Opportunities and challenges in teaching Systemic Design. The evoluation of the Open Systems master courses at Politecnico di Torino

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PRESENTACIÓN:

Estimados lectores:

Con esta tercera edición retomamos de nuevo la difusión de material de investigación centrado en los sistemas y el diseño. En este segundo volumen se recogen tres números correspondientes a los temas: Aspectos intangibles, Funciones de transformación y Aspectos tangibles; que comprendieron el **"6th International Forum of Design as a Process. Systems & Design: Beyond Processes and Thinking"** celebrado en Junio de este año en la Universitat Politècnica de València y del cual este equipo editorial, siendo parte de la *Red internacional de investigación en diseño (rDis),* junto con la *Latin Network for the Development of Design Processes (LNDP)* tuvimos la oportunidad de organizar*.*

Este número en particular (V2N1) corresponde a los *Aspectos Intangibles* que intervienen en el universo de la información inmaterial en las diversas dimensiones: sociocultural, económica, tecnológica y territorial; obteniendo como resultado: leyes, teorías, tesis, teoremas, etc… que favorecen el desarrollo del conocimiento humano de su entorno.

Desde **rdis®** esperamos que este material sea de interés y que contribuya a la motivación de los actores que intervienen en el desarrollo de la temática abordada a publicar en futuras ediciones.

Dr. Bernabé Hernandis Ortuño
Director **rdis®**

Opportunities and challenges in teaching Systemic Design

The evoluation of the Open Systems master courses at Politecnico di Torino

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Abstract

The contamination between design and theory of systems as a field of development of new design processes is nowadays consolidated. However, the issue concerning the methodology to apply in teaching systemic design remains an open question.

The approach adopted in the Master Degree in Systemic Design at Politecnico di Torino is based on the assumption that the teaching method must itself be systemic. Alongside designers, the degree course has involved from the very beginning experts from different disciplines (i.e. chemistry, physics, mechanics, history, economy and management) as teachers, in order to create a multidisciplinary environment for the development of projects. Born as master degree in academic year 2002-03 at Politecnico di Torino (Italy) from the close collaboration with Gunter Pauli, the course has changed name and form but not the content, until it reached the current title (a.y. 2015-16): master degree "Aurelio Peccei" in Systemic Design.

The Open Systems course has enabled students, in early years, to experiment the design of production processes. This was the case of the systemic project done with NN Europe, a company engaged in manufacturing ball bearings, in which the output management allows a positive economic impact. Over the years the course has shifted its focus from the production process of a single product to the wider company context. In 2010, the approach has been applied to the agricultural enterprise Ortofruit: starting from agricultural production, the students have defined the production system and the relationships with the market. Systemic Design, during this course, has experienced the transition from the design of industrial processes that are closely linked to the territory, and then enhance local resources, to the design of the whole territorial system.

The work done by the students of the course in recent years has led to the definition of scenarios about fields usually distant from the traditional design world. For example, the definition of the economic model, the corporate model that is built around relationships on cooperation with different disciplines.

This transition, from the product to the entire territorial system, allows the exploration of new contexts, but it also puts the designer in a complex and challenging position in according with complex theories.

Keywords: systemic design, education, sustainability

1. Background

Teaching, and learning, is a complex process that involve many variables with non linear accumulative effects (Dhindsa et al., 2010). The complexity doesn't decrease with the higher level of education, neither when the content of the lectures is related to the the Complexity Theories. That is exactly the case that we are going to discuss in this paper, because we analize the educational model in teaching Systemic Design Theories and its relation with the other Complexity Theories at Master Degree level (Politecnico di Torino).

More studies bring the research-practice gap in education changing research methodologies that modify the teachers as collabborators (Krockover & Shepardson, 1995) or the teachers as researchers (Pekarek, Krockover, & Shepardson, 1996). Krockover & Shepardson, in their introduction of the Journal of Research in Science Teaching (1995) underlined the need of "a more holistic image of education in which researchers investigate the interplay among the learner, the teacher, and the nature of the curriculum, instruction, and assessment". The new figure of teacher has a systemic view of schools and community, in order to develop a collaborative relationship with students.

