines, showing reciprocal influences, conscious and subconscious processes. The centrality of an "intelligent body" (Sibilio, 2002) binds the four leaves of the clover: it is central in Bio-education; it belongs to the sequence brain-body-artifact-world, the departing point of enactivism; it is present in Berthoz simplicity, who comes to many of his conclusions departing from human physiology; it is confirmed in the neuroscience field, if it is true that the various forms of human learning –

repetition, simulation, contextualized experience – find in the body their point of access (Rivoltella, 2012). Below comes an exploration the last two positions.

Complexity and Simplicity

To put action as the focus of research implies a non-reductionist approach. The action reifies the recursion between the doing and the knowing, the analysis of the action allows underlining the relationships between the various movements, a passage that would not be allowed by a reductive process. But the complexity causes problems for knowledge. Firstly, it does not define the scope and it requires infinite processes. Morin and, later, Berthoz, underline how reductionist approaches deny access to complexity. At the same time, to cross complexity, processes should simplify the paths that lead to knowledge.

On this subject, Berthoz finds in the concept of “Simplicity” a trend to repeat identical or similar schemes whose identification would free the human learning potential, trapped in a thick web made of inter-retro actions that generates unpredictable and difficult to decipher behaviours. “Identical or similar motifs are used throughout the living world to minimize energy, reduce entropy end even to transmit transmission faster” (Berthoz, 2011, 7).

The notion of simplicity, although tied to the organism’s adaptation mechanism to the environment, seems to be applicable to all levels of human activity. It offers properties and principles that appear to be original solutions, not simple, but capable to elaborate, “very rapidly, elegantly, and efficiently, taking past experience into account and anticipating the future” (Berthoz, 2011, 5).

“Simplicity – Berthoz says – is not simplicity. It is fundamentally linked to complexity, with which it shares the common roots” (*Ibidem*, X). “Simplicity is complexity decoded, because it is based on a rich combination of simple rules” (*Ibidem*, XI).

The principles of anticipation and prediction are blocked by a representation of reality according to which nothing seems predictable any longer. These principles reconquer their space, “this double strategy, both perspective and retrospective, situates the present in the dynamic flow of a changing universe. It enables comparison of sensory data with the results of past

action and prediction of the consequences of the ongoing action” (*Ibidem*, 15).

Simplexity “seems to resolve complex problems by rejecting dry determinism in favor of probability-change- the idea that order can emerge from disorder” (*Ibidem*, 17), leaving to the observer the possibility to choose which measure to take, tuning his instruments accordingly.

The shooting of non-linear problems, in a simplexity view, poses as a prerequisite a series of detours that often involve the use of composite variables, instead of the so-called simple variables. “Paradoxically, expressing the problem in terms of composite variables simplifies it. If a system exhibits complex behavior that normally can only be represented by «third-order» equations, using composite variables gives first-order system that is simpler to calculate and whose dynamic behavior is easier to predict” (Berthoz, 2011, 18).

The reflection on “simplexity” does not give space to the conclusion that it should be regarded at the basis of a scientific revolution. The model proposed here does not intend to deny what has already been theorised, imposing a new paradigm to the scientific community. The theory of “simplexity” offers, in short, potentially translatable new standards found in devices apt to adjust and justify, from a complementary rather than an alternative view, the activity of educational research, elaborating the complexity of systems that interact in the wider educational system through solutions that are not simple but simplexity (Aiello, 2012).

Among the principles that Berthoz (2011) proposes to deal with complexity he points out the principles of specialisation and selection (*Ibidem*, 14). He focuses on the role of decision in the complex analysis of action: “One species scans the world only for cues important for its survival” the indicators that are important for its survival [...] Most animals acts according to their Umwelt [...]. Deciding involves selecting from the information around us whatever is pertinent to the goal of action” (*Ibidem*, 14). Another principle is the probabilistic anticipation that has a direct and indirect impact on many of the elements that characterize complex acting. Anticipation is not planning one activity, but the building of a wide range of possibilities for action, based on the modeling of the system and to the simulation contained in it. Therefore, anticipating couples with simulating and with the processes pointed out by many authors as fundamental to planning in many contexts. Gallese speaks of incarnate simulation to describe the mechanism of mirror neurons, which will be seen below.

