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Design as a systemic activity: Elements of problem interpretation in the construction of training models in design education

Design como uma atividade sistêmica: elementos do problema da interpretação na construção de modelos de formação na educação de design

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Abstract

Based on the ongoing reorganisation of design studies at the Design Faculty at Politecnico di Milano, this article explores processes of training for design activities, with particular focus on instances where the design project is a complex system in which the final product (whether physical or immaterial) is considerably less significant than the set of practices and dynamics that exist both upstream and downstream of the process of defining that product. The focus is in particular on identifying innovation potential that emerges during the initial phase of the design process – commonly defined as The Front End of Innovation – in an attempt to define a profile of a design graduate with competences that can be applied in this phase of the innovation process.

Key words: design and systemic approach, products and process, incremental innovation and radical innovation, design and education, design and operative judgment.

Resumo

Com base na reorganização em curso nos estudos de design da Faculdade de Design do Politecnico di Milano, este artigo explora os processos de formação para as atividades de design. Destacam-se os casos em que o projeto de design é um sistema complexo e em que o produto final (físico ou imaterial) é consideravelmente menos importante do que o conjunto de práticas e dinâmicas que existe tanto a montante e a jusante do processo de definição do produto. O foco está na identificação do potencial de inovação que emerge durante a fase inicial do processo de projeto - normalmente definido como *The Front End of Innovation*, em uma tentativa de definir um perfil de um projeto de pós-graduação com as competências que podem ser aplicadas nesta fase do processo de inovação.

Palavras-chave: concepção e abordagem sistêmica, produtos e processos, inovação incremental e inovação radical, design e educação, design e julgamento operativo.

The nature of design complexity: some clues

In comparison with more recent design spheres such as fashion, services, and communication, product design has a fairly consolidated cultural, educational and professional tradition, nevertheless – or perhaps as a result – it is also the area that risks, being unable to absorb (especially in the static and inflexible word of education) the profound changes taking place in design culture in general, and in particular in the sphere dedicated to the tangible side of the articial word.

Some familiar themes from the debate design, and in particular product design, are reappearing in new guises, demonstrating that it is a scattered discipline that evolves continuously, and thus is forced to reflect on its theoretical status – in fact, even on its status as a discipline. This is happening in the educational environment where transmission usually involves knowledge that has been filtered, codified, and to a large extent stabilised.

Without attempting to address issues that might distract from the purposes of this paper, it will be identified a few more or less recent questions that are crucial to the task at hand.

By way of example, it will be listed only a few of the issues constituting part of the old-new debate on design:

- There are inherent contradictions and opportunities in the new nature of products divided between hardware and software. On one side, there is the material object that nevertheless relates less and less to function and more and more to a world of values, senses and cultural meanings; on the other side, there is the immaterial object in the realm of services, communication, creation of communities of practice and sense which pass through products that in this way become social connections and the setting for new experiences.

- Commodities are undergoing a transformation, and along with this the attention of design is shifting rapidly from those families and systems of objects that have contributed to the history of design and that still identify a generation of designers, to new types of objects, some never produced before, that propose aesthetic, formal and material qualities which seem tailor-made to fit into our daily lives without leaving a sign (Branzi, 2007; De Fusco, 2008)[1].