From the classical meaning of the word education, it derived from the Latin ex-ducere, so "draw forth from within". This concept emphasize the fact that the teacher should not put in information in students, but the learner build internal representations of new experiences in relation to past experiences (Anderson 1992). This kind of education was formally defined as Costructivist Learning Theory (Piaget, 1950), with its psycological applications, for axample with Bodner, 1986; Driver & Oldham, 1986; Novak & Gowin, 1984; Von-Glasersfeld, 1988. This theory is based on the active role of the learner in costructing interpretations of experience and in sharing with others common cultural experiences, in order to organize a set of informations. In that perspective, "the most important single factor influencing learning is 'what the learner already knows' " (Ausubel et al. 1978). Building a knowledge in memory is strictly connected with the ability of reasoning, understand concepts, and connect them with prior conceptions. Those kind of activities are crucial for effective learning, because they require a process of setting many information at a time, which is facilitated by the organisation of prior knowledge (Mitchell & Lawson, 1988). Hence, the teaching tecniques should help the students to organize their knowledge in memory and enhance learning of complex scientific ideas. The students should be actively involved in order to reconciliate disparate prior conceptions with more scientifically accepted new information in order to resolve inconsistencies, represent scientific content in a conceptual way, and build the knowledge organisation (Ebenezer and Gaskell 1995; Linder 1993; Nieswandt 2001; Smith et al. 1993). Therefore, in this process in which new information are built, the previous knowledge may be subjected to transformations, such as conceptual growth or, even, change because the learner actively attempt ways to merge new insights within existing frameworks.

The Constructivist Learning Theory comes from the same theroetical basis of the more recent Systemic Design Approach, that is the content of the lectures we are going to analyse and discuss. The use of Constructivist Learning Theory in theaching Systemic Design is coherent and effective.

The complexity theories evolved on the basis of the General Systems Theory by Karl Ludwig von Bertalanffy (1968), so some of the next rationales applied this theory on different artificial systems, such as the Generative Science. This trans-, inter-, and multi-disciplinary theory explores the natural world and its complex behaviours as a generative process (McCulloch et al., 1948; Wiener, 1948). From General Systems Theory have grown ideas within diversified areas, exemplified by the ecosystem ecology by Eugene Odum (1975), the living systems by Fritjof Capra (1997), the organizational theory by Peter Senge (1990), the financial research related to human resource development by Richard A. Swanson (1988), and so on.

The Systemic Design theory considers productive industrial organization as complex adaptive systems with the same behavoiur as the Nature has, where there is no waste because all the substances are used as resources by another natural reign. This approach comes from the Cluster Theory (Porter, 1990), the Industrial Ecology (Frosh & Gallopoulos, 1989) and the Industrial Symbiosis (Chertow, 2000).

The content of those theories are complex and need a large number of information already in the prior knowledge of the learner, so they were usually taught at Master of Science level of degree. At Politecnico di Torino, the academic curriculum in design has three levels, and in the first one (bachelor degree) just some theoretical basis on Systemic Design are taught, but in the second level (master degree) is totally focus on it, not by chance its name is "Systemic Design, titled to Aurelio Peccei", and in the third level (PhD corse) the research and the learning in that topic is mixed. In that paper we are going to go in deep with the teaching and learning of Systemic Design in the Master degree because it is the most crucial moment for learners.

2. Aims and Objectives

This study aims to examine the educational model used to teach complexity theories at university training and its benefit in the professional carriers of the students in different working activities. In additon, the specific analysis on the master degree courses in Systemic Design at Politecnico di Torino is used to answer the following research questions:

1- the use of teaching/learning theory close to complexity approach, like Costructivist Learning Theory, is beneficial in teaching/learning the complexity theories, like Systemic Design topic?

2- What are the competences needed for teachers and students?

3- What are the tools and the tecniques used by teachers in the process of new information acquisition by the learners?

2.1 Methodology

The subjects of this study were the students and professors of the Master Degree at Politecnico di Torino in Ecodesign, since academic year 2002-03, and then in Systemic Design, since academic year 2015-16. The students are about 100 per year (except for the first three years, where we can see an esponencial growing from 20 students to 80), and they are coming half from the other italian universities and half from the rest of the world with different academic and cultural background. Prior to being in the master classes, they had different academic curricula, not only in design but also in architecture and engineer. The lessons were in English despite it is the second or third language for both students and teachers. To have a complete documentation about the nature of the experimentation, we have collected data using observation instruments and students' visual mapping and reports.

