EDITORIAL
by Valerio Eletti

Focus on: Complexity Education

1.A Welcome

Welcome. And congratulations. I am delighted that you could make it. Getting here wasn't easy. I

know. In fact, I suspect it was a little tougher than you realize. To begin with, for you to be here now trillions of drifting atoms had somehow to assemble in an intricate and intriguingly obliging manner to create you. It's an arrangement so specialized and particular that it has never been before and will only exist this once…

incipit of "A short history of nearly everything", 2003, by Bill Bryson

… we have to recognize to the complexity the role of being the present (and, very likely, the future) forma mentis, and to establish itself as the social, cognitive, subjective paradigm of our time. […] Complexity without education is, as for Kant's categories per se and without empirical connections, "blind" and "empty". An abstract paradigm. The education is entitled to achieve its "incarnation"[1]

Franco Cambi, 2003, pp.138-9

1 Foreword

Let us start from a general remark: in the space of a few decades, or even of a few years, we have all been catapulted into a tangled set of new ecosystems, never seen before: an extremely complex environment, created by ourselves but rapidly grown autonomously with features and characteristics we – its unaware creators – just now begin to explore and understand.

[1] "... alla complessità va riconosciuto il ruolo di essere la forma mentis del presente (e del futuro, assai probabilmente) e di venire a fissarsi come il paradigma sociale, cognitivo, soggettivo, ecc. del nostro tempo. [...] La complessità senza formazione è, come accadeva per Kant alle categorie prese per sé e senza connessioni empiriche, "cieca" e "vuota". Un paradigma astratto. Alla formazione, all'educazione spetta il compito della sua "incarnazione", translated by Nicoletta D'Elia.

Let us try to make a list of some of the many environment changes we have been and will be forced to adapt in order to survive: the increasingly dense weaving of connections between populations, communities, and individuals ignoring each others until a short time ago (physical connections such as trains and airplanes networks, and virtual connections such as phone, television, and digital networks in general); the increasingly dense weaving of different cultures, economies, of enormous assets and information movements; the tensions and the conflicts originating from the short circuit between cultures that for centuries had been separated or even hostile. And finally the key-change (transverse, omnipresent, and yet extremely personal) deriving from the conflict nowadays acting in every individual, between his/her local culture and the global one: together with the consequent need of transforming this conflict in a fruitful dialogue.

And this scenario mingles with now operating changes having remote roots: in his essay (Callari Gambi, Cambi, Ceruti, 2003, p. 13-26) Mauro Ceruti listed a series of "irreversible phenomena" originated by the convergence of human populations begun five hundreds years ago, and become increasingly massive, after millions of years of divergence, separation, and diaspora processes. Among the ten irreversible phenomena listed by Mauro Ceruti, it is worth to remember the "artificialization of habitats and natural ecosystems", the "decrease of human and animal diversity", the "explosion of urban habitats", the "body virtualization", and the "exponential growth of stimuli and of the cognitive chances for each individual".

These all are phenomena reverberating in events apparently autonomous and independent, but actually deeply interconnected with feedbacks able to trigger global changes involving the whole humanity: from the climate tropicalization to the spread of transgenic food, from the medicalization of the advanced economies populations to the several financial bubbles – with the connected crisis, from the spread of terrorism to the multiplication of global and irreversible migrations, and finally to the crossbreeding of codes and languages (of any kind: musical, behavioral, expressive), happening at the same time in every society in the world.

The list is not complete. But it is enough to understand that we are always speaking about changes we are not able to explain. Unless in our learning and adaptation to the new tangle of environments, we rely on a new cognitive paradigm[2]: the *complex paradigm*.

[2] The concept of scientific paradigm is elaborated by Thomas Kuhn in The Structure of Scientific Revolutions. Here we want to extend the concept of paradigm to the mainstream culture, referring to Dario Simoncini's and Marinella De Simone's (2008, p. 29) definition: "The cultural paradigm is composed by that body of ideas whose definition is made by everyone of us. It also rules our actions, often without our awareness. [...] the cultural paradigm consists in those essential ideas that rule our life, our behaviors, and regulate our relations with the others: those essential ideas are our unstated assumptions, never made

We will see later what it means exactly. Now we give some basic coordinates in order to draw the scenario we are moving into, and to focus the aims of this Je-LKS special dedicated to the "***Complexity education***".

From what we said here, it is clear that the necessity of sensitizing – and then to educate – people to the complex paradigm is becoming more and more urgent. It is becoming fundamental to educate in this sense both the public and private management of today, and the ones of tomorrow – that are now being trained in the universities – and, finally on a wider level, all the new generations, starting from the primary school.

Obviously a similar massive and universal shift of paradigm can be launched exclusively with instruments that can fit the purposes: those digital devices belonging exactly to the complex environment we are interested in: a 'medicine' we can find in the 'mutant' body itself of the new vital transition of the society.

If it is relatively easy to operate on the awareness of complexity among the present and the forthcoming ruling class, the key-knot for the future is going to be especially in school.