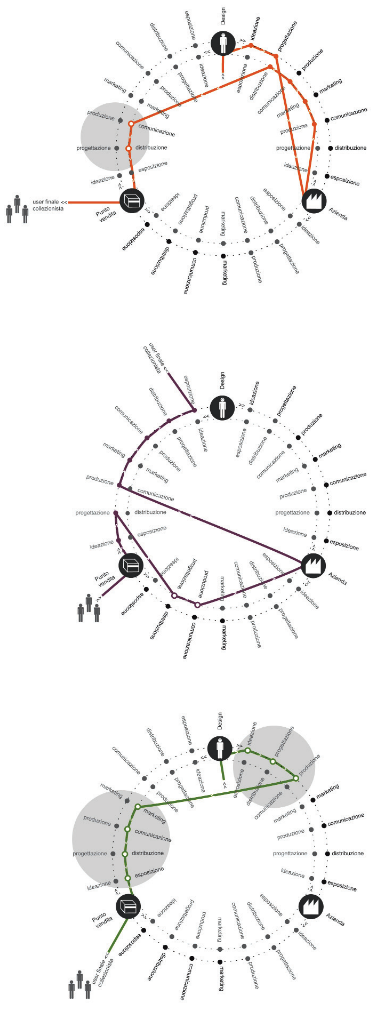

Figure 1. Silvia Casarotto, degree thesis 2009.

- Design chains are less and less homogeneous in terms of the commodity-technology-production sector they belong to (and they actually promote exhange among different production realities), and decreasingly linear in the classical succession from company to distributor to consumer-marketplace (a chain in which the designer was typically positioned behind the company). These "disordered" design chains (Figure 1) now have practices and points of entry to the design profession that are completely new to the designer, and require competences often linked to design process phases rather than to the final product design, such as the phases of initial exploration or intermediate conceptualisation, characterised by very specific vertical competences and often producing semi-worked products with high aesthetic and conceptual quality requiring specific training.
- The mixture between industrial and hand-craft production methods is passing from a phase of simple coexistence, to an interesting new phase in which there is, instead, a conscious search for connections between the two systems in the form of cross-contamination of materials, work processes, formal configurations, aesthetic and cultural sensibilities, etc.
- Design is now a mass phenomenon[2] which, partly through the proliferation of short degree programs, has led to the birth of micro-creativity areas and design communities producing capillary innovation processes that coexist with more consolidated traditional contexts (Casarotto, 2009).
- Parallel to this phenomenon, and perhaps both a predictor and a trigger, there is the reconfiguration of value chains in their traditional phases and order, from research to design, from production to distribution – all spheres where design occupies a central role.

The above-mentioned are only a few of the considerations that represent the basis for reconfiguring the educational profile of graduates of five-year Product Design programs.

The attention to processes as a central element of the educational profile definition

The five-year degree program in "Product design innovation" places the accent on the variety of processes and methods through which design can generate innovation within technological, social and economic systems.

The five-year program operates in a domain where the demand for design is ill-defined; it poses problems with a high level of uncertainty with respect to both the design object (the *what*), and the ways of resolving the problem (the *how*), thus requiring the capacity to give a structure to the design problem (*problem finding* and *problem setting*) and to build design scenarios.

[1] The poetics of interstitial design and weak originality are evident in the exhibition *The New Italian Design*, Triennale Milano, 2007. See in particular Branzi (2007) and also De Fusco (2008).

[2] The capillary spread at global level of design competences, along with the complex network of relationships that within the same production system unite micro companies and global companies where design assumes different roles in processes of value creation, is the subject of a Prin (National Research Projects) research proposal (Penati, 2008).

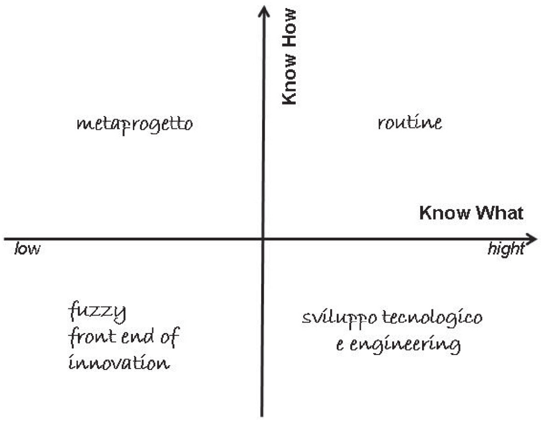

Figure 2. Work scheme by A. Deserti presented to the CCS scientific commission.