Gero (Gero, 1990; 1994; Gero, Kannengiesser, 2002) re-thinks design and believes that the process does not end in plotting of the route to be followed. After the first design is done, there is a simulation process in which the path is read mentally, to understand how the system might evolve. Simulation and anticipation require a relocation of the designer. While the first design starts from the viewpoint of the designer, in simulation he detaches himself and tries to observe the system from other perspectives. This is to understand how a proposed activity may change the system, and how the system may react, “adapting” to the intervention. The focus shifts to the relationship and to the indirect effects that may arise in the action. At school level, designing surely requires from the teacher this attitude of detachment. Every time he thinks of proposing one activity, immediately he asks himself questions such as: what reactions will students have? How much time will I need? Which difficulties will they meet? Which minor problems may arise affecting the flow of the process?

Another principle, suggested by Berthoz to face complexity, is the one of redundancy. The author recalls Wittgenstein’s criss crossings, where the diverse perspectives allow action through dialogue and the comprehension of complexity. Berthoz also affirms that

for living organisms, simplicity is what give meaning to simplification, insofar as simplex solutions are motivated by intentions, goals, or functions. The basis of the meaning is in the act itself. Meaning cannot be superimposed on life; it is life. The concept of simplicity includes the idea of meaning. Elaborating a theory of simplicity thus also entails elaborating a theory of meaning by redefining the term to incorporate the intended or desired act as fundamental (Berthoz, 2011, 21).

Cognitive neuroscience and embedded knowledge

Another element common to each clover leaf is the interest in cognitive neuroscience. This is a research paradigm (or, in better words, a multi-disciplinary field of research) in which some of the most debated questions of Western thought return to be asked. A main question is the relationship between mind, body and the world. Cartesian dualism has already been mentioned, it is the father of modern epistemology. To declare self-reflecting and non-communicating *res cogitans* and *res extensa* means, us-

ing Vanni Rovighi's beautiful metaphor (1984), to consider our mind "a locked room, furnished with ideas". According to Descartes, thought does not think things, but it thinks ideas, including the problem of showing not only how things are "out there", but also "that" they are there. This first "error" of Descartes (responsible for the philosophers' headaches at least until idealism) was followed by a second (Damasio, 1994), which consists in homologating the body with the other "things" assigning it to a deeply devaluating mechanist consideration. For centuries, it prevented the understanding how some crucially important processes did actually happened, from knowledge to affections.

Overcoming this vision is at the centre of the debate among those who rethink the role of the body in knowledge (Sibilio, 2002). Begg (2004) emphasises that the little interest devoted to cognitive neuroscience, just like for constructivism, has been a limit and shows the right synergy that should be developed between neuroscience and enactivism today; Varela and Thomson (2001) underline that the discovery of mirror neurons supports many of the intuitions of the 80s, especially by favouring the understanding of the mechanisms that connect the intra-psychic to the inter-psychic. Equally, Damiano (2008) underlines how experimental neurophysiology meets the emerging inter-individual subject.

If starting from past analysis of physiological problems, was highlighted how knowledge was accumulated, now the analysis of the body-brain system lets us indicate that knowledge passes through the physical dimension of our own corporeality, even at the most abstract level. The research on mirror neurons (Rizzolati *et al.*, 1999; Gallese, 2007, 2009) has shown that we see with our whole body, not just with our eyes. Generally, a number of aspects concerning the relationship between our perception and cognition – as observed also by Berthoz – have to do with the function that our body has as real "geometrical recognition", according to Merleau-Ponty's famous definition.

Experimental studies [...] have pointed out the impossibility of conceiving the motor system as an apparatus deputed only to the performance of actions. They have shown that in monkeys and in humans it plays a purely cognitive role, operating significantly already in the perception phase (Damiano, 2009, 221).

Co-activity and structural coupling

The relationship between subject and world is an element that caused the contrast between and idealism. A world objective and independent from the subject seems to require a passive observation and knowledge as a mimetic representation of the real world. On the contrary, a learning process as the construction of somebody's world, that for Collins "has a small or non-existent role in the construction of scientific knowledge" (Collins, 1981, 1), seems to be totally self-referential and preclude any possibility of validation.

In the educational field, the instructive hypothesis, where knowledge is transmitted from a subject who knows to another one who does not, and the constructivist hypothesis, in which knowledge appears to be built by the person while learning, appears insufficient and maimed to explain the complexity of the educational process. The first case undervalues the role of the subject learning, the second the second does the same with the teaching.

The ring between doing and knowing during action, the interaction between inter and intra-individuality, the simultaneous surfacing and the structural coupling proposed by the enactivism, and the concept of empathy in Berthoz, seem to provide possible ways to exit the contradiction described above.

The closure of the system is a structural feature of in the enactivist hypothesis, but the border between internal and external has a permeability, which allows the system to receive inputs from the outside.