What is the role of school? Many are wondering (among them: Ceruti, Simoncini and De Simone – already mentioned – and the central figure of Edgar Morin), and everyone is giving a different response: we will see later the most relevant.

1.B Concept map

We end this Foreword giving the concept map of this paper, namely the graphic representation of its structure. As you can see from the map, the text has been designed in a slightly hypertextual way. Why? Because if it is true that the reading on paper or Pdf is strictly sequential, we want in any case to give a concrete idea of the contents organization normally applied when speaking of the complexity education – which involves the non-linearity of the learning processes. If the paper was accessible in a hypermedial format[3], in fact, this even minimal hypertextual structure could support the reader's learning process by allowing everyone to provide personalized crossings of the single islands of text (known as lexias[4]): we can define these crossings 'personalized' since

explicit, never explained linguistically. Many of these assumptions belong to the collective unconscious, since they both form everyone's story and – at the same time – the roots of a community".

[3] This is a technique that found his qualitative maximum in the second half of the Nineties, all over the world, together with the second generation of the educational CdRoms, made to respond both to a personalization of the educational courses, and to a flexible use of the inductive and deductive approaches (cf. Eletti, 2002, 2003, and 2008).

[4] With the word lexia (spread in the digital context by George P. Landow in 1994) we mean a block of text, an island of auto-consistent content, occupying a node into the network of links in a non-linear hypertext; in our small map every lexia is indicated by a number (corresponding to a paragraph of the sequential text), or by a combination number-letter (corresponding to a sub-paragraph, to a box, or to an appendix in the sequential text).

they are motivated both by the background knowledge of the single user and by his/her momentary curiosity.

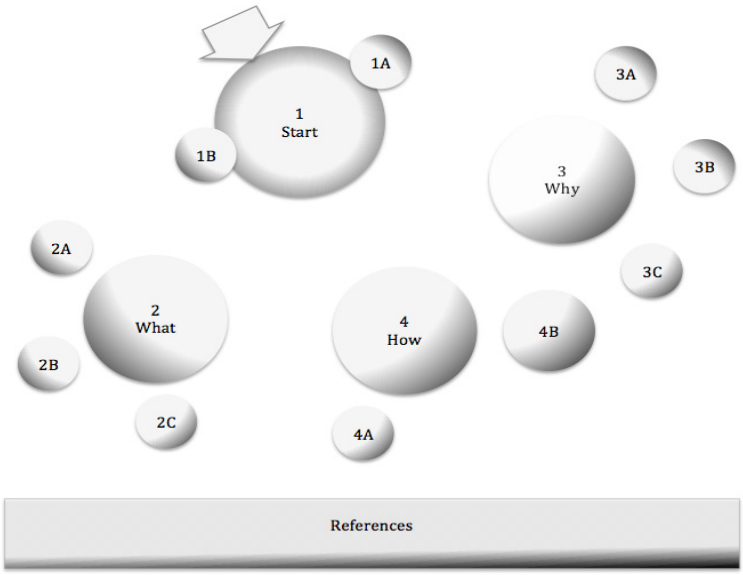
Obviously here we have just a small hint of the non-linearity, used just to suggest the reader the possibility to create cognitive maps able to satisfy the needs of different readers.

Then, the following text can be read in sequence, in the traditional way, or it can be "navigated" jumping some of the lexias and composing one's own specific preferential itinerary; in the legend you can find the commented titles that make possible a fast identification of the most or less interesting lexias for everyone.

A latere remark:

the hypermediality is just one of the two key-instruments we can use to let the learner approach the complex paradigm; the other essential element is the social support, involving the constructivist planning of the educational course to be developed.

COMPLEXITY EDUCATION: CONCEPT MAP ¢



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2 What: simple, complicated, complex

What do we mean with the word 'complexity'? Let us give first of all a provisional definition, then we will try to understand the differences between a complicated and a complex system (or problem, phenomenon, environment, organization). Later we will see the main features and characteristics of complex systems (especially of those able to adapt themselves to an endlessly changing environment), and the dynamics emerging from different network structures.

Definition. We do not have a "scientific" definition of complexity; but we can mediate between the various approaches and provide a description suitable in nearly all the disciplines: "we have an adaptive complex system when a great amount of elements (each simple or complex again), connected with each other in a network of actions and re-actions (feedback, loop, non-linearity of the system) ruled by local laws (even very simple) is gathered; and when the system considered as a whole is out of balance (a dynamic, turbulent status, on the edge of chaos), exchanging energy, matter or information with the environment (open, dissipative system)" (http://www.slideshare.net/valerioeletti/complexityeducation-by-valerio-eletti-14?from_search=4).

Complicated or complex? Often these two terms are used as synonyms, and this causes a dramatic confusion obfuscating the perception of the problems to tackle. Let us start from the etymology.