Design studios, through the choice of project-research themes, become the setting for forming the student's aptitude for exploration and experimentation, and for teaching the accuracy of methods, instruments and ways of tackling innovative projects, strongly connected with training in constructing visions and scenarios of creative approaches to solving design problems (Figure 2).

The purpose of theoretical courses is to introduce students to design cultures in their role of producing innovation and providing the interface between sociocultural changes and technological changes.

In the different phases of product planning and development where design brings innovation, attention has been focused mainly on the initial phases – the so-called "fuzzy front end" – of innovation, during which the process of conceptualising the design problem is important, and the tension between creativity and capacity to systematise is strong.

Not only product training but also process training

The problematic context in which one can imagine the design activities of the Design graduate calls for formation in the student of a very specific inclination and aptitude for design, consisting not so much in the ability to find answers to the usual questions, but rather to formulate new questions, including complex ones; in other words, knowing how to structure the perception of a problem or a fact in a different and original way, such that these processes are transformed into opportunities for third parties and are recognised as bringing cultural value and innovation (Ceppi, 2009).

It is also important to furnish the student with the right instruments for mastering innovation projects, and usually these instruments are transferred, reworked, and reconverted starting from other disciplines. The operation of transferring and appropriating instruments is thus an important passage in the production of innovation through design.

Managing complexity becomes one of the objectives of the design process, where the ability to define rules and combinations, to choose and judge as well as a willingness to break the rules are requirements of planning skill.

The figure outlines some of the capabilities, competences, knowledge, and instruments that the graduate from the three-year degree program must possess, contrasted with what is required of the full five-year graduate.

