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HOW DESIGN THEORIES SUPPORT CREATIVITY – AN HISTORICAL PERSPECTIVE

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Abstract: In this paper we analyse the relationship between creativity issues and design theory. Even if these two notions apparently correspond to two different academic fields (psychology, cognitive science and management for creativity; engineering science and logic for design theory), they appear as deeply related when it comes to innovation management. Analyzing three historical moments of design theory building (ratio method in 1850s catching up Germany, 20th century systematic design and 1920s Bauhaus theory), we show that there is a dialectical interplay that links creativity and design theory, articulated on the notion of "fixation effect": creativity identifies fixation effects, that become the targets of new design theories; design theories invent models of thought to overcome them - in turn these design theories might also create new fixation effects that will then be designated by creativity studies. This dialectical interplay leads to regularly invent new ways of managing innovation, ie new ways of managing knowledge, processes and organisations for innovating. We use this framework to analyse recent trends in creativity and design theories.

Keywords: *design theory, fixation, history of design theory and creativity*

1. Introduction: similar or opposite? – The paradoxical relationship between creativity and design theory

In this paper we analyse the relationship between creativity issues and design theory. Even if these two notions apparently correspond to two different academic fields (psychology, cognitive science and management for creativity; engineering science and logic for design theory), they appear as deeply related when it comes to innovation management. Still there are two contrasted situations: in engineering design, design theories that support innovation processes, seem to be at their limits when it comes to contemporary creative issues; conversely in industrial design, the innovation process of the industrial designer seems to meet contemporary creativity issues… but the underlying design theory is often hardly explicit, which make collaboration with other actors difficult. Is there an opposition between creativity issues and design theory? Or is there a convergence?

In the classical R&D perspective, innovation management aims at improving product quality and variety, by relying on engineering science, through project management processes based on R&D organizations. It is based on clearly established design theories (systematic design). Actually these engineering design theories claim to be creative. But creativity studies show that some types of innovation are actually out of the scope of classical engineering design: how to change business models, to involve users, to radically change technologies, to create disruptive innovation breaking design rules? Hence the opposition is caused by the *inadequation* between design theory and contemporary creativity issues, the latter underline the limits of the former to address contemporary types of innovation and the need for new organizational forms. Thus calling for *design theory renewal*.

Conversely, industrial design claims to be serendipitious, divergent and rule breaking: creativity issues would be more adequately addressed by industrial designer's method. But this raises another question: what is the (industrial) design theory that enables to address creativity issues?

Hence between design theory and creativity issues there is neither an intrinsic opposition nor a natural convergence. We rather intuit a "dialog" between both. At certain historical moments, this dialog enlights the limits of existing design capabilities confronted to new, emerging innovation issues. This can lead to the emergence of new design theories and new design capabilities. *Hence design theory and creativity issues would be two ways –one critical, the other normative- of dealing with innovation management. Their interplay would lead to invent specific forms of innovation and specific capabilities.*

To investigate the issue of the relationship between creativity issues and design theory, we will use an historical perspective: we revisit three historical moments of design theory building. These are: the ratio method, ie the design theory that will be used in the 19th century German industrial catch-up; systematic design ie the theory that will be used for organizing R&D departments from 1950s onward in the whole world; and 1920s Bauhaus methods and theory, that will be used in a large number of design school in the world. For each moment we study the stimuli, the type of innovation that is expected, and the types of design capabilities, ie the type of innovation organisations, that are inspired by design theory (part 2). We show that there is an interplay that link creativity issues and design theory, articulated on the notion of "fixation effect": creativity identifies fixation effects, that become the targets of new design theories; design theories invent models of thought to overcome them - in turn these new design theories might also create new fixation effects that will then be designated by creativity studies. This dialectical interplay leads to regularly invent new ways of managing innovation, ie new ways of managing knowledge, processes and organisations for innovating.

2. Part 1: an analytical Framework for Learning from the history of Creativity Issues and Design Theories

2.1 The tensions between creativity and design theory at the heart of innovation management?

Engineering design, as defined in the reference manuals for teaching design to engineers all over the world (Roth 1982; Rodenacker 1970; Pahl and Beitz 1977, 2006; Ulrich and Eppinger 2008; Pugh 1991; French 1999), aims at proposing convergent thinking method for developing new product, not relying on chance, based on scientific knowledge and design rules and even facilitating the application of known solutions.

It is striking to see that creativity was often defined in contrast with these features. Whereas engineering design will claim to be based on rational problem solving, decision making and optimization, creativity studies are precisely born from the intuition that there might be other forms of

intelligence. A lot of studies on creativity in psychology were launched in the 1950s after the presidential address given by a famous American psychologist, Joy Paul Guilford, who defined creativity as a form of intelligence to be distinguished from the one measured by IQ (Guilford 1950). Whereas engineering design process is organized to be linear and without surprises, the « creative process » is far from a predictable one: it relies on serendipity, on « flashes of insights » (Wallas 1926). Whereas engineering design relies on rules and established solutions, creativity consists in breaking rules and routines (Amabile et al. 1996; Boden 1990) instead of using the existing one.