Complicated derives from "*cum* + *plico*", namely "with foldings", folded, then ex-plicable, predictable (even if with some difficulties); then a system is complicated when its structure is linear, can be broken (analyzed) into its single components, is submitted to cause-and-effect relationships, is repeatable in the same initial and surrounding conditions. Some classical examples: an engine, a clock, that can be disassembled and reassembled with the same final result. When we deal with complicated problems we are in the full application of the reductionist paradigm belonging to Galileo, Descartes, and Newton.

Complex derives etymologically from "*cum* + *plecto*", namely "intertwined, woven together": in this case we are speaking about systems (or problems, phenomena, environments, organizations) consisting in several parts linked with each other and depending the one on the others. A complex system is not reducible to its components (the whole exceeds the sum of the parts), is non-linear, is non-repeatable, and non-predictable in a deterministic manner.

When facing a complex problem or system we must then move our attention from the analysis of its components to the relations existing and feeding with each other according to non-linear dynamics, with feedbacks that can give birth to great changes against small stimuli, and vice versa: it is therefore necessary

to move towards reticular, non-sequential vision and approach.

Application fields? All those regarding biological and social phenomena.

We can assert indeed, approximately, that what is inanimate can be tackled successfully by means of the classic, reductionist paradigm; and that what is living, or consisting in living systems (from the biology to the ecology, from the economy to the learning processes), requires a complex cognitive approach: it is even intuitively clear that applying a classic reductionist approach to complex problems means choosing the wrong model, and in this way going towards clamorous failures in the comprehension of the dynamics of the system – or the problem, or the environment – we want to inspect (http://www.slideshare.net/valerioeletti/semplice-complicato-complesso).

Marginal note: other than complicated and complex systems and phenomena, we can also have *simple* and *chaotic* (these of various types) systems; we refer to one of the many texts discussing about it in a wide and detailed manner, as for example Edgar Morin does in the second chapter of Morin E., Ciurana É.-R., Motta R. D. (2003).

Main features and characteristics of a complex system: in the limited space we have here, we can summarize them proposing again a list of the key-words identified in a now classic educational text (Gandolfi A., 1999, pp. 97-99): high number of elements, non-linear interactions between the elements, delayed (both in time and in space) effects, presence of positive and negative feedbacks, network structure (cf. paragraph 2.A); it is also an open system, it is universal (because we can find analogous systems on various scales) system, it is dynamic, robust, creative and innovative, it is unpredictable, it has diversified sensitivities (presence of critical points inside it), it is non-manageable, it exhibits auto-organization phenomena, it is organized in hierarchical levels, its components maintain a certain behavioral autonomy, displays paradoxes such as the coexistence of stability and instability.

The observer approach: we want to conclude this short presentation focusing our attention on an essential series of consequences and collateral concepts, which it is good to be aware of:

A) the abandonment of the principle of cause-and-effect,

B) the abandonment of the concept of the "*tertium non datur*",

C) the acceptance of the unpredictability and the uncertainty of the evolution of the system,

D) the fundamental difference between complicated and complex,

E) the interference of the observer on the observed phenomenon,

F) the idea of "comprehension" as "compression" of information or data.

On these basis emerges an immediate comprehension of the reason why we talked about "complex cognitive paradigm" in the introduction (paragraph 1).

2.A The network structure of the complex systems

Any complex system has its own basic structure, an architecture that can be represented by a network presenting a series of topological characteristics able to foster specific behavioral dynamics of the system, such as its resistance to external attacks more or less targeted, or its capability to effectively vehicle information or viruses.

The study of networks and of their architecture has developed exponentially in the latest years, both because of the strong stimulus deriving from the need to understand the World Wide Web dynamics, and thanks to the vertiginous growth of the computational and memory capacities of computers; and also, finally, because of the parallel and increasing interest towards the neural networks, both natural and artificial.

The interesting fact is that the features and characteristics of the complex adaptive networks and systems are "universal": we can find them in the functioning of the cell as in ecological systems, in the Stock Market processes as in the spread (contagion) of ideas, fashions, and behaviors (*memetics*).

In the space of a little more than a decade, the studies of networks and their topology led us to establish the basis of a science that today is able to define the standard quantities to be measured in order to describe the complex networks (from the *degrees of separation* to the *clustering coefficient*), and its proper morphologies (*random* networks, *small world* networks, *scale free* networks, etc.). (http://www.slideshare.net/valerioeletti/a-cmplxmgmt-spoletovereti11a-go13ve27lug2013).

It is easy to deepen into these highly fascinating themes by means of good educational texts, easily accessible even to the non-experts, and written by researchers at the forefront in the network studies. We just mention here two of them: Barabasi A-L. 2002, and Buchanan M. 2003.

2.B Memetics

We mentioned the word "memetics" in the paragraph 2.A, *à propos* of the contamination of ideas, fashions, and behaviors.

This term arises debates since its coin, in 1976 by Richard Dawkins: someone speaks about it as a science, someone else as a simple metaphor, and someone claims it to be even a blunder (Jouxtel P., 2005, pp. 120-122).