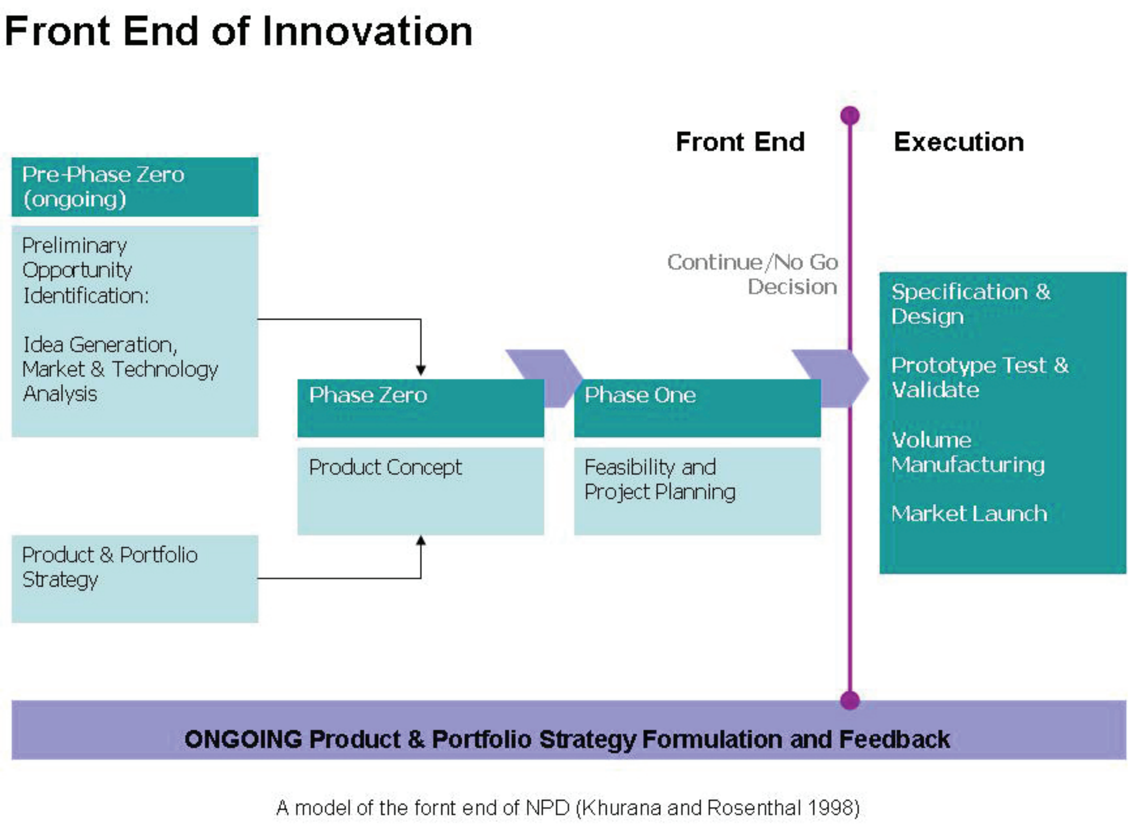

Figure 3. A model of the front end of New Product Development (NPD) (Khurana and Rosenthal, 1998).

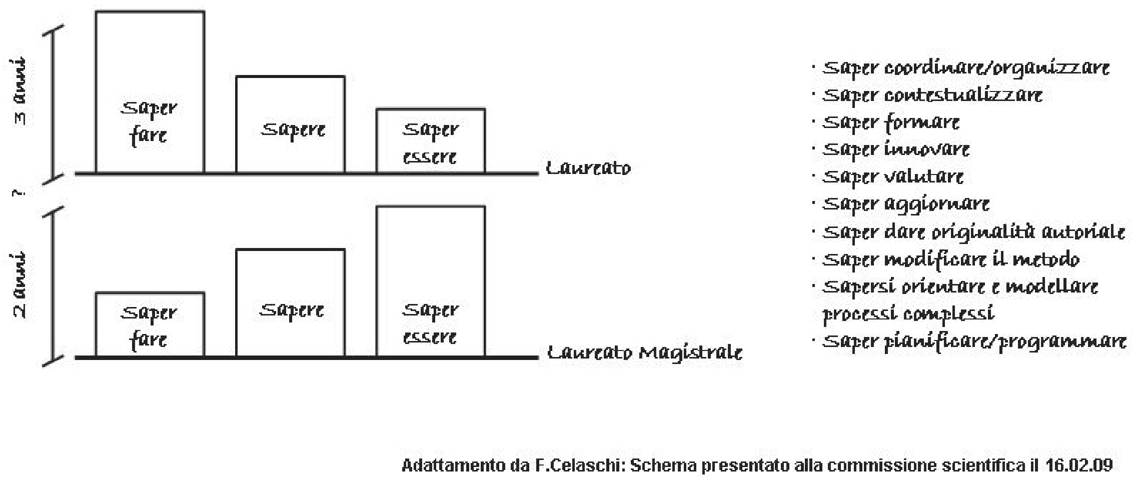

Figure 4. Knowing how to do, Knowing how to be: work diagram by Celaschi presented to CCS scientific commission.

Design as engine of system innovation

Every design activity, whether simple or complex, bases all of its innovative force on the ability to imagine future solutions to today's problems, while conscious of the fact that the full force of the effects often transcends the specific dimensions of the problem that generated the activity in the first place.

As with all decision-making activities, ascribing to design the task of anticipating a future situation means recognising its cognitive process nature even before its proactive instrumental quality.

In a world saturated by innovative phenomena that impact each other at various levels and that lead to relationships of interaction and interdependence among a multiplicity of factors, theoretical reflection has recently been focused on the forms and efficacy of design expertise for triggering innovation and governing the dynamics of what follows when they touch socio-technical systems that are highly complex and constantly evolving.

There are many problems that complicate the task of confronting, with the appropriate instruments, the activities of managing and controlling an innovative system, addressing the evolutionary dynamics along a predefined line of development.