The observation is made up of two components: the former is the historical evolution of the structure and content of the master courses in Open Systems at Master Degree in Ecodesign/Systemic Design (Politecnico di Torino), the latter is the actual learning model used in the lectures by different professors in the same course. The historical evolution analysis considers the wide changes in the organisation of the courses and the content of the project during the years (from academic year 2002-03 to 2015-16), in order to verify if there is an increasing of complexity also in the way to face the Systemic Design projects. The analysis on the actual learning model goes in deep on the taught methodology, in order to understand the convergence between the model and the content.

The limit related to these two observation is the absence of comparison with other courses in some other institution, but unfortunatly any other university in the world has an entire master degree course lasting two years in that topic with the contribution of many disciplines. Many other universities have singular course on Systemic Design and Complexity Theories that last one year, at maximum.

The final considerations of these two observation are enriched with the Alma Laurea's data about the rate of satisfaction of students and their rate of employment after the degree, in order to understand the real benefit in their career and what kind of information pass through the long term memory. The Alma Laurea is an Italian consortium that groups 72 university in the Country, with the purposes of collect the evaluation from graduates and of publish their curricula to match with the job market. This data set is extremely interesting because it collects first hand information from the primary engaged actors and because it keeps track of time and its changes.

3. Results and discussion

The Master Degree in Ecodesign/Systemic Design at Politecnico di Torino has involved from the very beginning experts from different disciplines (i.e. chemistry, physics, mechanics, history, economy and management) as teachers, in order to create a multidisciplinary environment for the development of projects. Born as master degree in academic year 2002-03 at Politecnico di Torino (Italy) from the close collaboration with the economist Gunter Pauli, in the last year, the course has changed name and form in Systemic Design, titled to "Aurelio Peccei". This master degree was organized in 4 modules: Virtual Design, Innovation, Product Components, and Open Systems (in chronological order, once a semester). Those modules have an increased complexity in the taught contents, and especially the first one gives the basic also for the visual representation of multiform concepts. Each semester a single complex project should be designed by the students with the help of different disciplines, explained by different professors.

In the last years, one more modules was added (Atelier inside/outside) in collaboration with the master degree in Architecture, so students can freely choose between this one and Innovation. The enlargement in the academic offer it is a way for the students to define better their competences and curricula.

The Open Systems course is mandatory and it is the last course before the degree. It includes contributions in various disciplinary fields (see figure 1): Systemic Design (design), Environmental Sustainability Processes (engineering), History and theories of Systems (humanities), and Economical evaluation of projects (economics). The core teaching in this module is the configuration of a new development model (economic and social) in which the outputs of a system become input of another one (Bistagnino, 2009).
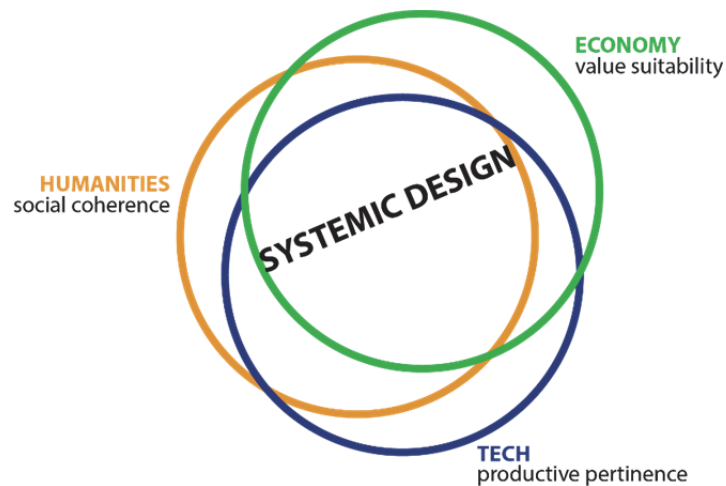
Fig. 1 Disciplines contribution to Systemic Design.