But here we do not care about the scientific or not scientific status of the memetics: we can use it in any case as a cognitive instrument in order to ap-

proach the increasingly complex reality surrounding us.

We share therefore here a definition/description summarizing its useful features for our glance on the complexity education (these features are already widely employed in sectors such as the viral marketing):

"Behaviors, fashions, ideas, and religions extinguish and establish themselves in the social environment according to the sieve of natural selection, as the genes do in the living organisms. The memes spread in the social web with laws analogous to the plagues ones, with different speeds according to the environment they are operating in (cf. 2.A and the topology of the network). In the last century many powerful accelerators of memetic processes established on a global scale: first the cinema, the radio, and the telephone, then the television, all now exceeded in effectiveness and pervasiveness by the new digital technologies, and especially by the social networks on the Internet" (http://www.slideshare.net/valerioeletti/reti-memetica-e-contagio-di-idee-ecomportamenti-parte-33). If you want to deepen this matter I advice to refer to Susan Blackmore's volume, published in 1999.

2.C Complex structure of language and culture

The metaphor of memes, second kind of replicators appeared on Earth some billions of years after the genetic one, emerges from the concept of language and culture as evolutive, or better co-evolutive phenomena.

This means that we can (we must) use a systemic approach, a complex cognitive paradigm, not only to get close to the problems recently exploded together with the globalization, but also to move towards the roots of our very nature of human beings.

The topic is obviously incredibly articulated, eminently multidisciplinary, and full of hints for reflection and discussion. We are not going to face it now: we just mention it in order to give it the right place into an all-round discourse about the complexity education.

For an exhaustive overview of the problem we advice you the (easy and pleasant) reading of the famous book by Luigi Luca Cavalli-Sforza of 1996, published in Italy by Adelphi with the title "Geni, popoli e lingue". Mauro Ceruti summarizes (in Callari Galli *et al.*, 2003, p. 26) the Cavalli-Sforza's position in this way: "The relationship between genetic makeup and language is not causal – in the sense that the genes influence the language or *vice versa* – but resulting from a common evolutive history: the isolation, cross, and separation events that a population meets, select at the same time the genetic makeup and the linguistic expression. Thus these two spheres maintain an independent but parallel relationship"[5].

[5] "Il rapporto fra patrimonio genetico e lingua non è tanto di natura causale, nel senso che i geni influenzino il linguaggio o

3 Why: why educate for complexity

Why are we interested in networks and complex systems? And why are we interested in them as a whole, from the 21st century citizen basic education perspective? Summarizing and completing what has been exposed in the previous paragraphs, we can answer as follows:

A) because more and more complex are and are going to be society, our global world economy and finance, natural environments and the artificial networks we are plunged into or anyhow involved, the work world and the markets we are continuously in touch with, the sphere of information, commercial communications, and narration surrounding us;

B) but also because always complex are and had been (even if without our full awareness) physical, chemical, ecological, and social systems that we have been studying in a partial and reductionist manner until today: from the emerging of life from matter, and of the intelligence from life, to the propagation of physical plagues, of digital viruses, and of beliefs and fashions; from the interactions between different civilizations in the world history to the traffic problems of our cities.

And therefore, we are interested in complexity and in the complexity education both because of 'present reasons' – linked with the exponential development of globalization implications and of the network connection of these last decades –, and because of an as much dense series of reasons involving our origins – which we can call 'ancestral reasons'.

We therefore affirm that we consider the complexity education fundamental because it allows us to reread all the world inside and around us in a new way: an opportunity occurred, in an analogous manner, as much rich and revolutionary, just three centuries ago, after Newton's elaboration of his "scientific method". And we can not be contemporaries of a new way of looking at the world, and do not have even the faintest idea of what is profiling in the minds of thinkers and researchers, of scientists and philosophers, who are now strengthening the basis of the new complex knowledge which is probably going to be the characteristic of this century (if you want to have an initial idea of "how the collective intelligence is changing science", you can read Michael Nielsen's book "*Reinventing Discovery. The New Era of Networked Science*", 2012).

Now let us try to focus our attention on three different application areas of the complexity education: in general to "educate for the planetary era" (3.A), in concrete to face the digital globalization, namely Web 3.0 together with its

viceversa, quanto risulta da una storia evolutiva comune: le vicende di isolamento, incrocio e separazione cui va incontro una popolazione selezionano contemporaneamente il patrimonio genetico e l'espressione linguistica, di modo che i due ambiti mantengono una relazione indipendente ma parallela", translated by N. D'Elia.

big data (3.B), and in practice for the sensitization of managers and decision-makers who have now to move into an increasingly complex world (3.C).

3.A ... to "educate for the planetary era"

The dutiful reference about the complexity education as an instrument to educate young people for the new planetary era is the wide and detailed work made by Edgar Morin in the last decades.