Many of these difficulties result from the inter-dependence among the variety of technological, scientific, economic, productive, organisational, social, and cultural factors that define the system, imposing a nonlinear configuration on its own logical relationships. The dynamic interweaving of these factors makes it pointless to isolate the individual product or the individual technology from

Triennio L		Biennio LM
1°-2° anno	3° anno sintesi	1°-2° anno
naif	tecnico / esperto	progettista / professionista
problem solving problem setting	**problem solving** **problem setting**	problem solving **problem setting** **problem finding**
capacità di **operare entro un contesto** di progetto **definito**	capacità di **definire autonomamente il contesto** di progetto	capacità di **visualizzare nuovi contesti** di progetto
prioritaria la capacità di definire **i vincoli**		prioritaria la capacità di definire **le opportunità** dando per acquisita la comprensione e gestione dei vincoli
Strategia: - capacità di leggere il **posizionamento** aziendale nel mercato di riferimento e di ridefinirlo attraverso il sistema-prodotto; - **orizzonte temporale** dell'azione progettuale a breve-medio termine		**Strategia**: - Nuove convergenze tra aziende e settori come esito dell'azione progettuale; - Progettare sperimentando tecnologie e immaginando scenari socio-culturali futuri; - Progetti che spostano il modo tradizionale di rispondere al bisogno; - Progetti che anticipano nuovi modi d'uso;
- capacità di leggere il mondo dei bisogni; - capacità di leggere i modi d'uso; - altro	- capacità di dare risposte progettuali innovative ai bisogni esistenti; - capacità di innovare i modi d'uso	
Complessità Accento sulla - complessità dell'oggetto; - complessità del soggetto; - complessità del contesto; come elementi specifici dell'analisi progettuale	Capacità di gestire contemporaneamente questi diversi livelli della complessità progettuale	Il progetto come agente di trasformazione della complessità attraverso: - processi di semplificazione - individuazione di soluzioni sostitutive - di ibridazione tipologica, formale, tecnologica - di soluzioni reversibili - ....
Per quale contesto economico-produttivo e per quale **ruolo professionale**?	- studi professionali, piccole imprese con ruolo di tipo esecutivo; - ufficio tecnico	- grandi imprese, istituti di ricerca (compreso dottorato); designer auto imprenditore; capacità di inserirsi in modo paritetico in gruppi di progetto interdisciplinari e di iniziativa autonoma; - divisione design

Figure 5. Competences and capabilities in the two levels of study.

the system that revolves around the innovation itself. Even examining a single innovative action always calls for explanations that take into account the system in which the action occurs.

Innovation by its very nature is a highly uncertain process, defying attempts at controlling and predicting that rely on the deterministic principle of simple causality.

Innovation processes are the result of a set of complex choices and decisions that reveal the inherent weakness of the "global rationality" model.

For example, the difficulty of defining the exact direction that a socio-technical-economic system will follow during its development has led forecast studies to go from traditional forecast techniques based on extrapolation, aimed at constructing the only scenario compatible with the current state of the system, to predictive actions that accept the possibility of different development alternatives coexisting (Roveda, 1996).

It is accepted that the progression of a dynamic system in a state of evolution cannot be the wholly predictable consequence (Kaufman, 1968; Sowell, 1980; Resnik, 1990) of the system's starting conditions (Boudon, 1987; Simon, 1974). Nevertheless, accepting the limits of our predictive capacity does not mean delegitimising the role of rationality; it means accepting that the progress of innovation will not necessarily follow a single developmental trajectory (Elster, 1989; Sciolla and Ricolfi, 1989) but will probably generate a map of possible events (Laszlo and Laszlo, 1994) that depend on the interweaving – producing both constraints and opportunities – of technical and scientific knowledge, economic incentives aimed at particular technological applications, processes of transfer of technologies and applications, levels of competitivity in specific sectors, innovations in the world of consumption and the market, new social needs, cultural evolution, etc. Furthermore, in this new perspective, giving a form to the future means progressing from the aptitude for forecasting to the ability to design multiple horizons, aware of the fact that the early choice cannot be isolated from the subsequent series of decisions and choices made by a multiplicity of subjects who will push the innovation in certain directions (Lindbolm, 1976).