Various authors describe, using different concepts, the inputs that seem, at first sight, to have strong convergences. Ferraris speaks of "the friction of reality" to point out that the surrounding world puts up obstacles to our working. The complex approach underlines how reality presses at the borders of the system, Varela speaks of emergency to describe how the balance of the system could be questioned. In any case, there is a system, and an external environment that, with its inputs, creates a state of discomfort such as to trigger an adaptive and auto-poietic process of the system.

The external input does not determine the next state, it does not impose, in any mechanical way, the future. It undermines the system, it breaks the previous equilibrium, it sets limits and stimulates the system to build a new coherent balance provided with its inner characteristics.

Such a path, in educational terms, aptly describes the processes of learn-

ing and teaching. The system re-organises itself during the learning; it is a conscious choice, motivated by the subject. However, it is the teaching hat undermines the system, it highlights where the balance can be broken, it sets up the process and places limits the possible avenues.

The four cloverleaves, although in different ways, overcome the instructive-constructivist dichotomy. In relation to the educational applications of cognitive neuroscience Rivoltella (2012), it is evident that in the processes of learning, the building up knowledge demands, at the same time, the governance of the teacher and the attention of the student, with a come back to traditional methods (cannot learn without repetition, there is not learning without effort and fatigue) and the use of didactic techniques and contextualised experience. Enactivism speaks of structural coupling to show the shared emergencies between two independent systems. The term structural coupling has many affinities with co-activity, introduced by Altet (2012) and Vinatier (2007).

Conclusion. Paths for research

The next papers will decline and deepen the above.

What the paper wants to emphasise in closing is that in addition to research in different fields, it is essential to focus also on the research methodology to be adopted. The return to reality and the need for a return to rationality after recent populisms and skepticism (Solé, 2011; Latour, 2004; Ferraris, 2012) has, in many areas, resurfaced the temptation to positivist drifts. It is the case of the *Evidence Based Education*, where it seems possible the rise of the myth of the absolute numerical value, and the external observer of the system made a comeback.

The bet that we wage today is of a steady and contextualised research, that, on the one side contemplates, the centrality of action and a relation between observer and observed. And, on the other, it produces new experimental devices equipped with well-calibrated and measurable indicators. We believe, that in this case too recursion is a potent instrument. The recursions between action and decision, doing and learning, were dealt earlier. This time, it is the recursion between immersion and removal. As it is known nowadays the surrounding reality, even with its systemic laws, changes daily through the dialogue with human acting and the political choices design the outside world, interacting with reality's own laws.

In educational acting cannot be but relative to systems that we observe and act upon at the same time. Seeing the process as external and alien to our acting, as an expression of an independent and absolute reality, denies the systemic relations that they contain.

Here is therefore the need to encourage a dialogue between the system and the environment (Varela *et al.*, 1992) or, as Berthoz would say, the simple and the complex, the particular and the universal (Berthoz, 2011, 164), the story and the map (*Ibidem*, 137), the description of the set (the story) and the construction of interpretative hypotheses (the map). “It is unnecessary to assume a subjective quantity apart from the act. It suffices in itself, which leads to a principle of economy involving the primacy of the act and obviating the notion of representation as an independent act” (*Ibidem*, 166).

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References

- ALTET, M. (2012), “L’apporto dell’analisi plurale delle pratiche didattiche alla formazione degli insegnanti”, P.C. Rivoltella, P.G. Rossi (Eds.), *L’agire didattico*, La Scuola, Brescia.
- AIELLO, P. (2012), “Appunti per una fondazione epistemologica semplessa dell’agire didattico”, *Traiettorie non lineari nella ricerca nuovi scenari interdisciplinari*, Lecce, Pensa Editore.
- ASDAL, K. (2003), “The Problematic Nature of Nature: The Post-Constructivist Challenge to Environmental History”, *History and Theory*, Vol. 42, n. 4, Theme Issue 42, Environment and History, 60-74.
- BAUDOIN, J., FRIEDRICH, J. (Eds) (2001), *Théories de l’action et éducation*, Bruxelles, De Boeck.
- BEGG, A. (2000), *Enactivism, a personal interpretation*, <http://www.ioe.stir.ac.uk/docs/Begg%20Enactivism%20.DOC> (verified in October 2012).
- BERTHOZ, A. (2003), *La Décision*, Paris, Odile Jacob.
- (2011), *La semplessità*, Torino, Codice Edizioni.