As Mario Ceruti says, the challenge is that of "the emergence of a planetary humanity as a new evolutive chance for the mankind able to extend the range of chances of every individual and collectivity, and to strengthen the values of community, solidarity and participation, that are exactly the ethical incarnation of the cognitive idea of interdependence"[6] (Ceruti, 2003, p. 16). The aim is therefore among the highest imaginable.

And in such an overview, it is fundamental to understand the role of education, especially the one enhanced by the new technologies.

These, with their digital network enveloping the whole world and transforming us in active nodes of a connection increasingly rich in complexity, "opened a new, huge space of chance for the diversification of experiences, time, rhythms, places. Ours, then, is that time in which unity does not necessarily mean uniformity, and in which diversification does not necessarily mean atomization. The task of the educational institutions becomes that of valuing the variety and the diversification of the single individual experiences, weaving around them and together with them a rich texture of multiple connections"[7] (Ceruti, 2003, p. 23).

The literature about this topic is certainly wide; the advice, for those willing to read more about it, is to start from one of the many essays by Edgar Morin. We mention just two of them, whose Italian translation is also available: the first, "*Les sept savoirs nécessaires à l'éducation du futur*" (1999), is a lively small volume connecting the two previous books on this same topic (*La Tête bien faite and Relier les connoissances*, both published in 1999), and the next titles, such as the already widely mentioned "*Éduquer pour l'ère planétaire*", released in France in 2003 and translated in Italian in 2005.

3.B ... to face the digital globalization

[6] "dell'emergenza di un'umanità planetaria quale nuova possibilità evolutiva (sic) per la specie umana, che estenda lo spettro delle possibilità per ogni individuo e ogni collettività e consolidi i valori di comunità, di solidarietà e di partecipazione che sono l'incarnazione etica dell'idea cognitiva di interdipendenza", translated by N. D'Elia.

[7] "hanno aperto un nuovo, enorme spazio di possibilità alla diversificazione delle esperienze, dei tempi, dei ritmi, dei luoghi. Il nostro, dunque, è il tempo in cui l'unità non comporta più necessariamente l'omologazione, e in cui la diversificazione non comporta necessariamente l'atomizzazione. Il compito delle istituzioni formative diventa quello di valorizzare la varietà e la diversificazione delle singole esperienze individuali intessendo intorno ad esse e insieme ad esse un ricco tessuto di connessioni multiple", translated by N. D'Elia.

The complex cognitive paradigm is indispensable particularly for us to be able to face the social, economical, and political revolution brought by the exponential explosion of the amount of digital data collecting in the world's servers (the so-called *big data*), from which institutions and private corporations are extracting precious information, thanks to new and highly efficient instruments, such as semantic search engines, genetic algorithms, and neural networks. What are we speaking about?

Big data is a term (often used inappropriately) identifying a new territory, huge and varied, that we ourselves are creating, knowing little or nothing about it: a sort of primordial soup of our memes, an endless and still shapeless stockpile of digital data, going to collect themselves in databases, in different sectors: data coming from our geographic location when we make a call from a mobile phone, from our social networks profiles, from the websites we browse, from the sentiments we express via Twitter, from the health, economic, and financial data we commit to the various clouds thickening in huge racks full of servers.

Thus mines of information are formed, and inside them it is possible to identify veins as knowledge structures and current trend profiles. Two considerations:

A) by connecting the single 'mines' we obtain a set which is much more of the mere sum of the single data sets, a reticular and hyper-complex whole able to provide not only answers to old questions, but also to let emerge new questions of special strategic relevance for the world economies, for the environment, for the relations among nations, policy, and multinational corporations;

B) private and public finance are already running to develop effective "intelligent" (*semantic*) instruments useful to analyze and manage these huge masses of data, not to be tackled with the limited instruments used to capture, manage and process normal databases in a reasonable amount of time (we are speaking about several hundreds of *exabyte*, namely hundreds of billions gigabytes of information).

We can therefore assert that the big data explosion and the emerging of semantic Web (the so-called Web 3.0) represent a further stimulus for the development and the success (in management, marketing, policy, and finance) of a systemic approach, complex and reticular, with methods of computation and information processing relying on a new methodology of thinking: that based on the complex, circular, cognitive paradigm, considering the traditional linear reasoning – based on the cause-and-effect principle – just as a proper subset of a wider and more varied range of new possibilities of thinking, planning

and operating.

For an initial approach to these topics I refer to my brief essay released in Italian this year (2013), published by Guaraldi with the title "*Ricominciamo da Internet?*", and in English inside a collection of studies published by Aracne with the title "*Contributions to theoretical and practical advances in management*" (2013).

For those interested in the topic of big data, I advice the reading of a book just published in the United Kingdom: "*Big data. A Revolution That Will Transform How We Live, Work and Think*" by Mayer-Schönberger and Cukier K. (2013).

Finally, for those who want to access big databases of open data mutually related, there is a public Google (!) access: http://www.google.com/publicdata/explore?ds=d5bncppjof8f9_

3.C ... to give instruments to the decision-makers

In this time of great turbulence, when the individuals and the planet's populations are relentlessly carried in a new and unknown, globalized, interconnected, digitalized environment, the managers and the policy makers are at the forefront to identify new opportunities and new threats.