The complex decisional context where the dynamics of innovation take shape introduces a further difficulty. Instead of a single operator acting according to the criteria of his individual rationality, there is a web of interactions among a number of operators whose natures, roles, interests and individual goals are sundry and sometimes conflicting, challenging the rationality (Nelson and Winter, 1982) of the innovative decision-maker in relation to his manifold and complex nature as a collective actor.

An interpretation which accepts that the results of a process derive from the "building" (Flichy, 1996) of consensus among groups of actors animated by different interests, expectations and objectives, also accepts that these results may not respond to a principle of optimality. Instead, they represent a sort of "negotiated closure" of a problematic stage in the process that allows a period of stabilisation – often transitory – of the system that lasts until the moment when the emergence of new problems, and the construction around these of new expectations and solutions, triggers, with the same logic, further evolutionary phases in the innovative system (Bijker *et al.*, 1993; MacKenzie and Wajcman, 1985).

Learning as a form of management of dynamic complexity: Some issues

The dynamic dimension of the innovative process forces us to face – on the methodology side – the delicate issue of the "construction" of boundaries of the field of reference; the observation unit of evolving phenomena cannot be considered definitive, because during the innovative process it can absorb new significant elements or actors, with a continuous redefinition of the analytical boundaries.

Thus the system is not "given" but "constructed" with respect to a scheme of reference, to a viewpoint, to an observer's objective (Addario, 1989).

The problem then is to identify the elements that compose the system as well as the "social groups" entering – with aims that change over time – into the process of defining innovative dynamics, bringing their own problems and solutions.

The same logic of action of the agents participating in the innovative act, and the convenience of their involvement in the process, cannot be presupposed (Flichy, 1996). These are constructed and defined, that is to say they assume an identity, within the action considered (Hippel, 1988; Sobrero, 1996).

In this perspective, the definition of the boundaries of the problem area, intended as a "dynamic area", is not situated outside of the design domain, but instead constitutes one of the main methodological and operative crucial points.

Anticipating the future stages that a system may evolve can mean assuming a role that is not neutral but actively engaged in formulating objectives, choosing among available options, defining instruments tools and actions.

Challenges for education

The difficulties to design within a scenario characterised by innovative dynamics that have little time or space to become established, producing strong discontinuity, force itself to come to terms with an issue – not at all new, but newly relevant and thus at the centre of important research areas – regarding the forms and methods for anchoring new knowledge within the corpus of established knowledge; especially when the new is very distant from the old and consolidated. Added to this is the fact that the speed of change makes contents and forms of knowledge just as quickly obsolete, so that learning how to access knowledge and being able to elaborate it count more than simply acquiring it (Amietta, 2000). The mental model of the processes of acquiring and improving of knowledge shifts from "treasuring" the things learned, which derived from sharpening the mechanical and superficial cognitive instruments dependent on memory, to continuous learning that involves acquiring logical processes, research, and meta-cognitive abilities (Sasso and Toselli, 1999; Nonaka and Takeuchi, 1997). Finally, in various points of this account it has been stressed the need to reutilise the material and immaterial results of research through their application to various contexts.

This last point also raises a series of issues regarding those critical processes that are the subject of research within companies. All of these elements, considered as a whole, show a strong increase in the complexity of knowledge managment in innovative and design processes. And when this activity is located within a complex and rapidly changing reality, it forces us to think about the tasks and problem areas to be attributed OK (piuttosto "dealt with in"?) to design education.