The projects developed in Open Systems module have seen an evolution in content: in early years, the students experimented the design of production processes related to single product, then of wider company context, and of industrial processes that are closely linked to the territory, and its local resources, and finally the design of the whole territorial system. The first step of this escalation was the case of the systemic project done with NN Europe, a company engaged in manufacturing ball bearings, in which the output management allows a positive economic impact. The second one, around year 2010, was the project with the agricultural enterprise Ortofruit, that has many different industrial processes and gives the chance to understand the relationships between local production and the market. The last step involves the students in the definition of scenarios about fields usually distant from the traditional design world; for example, the definition of economical model, the corporate model and other cultural paradigms (see figure 2). This transition, from the product to the entire territorial system, allows the exploration of new contexts, and puts the designers in a complex and challenging position in according with complex theories.

Fig. 2 Results of Open System module at academic year 2015-16 with different cultural paradigms.

The methodology taught and applied in Systemic Design project consists of a preliminary Holistic Diagnosis, the definition of design eco-guidelines, the systemic design project and its implementation. The Holistic Diagnosis considers natural, anthropic, social and economic aspects of a context and it is organised in three steps (see figure 3):
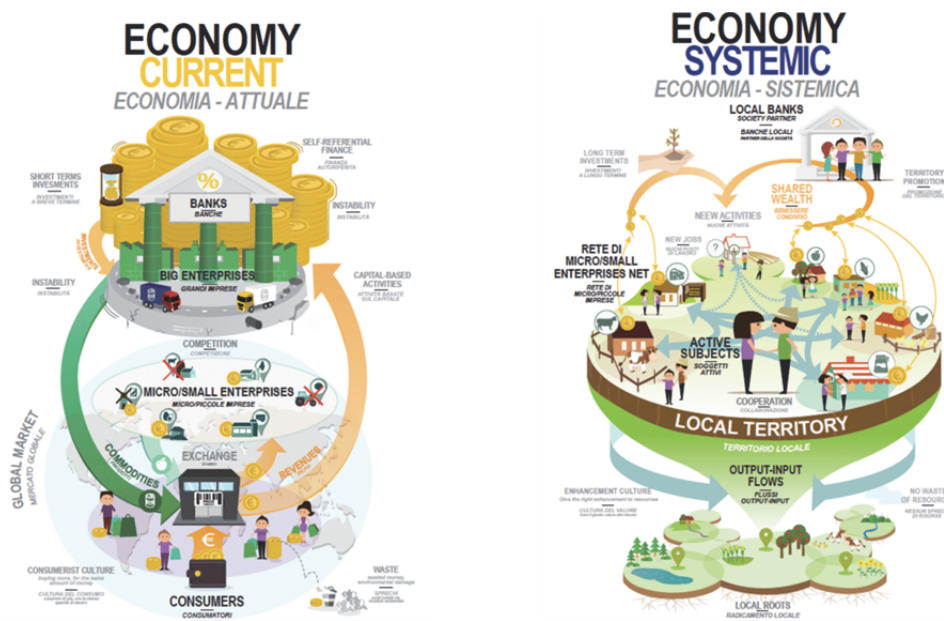
1- desk reseach on Exhisting information, with a mix of quantitative and qualitative data (from database, statistics, reports, case studies, scientific reviews, general readings, to social media);

2- field research to Integrate information, with a mix of quantitative and qualitative data (from data recording, mapping, case studies analysis, survey, perception, to emphaty);

3- research synthesis with Information Design Visualization, in order to have the data correlation and its visualisation, the list of criticalities (needs, problems, etc.) and the lists of potentialities (resources, etc.)