They are therefore, and on tight deadlines, the concrete addressees of the new education to the complex approach. In some countries such as France, the government supports with considerable sums of money schools of higher education dedicated to the sensitization of the ruling class (the current and the future one) to the systemic and complex approach: see, for example, the continuous initiatives of the Institut des Systémes Complexes, ISC, Paris (http://www.iscpif.fr).

Italy lacks a central coordination, but the initiatives - either local or particular, sector-based or general - keep multiplying every year.

In the paragraph 4.B you can see some of the most interesting case studies of the last years. Here we refer to a collection of theoretical analysis, practical experiences, and multidisciplinary considerations giving the cross section of the Italian condition in this respect: it is the rich volume "*Decisioni e scelte in contesti complessi*", edited by Sergio Barile, Valerio Eletti, and Maurizio Matteuzzi, and published by Cedam in 2013.

4 How: how to educate for (and with) complexity

The first problem we have to think about when beginning an itinerary of sensitization and education for complexity, for the complex thought, for the systemic approach, is that of identifying learning processes that do not simplify

concepts – thus destroying the idea itself of the emerging of new concepts from the weaving together of non-linear and interconnected elements.

As we saw through the structure of this paper, the plan must be reticular, non-sequential; and it must operate both on the individual learning process, and on the process originating from the interaction with the other learners, in a social constructivist perspective.

Today we can identify three big non-linear methodologies families, aimed to the sensitization and the education for (and with) complexity:

A) frontal lectures, either online or blended, designed in order to give the learners not a rigid sequence of concepts but a series of stimuli, readings, considerations, inductive and deductive moments strictly connected with each other, and capable to raise discussions between teacher and learners, and between the learners themselves in a social constructivist perspective, through the so-called learning 2.0 (see the case studies presented in 4.B and those provided by De Toni, Cravera, Gandolfi, Forino, and others in Barile, Eletti, Matteuzzi, 2013);

B) project works based on manipulation (or even on construction) of evolutive environments: key-landmark in this genre of non-linear learning instruments is certainly NetLogo, together with its software and algorithms easy to process, and with its library full of hundreds of models based on the parameterized evolution of cellular automata, in many and various disciplines: from art to biology, from computer science to the networks, from the social science to the systems dynamics ("*NetLogo is a multi-agent programmable modeling environment. It is used by tens of thousands of students, teachers and researchers worldwide*" - http://ccl.northwestern.edu/netlogo/);

C) *edutainment* based on simulations, business games, serious games, and other interactive games both in single player and in multiple players mode, both in classroom and online; from our perspective the extremely interesting thing is that these games, being built on reticular, hypertextual and interactive itineraries, are based, in turn, on engines complex and reticular (for details see 4.A): engines composed either by systems of equations developed top-down in a system dynamics perspective, or by neural networks built bottom-up gaining historic information from pre-existing databases; it is easy to realize that it is possible to make a further step for the more advanced courses, proposing project works where learners are involved in the design and in the formation of simulations with engines of both types (http://www.slideshare.net/valerioeletti/complexity-education-by-valerio-eletti-34).

Summarizing, we can say that the levers to be used in the complexity education are the non-linearity of the learning process, the crucial engagement of the learners, using deductive and inductive phases, the constructivist and social formulation of the learning processes, the ludic engagement on reticular, hypertextual and interactive itineraries, the neural networks, cellular automata, and genetic algorithms experimentation.

4.A Focus on the digital network instruments

In sensitization and education for (and with) complexity, the new digital technologies are increasingly used. As an exemplar case, we here analyze the more intrinsically complex instruments among those presented in point C) of paragraph 4, namely the **simulations**, topic of a special Je-LKS I edited for the number 2 of 2009.

Let us start from stating that, since some decades, all the education inserted in a cognitivist and constructivist perspective of learning, can be normally and automatically be included in the paradigms of complexity, of networks, of feedback loops, of bottom-up processes.

We see that the linear and sequential use continues to constitute the great majority of the e-learning nowadays diffused in Italy and worldwide, even if we have to distinguish between the courses consciously and properly designed in this form (for example the tutorials), and those planned in this way because of laziness, wrong analysis of the learning process, or because of urgent economical reasons that flatten the online education on behaviorist mechanisms now obsolete even in classrooms. But it is undeniable that effectiveness, efficiency, and appreciation by the learners can be found nearly exclusively in interactive, ludic, non-linear itineraries, based on an engaging, reticular and interactive learning perspective.

We now approach the simulations, reminding their basic typologies, and referring to Je-LKS number 2, 2009 for a more detailed taxonomy:

A) laboratory simulations (*Lab Sim*) based on cellular automata and evolutive algorithms;

B) participative simulations (*Tale Sim*) based not only on trees and charts, but also on dynamic systems and neural networks – especially bayesian ones;

C) mixed simulations (*Tale Lab Sim*) presented with management dashboards, typical of many business games.