In order to illustrate these problem areas in synthetic terms, it will be listed the forms of use and valorisation of knowledge that have a place in complex design activities, and that pose new questions for the educational world where processes and their dynamics represent the heart of the training process. Among these are:

- the processes of anchoring new knowledge to old;
- the role of experience in incremental innovative processes and in processes of radical innovation;
- the processes of rearrangement of knowledge as the outcome of the flexibility imperative;
- the processes of integration of cognitive resources which in technological production systems are multiple and fragmented among many actors;
- the processes of reusing acquired knowledge, which in most cases coincides with a process of transfer to other usage contexts;
- the processes of transfer and reuse of knowledge acquired through forms of learning by experience;
- the processes of development of the intermediate components of a broader cognitive system, etc.

Furthermore, the turbulence of the context and its state of continual change raise all the issues relating to project and innovation, which from their original aim of pursuing objectives that were fairly well defined and stable over time, are increasingly at the mercy of growing levels of uncertainty.

From incremental to radical innovation

Of the various issues that give concrete articulation to learning dynamics, it will be investigated those that seem closest to bringing out those themes of research and design education that should be considered above all in the present phase, in which It is required a complete restructure of university education systems and thus the places where design education takes place.

It was affirmed earlier in this article that the modern logic of innovation and design is dominated by those ways of creating the new that proceed by jumps rather than following incremental lines of development. This first effect has important repercussions on the practices of design as an activity intended to produce innovation by linking new knowledge to pre-existing and consolidated knowledge.

While a consistent body of reflection has developed in various study contexts on incremental innovation, contributing to modeling the methods that are used repeatedly to give life to the new, there are few data on forms of radical innovation. In evolutionary theories inspired by the dominant dynamics of the biological world, it is supposed that innovation often results from a sort of do-it-yourself handiwork that produces something new by mixing pre-existing elements (Ceruti, 1995).

In the field of cognitive science, which is our main focus of analysis, the activity of decision-making and discovery that takes place during problem-solving, as a practice that produces innovation, has always been seen as an activity that has as its starting point a referral to what is already known. It is evident that problem-solving always begins by comparing the new problem to ones already solved with positive results.

The search for similarities or differences, the comparison with our past experience and with categories of problems already resolved, are a fundamental part of resolving new problems (Simon, 1980). What normally takes place is that the primary problem is broken down into sub-problems, the solutions to which can contribute to the solution of the main problem. The sub-problems in their turn can generate other sub-problems, and this process continues until a problem is encountered that can be resolved immediately because it has already been dealt with in the past. In fact, the least laborious way of solving a problem is to refer to our past experience, and ascertain whether the new problem can be considered as similar to another one for which the solution is already known, then try to remember what solution was applied in the previous cases. The strategy of looking for ready-made solutions is commonly adopted because it allows us to save cognitive energy.

The success of this strategy hinges on having a good definition of the problem and a valid management of the criteria of analogy and similarity, both essential for choosing solutions that will prove effective in dealing with the current problem. One of the most obvious advantages of this experience, as a way of acquiring knowledge, values, contextual information and specialised competences that provide a framework for assessing and assimilating the new, is that it gives us a historical perspective from which to observe and understand new situations and events, and allows us to draw parallels between what happens in the present and what happened in the past (Davenport and Prusak, 2000).

However, when the subjects, technology, products, environment, and forms of knowledge change constantly, analogical learning processes, in other words processes in which one looks to similar problems already encountered and solved in order to approach new problems with progressive approximation, do not seem to interpret those forms of learning and problem-solving for which the past represents a very weak point of reference. In this regard, there is a total lack of research which might provide design models as an activity aimed at resolving problems and generating innovation.

When faced with methods for producing radical innovation where pure creativity has to dominate, further research is needed on the way in which creativity and method confront each other. Every exploratory process that leads to innovation – be it incremental or radical – is always composed of systematic actions based on routine and creative acts. The latter in particular are in need of fresh theoretical exploration, especially when creativity takes place within forms of innovation not belonging to the art world, but to socio-technical systems with all their constraints.