The first two steps derives from the theories of Celaschi and Deserti (2007) about the combination of desk and field research in design processes; especially the reiteration of these two steps is marked by the gap analysis and the visual framing in order to fulfill all the information needed to complete the holistic diagnosis. The crucial function of visualisation will be deeper faced later on in this paper.
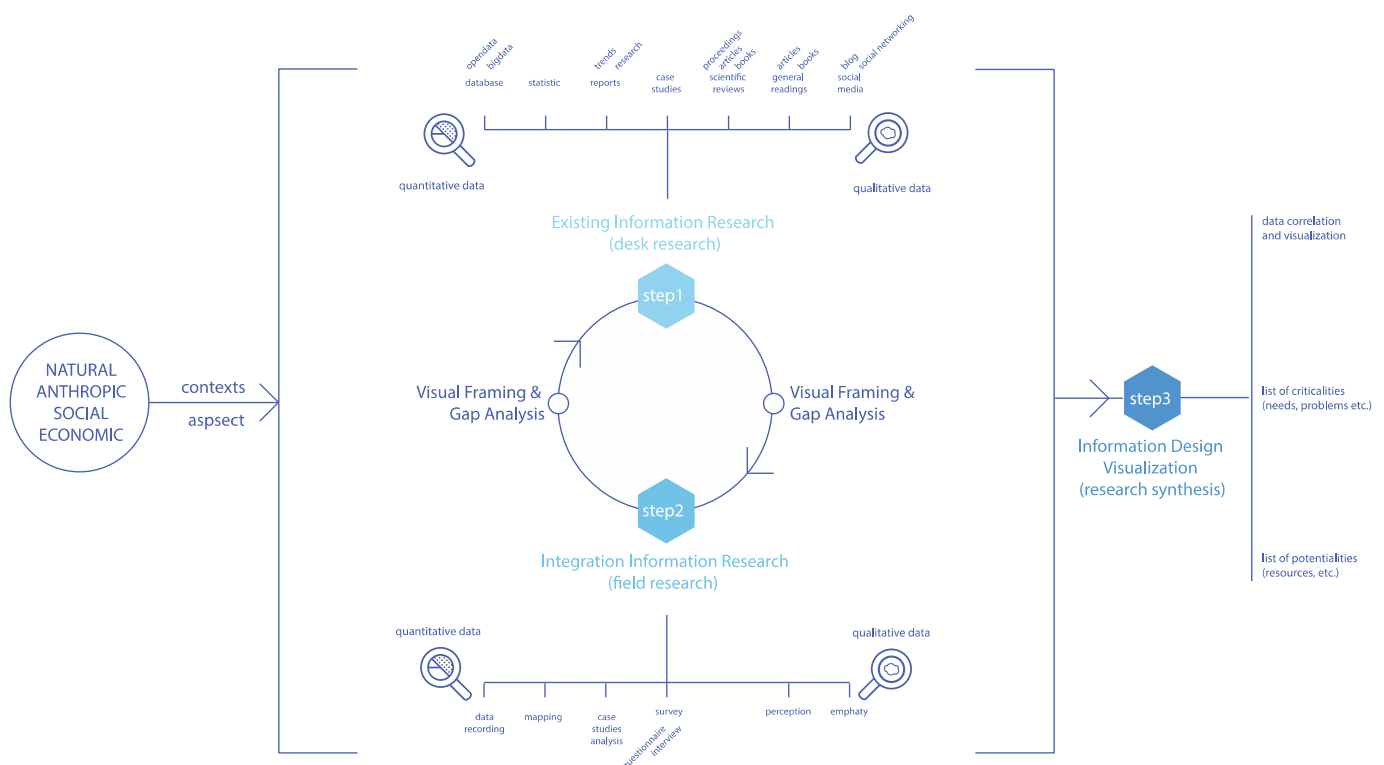
Fig. 3 Results of Open System module at academic year 2015-16 with different cultural paradigms.

With the complex data visualised in different maps and lists that underlines criticalities and potentialities, the designers can gather the design eco-guidelines in order to start the design of the entire system. The goal of the design phase is to optimize all the energy and material flows in the system and to valorize all the waste as resources, in order to obtain zero emissions. The last phase is the implementation of the system with the realization of the system in the specific context and the evaluation of the feasibility of

new business plan. The implementation of the project gives a lot of new input to improve the project and let it autopoietic (Maturana et al., 1972).