What are the characteristics distinguishing the two extreme models (the mixed one is a derivative)? And what engines do they use?

Tale Sim: participated simulation; personal experiences simulated; simulation similar to stage, theatre. Features:

- simulation made to inhabit, live, travel, explore, personally (subjectively or in avatar form);
- the user is the actor (or one of the actors) of the story and/or of the environment to explore;
- this is an explicit learning itinerary (on the contrary of the Lab Sim);
- learning can pass either through the personal navigation into a story and/or a virtual environment (more or less immersive), or through the interaction with other people or avatars in the environment;
- the learning phase is normally ended by a debriefing.

The model (engine) can be based on tree paths or charts, on dynamic systems (systems of n equations in n variables), or on neural networks (trained on bayesian networks); for details, even technical, see Ronsivalle G.B., 2005 and 2013.

Lab Sim: laboratory simulations in which the user is an external observer. Features:

- virtual laboratories in which autonomously develop (evolve), on the basis of the parameters established by the user from time to time, phenomena or populations the user observes, explores, analyzes, in order to glean a knowledge of the internal mechanisms of the phenomenon and its processes;
- the learning phase is distributed between briefing, observation and consequent analysis, reflection and/or discussion according to assessments and pre-constituted guidelines (Landriscina F., 2009, cap. 6).

The model (engine) can be based on the evolution of cellular automata or on dynamic systems (systems of n equations in n variables); in this case it is impossible to use guided tree itineraries or charts.

4.B Case studies

In this island of contents we now provide some concrete cases to be used as a landmark for the sensitization and the education of decision-makers and managers for the complex cognitive paradigm.

We took as case studies, among the many available, five educational courses realized in Italy, France and United States from 2006 until today: we are now going to identify their fundamental features, their differences and methodological similarities.

2006. Educating managers in complexity. European project financed by the "Leonardo da Vinci Programme" through the Isfol Italian Agency, managed by the consortium "Cetra – Learning Complexity", and coordinated by the University of Modena and Reggio Emilia, Italy; partners from Germany, Spain, Belgium, Austria, Portugal and Hungary.

Targets and aims are clear from their very presentation: "*Cetra uses the Science of Complex Systems to concrete support for vocational trainers to help them (and their students) to understand change and the relationship between different levels of change. By learning bout complexity (e.g. complex networks, generative relationships, non linear dynamics, and dynamical self organization) the target group shall be enabled to understand the dynamics of the internal and external processes in which organizations engage and in which knowledge, innovation and emerging technologies are created*" (Villani M., 2006, p.295).

Instruments and methods: the originality of the project was not in the instruments employed (which were still constituted by the traditional classroom) but in leading to the dignity of University course the study of the new cognitive paradigm, by means of applying it particularly in some higher education courses of management.

Result and comment: the specialized and definitional contributes, the syllabi, and the programs of courses planned by the consortium are all very interesting and still valid. They are collected in the volume and in the attached CdRom edited by Marco Villani, 2006, purchasable online on this website: http://www.libreriauniversitaria.it/educating-managers-complexity-cdrom/libro/9788854812406

2008. Second French Complex Systems Summer School. Higher education course dedicated to graduate students and researchers in any branch of knowledge, and coming from every region of the world, all involved in understanding what complex systems are.

We are focusing here on the second edition – the one attended by the author – of the summer school taking place every year since 2007.

The summer school is organized by the national network of the French Complex Systems Institute ISC (namely by ISC-PIF Paris Île-de-France and IXXI Rhône-Alpes di Lyon), supported by CNRS, INRIA, and by other French institutions and universities.

Something about the 2008 edition: the first part ("Fundamentals of Complex Systems") was held at the Ecole Normale Superieure in Lyon; the second one ("Advanced Topics and Practice") at the ISC in Paris.

Targets and aims are clear from their very presentation: "*The aim of the school is to provide in-depth reference courses to a multi-disciplinary audience*

of researchers and students. The level of lectures will range from introductory to advanced, as attendees are not expected to be familiar with all the fields covered. Lecture topics will address specific objects from various disciplines pertaining to complex systems (physics, biology, sociology, etc.), or interdisciplinary tools and methods (mathematical, computational), or both".

Instruments and methods: were still constituted by the traditional classroom, with the important support of collective project works.

Strong points of this experience of complexity education have been the inter-disciplinary planning and the rich international exchange of views: in fact, teachers were coming from different French, American and Canadian universities, and students were coming from Europe, China, Russia, Siberia, Latin America and Africa.