Some important references can be found from the cognitive sciences where, for example, forms of creativity have been studied as the ability to create associative links between one scheme of reference and another, and between different languages and levels of reasoning (Johnson-Laird, 1990). In other cases, researchers insist on the influence that the objectives set during the course of action have on creative acts. In still other cases, what is highlighted is the fact that creativity is a process that starts from certain given elements. For example, the field of Philosophy of Technic proposes the model of cumulative synthesis developed by Abbot Payson Usher in his "A History of Mechanical Inventions" (revised edition, Usher, 1954), in which it seems clear that, in the heuristic processes that are born within highly constrained systems – such as the processes at work in technologies and knowledge within social systems that determine the design act – creativity is never an instantaneous inventive act, unlike what often happens in art forms. It is a multi-stage architecture instead, a process made up of successive passages, each of which re-elaborates and recombines – in part through acts of intuitive acts? – data, knowledge and information consolidated during the process and measured against the objectives and requirements of the context. It is believed this type of creativity should be an important area of interest for research on innovation-oriented design.

The Anatomy of Judgment

To conclude, I would like to borrow from the interesting *The Anatomy of Judgement* by Jane Abercrombie (2003), which aimed at confering scientific dignity on processes of operative judgment.

Abercrombie (2003) defines the term "judge" based on the Shorter Oxford Dictionary: essentially it means forming an opinion, estimating, inferring, drawing conclusions, for example arriving at a decision or a conclusion based on the available clues and probabilities, even when the facts have not been clearly ascertained.

Working in a particular sphere of medical science – psychiatry – and in particular emergency situations where the capacity to interpret the context "at first sight" is one of the elements that separates the expert from the novice, Abercrombie places central importance in didactics on developing the capacity to interpret unknown conditions on the basis of past experience, and utilising them to predict the more or less immediate future. These acts of comprehension, according to the author, are equivalent to forming a judgment.

To achieve this aim, it is necessary to construct experimental training methods in which students not only encounter theoretical constructs but also have to come to grips with the practical dimension of problems.

There are three important elements in constructing a process of expressing a judgment: the perceptive process, the learning process, and the process of communicative verbalisation. Within these three elements of learning, one of the key stumbling blocks is the knowledge actively acquired through interactive didactic activities, rather than the traditional dependence of knowledge acquisition on the schemes transmitted by the teacher from his position of authority.

In the process of learning through experience, the student achieves a greater understanding of his own work methods and thinking processes. He learns how to arrive at a more effective response to similar problems.

In conformity with the well-known discoveries of Gestalt psychology, according to which the information acquired depends on a particular context, Abercrombie (2003) observes that our experience is conditioned by so-called schemes that are codified on the basis of past experiences. According to the author these "schemata" are aimed at dominating the perceptive chaos that appears moment by moment before the eyes of workers in the helping professions.

Thus mental schemes are a sort of containment system through which information from both the exterior and interior worlds can be received by the individual mind, and are endowed with contextual meaning. The act of judgment is here understood as the creative synthesis of the nexus linking the interior and exterior worlds, the I and the Other.

The schemes should therefore be interpreted not as dynamic structures deriving from the passive storing of knowledge, but as structures of active codification within which new experiences are influenced by previous reactions and experiences that have some aspects in common. The scheme is a body of knowledge that provides a framework in which new schemes can be placed. Bordieu (2003) would say that schemes are forms of praxis-based knowledge whose object is not only the system of objective relationships but also the dialectical relationships between these objective structures. From this standpoint, a didactic method based on the capacity to construct schemes of action should also envisage an "openness to diversity and peculiarity" (Sennet, 2008), and not only the capacity to rigidly and formally apply general rules to particular cases.

Finally, it is believe that a didactic method that trains students to understand dynamic processes, and that leads through design to radical forms of innovation has to reason, in research terms, on the role of mental schemes, how they are formed and utilised, and what role they play in structuring complex problems.

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