- COLLINS, H.M. (1981), "Stages in the Empirical Programme of Relativism", *Social Studies of Science*, volume 11, 3-10.
- DAMASIO, A. (1994), *Descartes' Error. Emotion, Reason and the Human Brain*, New York, Avon Books.
- DE MENNATO, P., OREFICE, P., SARRACINO, V. (Eds.) (2006), *Cinquant'anni di pedagogia a Napoli. Studies in honour of Eliana Frauenfelder*, Naples, Liguori.
- DEWEY, J. (1925), *Experience and Nature*, Chicago, Open Court.
- FERRARIS, M. (2012), *Manifesto del nuovo realismo*, Bari, Laterza.
- FRAUENFELDER, E. (1994), *Pedagogia e biologia. Una nuova alleanza*, Napoli, Liguori.
- FRAUENFELDER, E., SANTOIANNI, F. (Eds.) (2002), *Le scienze bioeducative. Prospettive di ricerca*, Liguori, Napoli.
- GALLESE, V. (2007), "Dai neuroni specchio alla consonanza intenzionale. Meccanismi neurofisiologici dell'intersoggettività", *Rivista di Psicoanalisi*, 53, 1, 197-208.
- GALLESE, V. (2009), "Mirror Neurons, Embodied Simulation, and the Neural Basis of Social Identification", *Psychoanalytic Dialogues*, 19, 519-536.
- GERO, J.S. (1990), "Design Prototypes: A Knowledge Schema for Design", *AI Magazine*, Winter, 26-36.
- (1994), "Computational Models of Creative Design Processes", T. Dartnall (Ed.), *AI and Creativity*, Kluwer, Dordrecht, 269-81.
- GERO, J.S., KANNENGIESSER, U. (2002), "The Situated Function-Behaviour-Structure Framework", in J. Gero (Ed.), *Artificial Intelligence in Design '02*, Kluwer Academic Publishers, Dordrecht, 89-104.
- JOAS, H. (2001), "La créativité de l'agir", in J. BAUDOUIN, J. FRIEDRICH (Eds.), *Théories de l'action et éducation*, Bruxelles, De Boeck, 27-44.
- LATOUR, B. (2004), "Why Has Critique Run out of Steam? From Matters of Fact to Matters of Concern", *Critical Inquiry*, 30, 2, 225-248.
- REIGELUTH, C.M. (1999) (Ed.), *Instructional-design theories and models: An new paradigm of instructional theory, Volume II*, Mahwah, Lawrence Erlbaum Associates.
- RIVOLTELLA, P.C. (2012), *Neurodidattica. Insegnare al cervello che apprende*, Milano, Raffaello Cortina.
- RIZZOLATTI, G., FOGASSI, L., GALLESE, V. (2001), "Neurophysiological mechanisms underlying the understanding and imitation of action", *Nature Reviews, Neuroscience*, 2, 661-670.
- ROSSI, P.G. (2011), *Didattica enattiva*, Franco Angeli, Milano.
- ROUSE, J. (1996), *Engaging Science. How to Understand Its Practices Philosophically*, Ithaca/London, Cornell, University Press.
- (2002a), "Vampires: Social Constructivism, Realism, and Other philosophical Undead", *History and Theory*, volume 41, 60-78.
- (2002b), *How Scientific Practices Matter. Reclaiming Philosophical Naturalism*, Chicago/London, University of Chicago Press.

- ROWDINDS, M. (2003), *Externalism. Putting Mind and World Back Together Again*, Chesham, Acumen Publishing Limited.
- SCHATZKI, T., KNORR CETINA, K., VON SAVIGNY, E. (Eds.) (2001), *The Practice Turn in Contemporary Theory*, London/New York, Routledge.
- SIBILIO, M. (2002), *Il corpo intelligente*, Naples, Simone.
- SOLÉ, R. (2011), *Phase transitions*, Princeton, Princeton University Press.
- VARELA, F. J., THOMPSON, E.T., ROSCH, E. (1992), *The Embodied Mind: Cognitive Science and Human Experience*, MA, MIT Press.
- VANNI ROVIGHI, S. (1984), *Istituzioni di filosofia*, Brescia, La Scuola.
- VINATIER, I., NUMA-BOCAGE, L. (2007), "Prise en charge d'un enfant en difficulté de lecture par un maître spécialisé: gestion de l'intersubjectivité et schème de médiation didactique", *Revue française de pédagogie*, 158, 85-101.
- WEHLING, P. (2006), "The Situated Materiality of Scientific Practices: Postconstructivism – a New Theoretical Perspective in Science Studies?", *Science, Technology & Innovation Studies – Special Issue*, volume 1, July, 81-100.