References and material: using Google, it is easy to find and download all the programs, all the abstracts and all the slides of every course of every one of the seven editions of the summer school held from 2007 to 2013. Anyway you can find materials of the 2008 edition here: http://www.iscpif.fr/Summer%20School%202008... and the last edition, held in 2013 and entitled "*Collective Behavior and Mobility in Complex Systems*", here: http://www.iscpif.fr/tiki-index.php?page=CSSS2013

2010. Complexity education. Introduction to the complex thinking. Higher education course dedicated to the managers of the *Ministero dello Sviluppo Economico*, to the PhD students in Scienze della comunicazione and in Ingegneria gestionale: ideated and projected by the work group "Complexity Education Project" (http://www.complexityeducation.it) of the LABeL, the laboratory of e-learning of the Research Center Cattid, Sapienza University of Rome, the higher education course was financed and hosted by the *Istituto ISCOM, in the Dipartimento per le Comunicazioni of the Ministero dello Sviluppo Economico*, in Rome.

Aims: "*A) make the learners aware that what is complicated can be simplified by reducing it to linear working plans, while what is complex must be faced in its whole, considering the non-linearity of the processes and abandoning the dangerous illusion that a rigid and hierarchic control can lead to success; B) introduce the learners to the complex way of thinking and to the complexity theories [...]; C) accompany the learners in the construction of cognitive bridges between disciplines apparently distant from each other, such as network technologies, management, and interpersonal communications [...]; D) let the learners acquire the conceptual and algorithmic instruments that can allow them to consciously face complex problems in complex environments*".

Instruments and methods: the first phase of the course took place in a

classroom, divided in turn in a first general part and in a second part dedicated to the case studies, with group analyses and open discussions; in a second phase, in 2011, the classroom video shootings had been elaborated and edited, by connecting them with the contents showed in the slides, and thus creating some learning object in "extended-e-learning" format (Eletti V., 2002), and therefore rich in interactions and inductive passages alternating to the deductive ones.

References and material: here it is possible to download the program, the abstracts, the slides, and the learning objects made in extended-e-learning: http://www.isticom.it/index.php/archivio-eventi/6-articoli/175-complexity-education-introduzione-al-pensiero-complesso

2013. 1st CMSS, Complexity management summer school. Full-immersion educational experiment, residential, for entrepreneurs, managers and work consultant: organized by the Complexity Institute (participating to the *Francisco Vanela Project*), in it teachers and learners – in an unusual one-to-two proportion – have been working on theoretical concepts, case studies discussion, and laboratories. Location: the ancient Agghielli Monastery, in the middle of the woods on the hills above Spoleto, for two weeks, between July and August 2013.

Aim: the CMSS is dedicated to the "*knowledge and the deepening of the complex systems tackled in a managerial perspective. Every year the attention in focused on one aspect of the complexity management through teachings, debates with specialists, individual and team works, generative dialogues with the teachers permanently available*".

Instruments and methods: in this case we have two phases, too: the first based on the intensive co-learning formula: a permanent share "participants-teachers-specialists" on the topics of complexity in the areas of the *business organization* and the *complexity management*; a second phase (still under elaboration while this paper is being written) based on the creation of a community of practice, to whom the slides editing and the shoots of didactic unities will be distributed as starting material to share online.

Results and comment: it has to be underlined the great effectiveness and the high appreciation of the so-called "*generative meetings*", taking place in the afternoon, together with guests and testimonials sharing and discussing their case studies.

The final laboratories also turned out to be precious instruments: during them all the participants built together the concept map of the course, and the social network born and adjusted during the two weeks of full-immersion and cohabitation in such an isolated, peaceful place.

Reference and material: program, abstract, and slides can be found online

on the *Complexity Institute* website: http://www.complexityinstitute.it/?page_id=2013

2013. Complexity Explorer. Here we are facing something opposite to the 1st CMSS: no full immersion and no strong interactions between teachers and students, but *Massive Open Online Courses* (Mooc), built on the basis of the guidelines of a traditional lesson in classroom, with the support of online discussions and collective workshops.

Complexity Explorer is the new online school of the Santa Fe Institute, the well known American research center founded in 1984. A few months ago it started to put online basic and advanced courses dedicated to different aspects of the complexity, both theoretical and practical.

Very esteemed teachers are involved, such as Melanie Mitchell who manages the online course dedicated to the *Introduction to Complexity*.

While this paper is being written, she is going to start the second edition of her course, that in the first edition – held before summer – collected on line more than 70 thousand students from all over the world.

The planning of the course is very simple (shooting of linear lessons), but it is enriched by collective project works shared online, and open discussions about some basic topics: "*What is Complexity? Dynamics and Chaos. Fractals. Information, Order, and Randomness. Genetic Algorithms. Cellular Automata. Models of Self-Organization. Cooperation in Social Systems. Scaling in Biology and Society. Networks. Wrapping Up; Virtual Field Trip*".

The strong point of the course is certainly the "Virtual Laboratory", consisting of "*open-source simulation programs illustrating complex systems ideas, theories, and tools, accompanied by curricula designed for both teachers and independent learners who want to take advantage of these simulations*".

Reference and material: you can choose the course you are interested in, sign up with no charge, and follow the lessons, starting from this web page: http://www.complexityexplorer.org

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