During the lectures, students are challenged by new experiences that require them to rethink their understanding based on scientific evidence from past experiences. The work is organised in small group in order to foster contrasting ideas, encourage reflection on experimental data, and motivate them to evaluate again and again prior ideas in relation to emerging evidence. In this way the students are forced in a conceptual change process where the brain actively interprets new experiences based on the mobilization of stored information in memory as a framework for the new knowledge construction (Anderson, 1992). One of the crucial aspect in the development of the lecture is the use of visual mind mapping by the students, every time new information and concepts come out. This is a technique of representing knowledge by organizing it as a network or other non-linear diagram incorporating verbal and symbolic elements. In general, this technique is consistent with modern constructivist approaches to learning, and emphasize the active involvement of the learners who utilizes existing knowledge structures to construct new knowledge by inter-relating new content with existing knowledge in memory. Longo, Anderson and Wicht (2002) demontrated how this tecnique helps the students to organize their knowledge and make it more salient in long-term memory, compared to the more traditional lecture-centered format of teaching. Mind mapping teaching techniques, compared to some traditional methods that emphasize ''knowledge transmission from expert teacher to novice students,'' are more student-centered and involve students' active participation in the learning process. During discussion, students were encouraged to share ideas and reach an agreed-upon structure for the organisation of their ideas, and to fix them in visual maps. In such a student-centered learning environment, the students have a crucial role in the organisation of learning activities, in order to build a more effective and efficient set of new knowledge. However, a limited number of organised lecture presentations are included, assuming that the teacher has taken care to determine the prior status of the students' learning and to engage them in multi-modal learning activities. The quality of information organised in students' cognitive structures help them to reconstruct correct information quickly and to accurately answer questions during discussions and examinations. Thus the constructivist-visual mind map teaching approach may enhance more broadly students not only in academic performance, but, better, in solving problems in daily life.

Recovering the data from Alma Laurea, we can say that this Master of Science is dense of contents, so generally students take a little more time than the convential 2 year to reach their degree. However, the final score is high, on average: about 30% students gain the 110 with honors. Furthermore, the data shows a good interection between students-professors, with highest rates about the satisfaction of students in the availability of teachers (83%). A very positive rate is given to the general satisfaction of the degree course, with the 88% of positive answers and the 63% of the graduates that state their wish to sign up again in the same master degree. To confirm this data, we have done a cross-evaluation with the data collected in "Comitato Paritetico per la Didattica" (CPD) Questionnaires by Politecnico di Torino, supervisioned by the internal Joint Committee for Education. In those questionnaires the students reveals the high utility in attendance the educational activities for learning purposes (64%).

Reflection on learning outcomes and market demand is mirrored in the results of the consultation with the professional members of the Consulta, that confirmed the validity and effectiveness of the Master Degree as a whole. About the employment status, one year after the graduation, the 73% of graduates work in the systemic design field.

4. Conclusion

We would like to especially underline that the consistent use of visual maps in a constructivist teaching environment significantly improves information organisation in students' cognitive structures. The students of the master degree in Ecodesign/Systemic Design are exposed to a constructivist teaching and learning environment, because they are actively engaged cognitively and operatively in reflectively processing information that is presented in a way that encourages the learner to relate new knowledge to prior existing knowledge in memory. The theoretical advantages of using mind maps in learning is partially rooted in scientific evidence that early visual processing systems of the brain categorise visual input into constructs of colour, shape, location and motion (Ungerleider 1995). Prior published research has documented the validity of using flow-mapping as a representation of knowledge organisation and its effects on science learning outcomes (Anderson and Demetrius, 1993; Dhindsa and Anderson, 2004). This technique also has been successfully used in a number of studies involving constructivist teaching to obtain evidence of students' cognitive structures. The benefit of using visual maps is blown for that reason the first module of the Master degree is in Virtual design.

Evaluating the results explained in previous paragraphs, we can say that the Master Degree in Ecodesign/Systemic Design at Politecnico di Torino, really embodies the complexity theory also in teaching models with the adoption of Costructivist Learning Theory, and it achieves with the practices the real sense of project. The term project derives from the Latin words: pro-jacere, so throw forward. Looking at the projects done every year by the students, we can see how their contribution to the community is very broad and pitches the next twenty years.

In the end, we can conclude the graduates are open and willing to express critical opinions towards the subject, ready for negotiations. These results suggest that the cognitive structures of master students are extensive, robust, and interconnected.

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