The tensions between engineering design and creativity match three main debates in innovation management:

- how to deal with knowledge? Studies on R&D organizations underline the importance of relying on knowledge and competences. For instance the notion of Absorptive Capacity characterizes the contribution of Research to the innovation process as the capacity to absorb relevant external knowledge (Cohen and Levinthal 1990; Lane et al. 2006). Conversely studies in creativity have shown how knowledge can be "fixing" (Jansson and Smith 1991; Smith et al. 1993), how knowledge can become a core rigidity instead of being a core capability (Leonard-Barton 1992). Hence knowledge might be a limit and a support of innovation. And compromises are not so easily thought (Weisberg 1999; Basadur and Gelade 2006).
- Is the innovation process diverging or converging? Creativity studies will insist on the necessity to diverge, even if some authors will admit that convergence is also important, often advocating for an initial divergence followed by an unavoidable convergence (Eris 2004; Dym et al. 2005; Cropley 2006). Conversely literature on the innovation process will favour convergent thinking, even if divergence might be also interesting from time to time (eg: diverge in the fuzzy front end (Koen et al. 2001; Reid and De Brentani 2004); or diverge during the processes, in flexible product development (Kelley 2009; MacCormack et al. 2001)). Here also the interplay between creativity and design theory might help us to think out new combinations between divergent and convergent process.
- Is the innovation process based on strong leadership and well-administrated projects or it is more based on autonomous creative teams? Since Osborn's invention of brainstorming at his communication agency BBDO (Osborn 1957), creativity studies in organizations tend to analyse teams creativity (Hargadon and Sutton 1997; Paulus and Brown 2007; Paulus and Yang 2000). Conversely the study of organisation of innovation will insist on the structures, methods and administration of innovation, following, as advocated by O'Connor, a "system approach" to radical innovation (O'Connor 2008). Some authors in the organization of innovation call for a combination of creative teams and non-creative one in ambidextrous organization (Tushman and O'Reilly III 1996), but empirical studies have stressed the limits of such simplifying compromises (Brown and Eisenhardt 1997).

2.2 Beyond compromises: the dialectical interplay between creative issues and design theories?

Interestingly enough the tension between creativity and design theory suggests more than just compromises –compromises in knowledge to balance fixation and un-fixation, compromises between convergence and divergence in innovation processes, compromises between control and autonomy in innovation organization. The intuition comes from two clues:

1. One might think that creativity has no place in design theory. This is far from truth: creativity was an historical issue for the theorists of Systmatic Design, as underlined by Wolfgang

König (König 1999). For instance in the 1850s, the great ancestor of German systematc Ferdinand Redtenbacher proposed a proto-version that intend to make the designer (the technician of that time), "more innovative" (Redtenbacher 1852). The first teacher of an elaborated "systematic", the Russian professor Peter Klimentitsch von Engelmeyer called his method a "theory of creative work" (Engelmeyer 1895). As analysed by Mathias Heyman (Heymann 2005), in the 1970s there were multiple debates in the German systematic community to clarify how far systematic design was already addressing creativity issue. More recently Udo Lindeman, former president of the Design Society, has shown how classical systematic design took into account the creativity required from design engineers (Lindemann 2011). This means that past design theories have certainly "invented" ways to manage knowledge, processes and organisation for innovation. Hence design theories, event past design theories, might be a good wellspring of knowledge for working on innovation management.

2. In certain fields, like industrial design, design and creativity are not in tensions but, on the contrary, are considered as synonym. If there is some kind of design theory or method in industrial design, then this theory or method might propose some ways of dealing with knowledge, processes and organization for innovation management.

We are led to reinterpret the above-mentioned tensions in a more "historical" perspective. At a certain moment in time, the installed design capacities appeared as too limited – with regards to societal issues, new imaginary,… Creativity precisely identifies "fixations" that limit past design theories and that have to be overcome by new design capacities. Under these critics, new design theories are proposed to "stretch" design capacities to overcome fixations. By so-doing they propose new frameworks that enable new ways of dealing with knowledge, processes and organizations for innovation. And they finally enable new types of innovation outputs. This is our main research hypothesis: *there might be a "dialectic" interplay between creativity issues and design theories, that led to regularly invent new forms of design capabilities (ie new types of innovation management) and new types of innovation outputs*.

2.3 Method: analytical framework to study historical cases

To study this hypothesis, we investigate three historical moments of creation of design theory to analyse whether and how it copes with creativity issues and what the formal proposals tell us about knowledge, process and organization for innovation.

We selected three theories that had historically a great diffusion – ratio method was taught in a large majority of German Technische Hochschule from 1850s to early 20th century, Systematic Design is still at the basis of main courses in engineering design, Bauhaus theories inspired industrial design teaching since its creation in 1920s. We chose two theories in engineering and one in industrial design.

In each case we followed the same analytical framework:

- We characterize the creativity issues that the theory intended to address – the kind of "fixations" to overcome.
- We analyse the principles of the theory (we briefly present some illustrations) and the way it enables to address the creativity issues, to overcome the fixation effects. In particular we underline how it leads to new ways of dealing with knowledge, processes and organization for innovation – ie how it leads to propose new design capabilities.
- We finally analyse the types of innovation that is expected from the theory.

3. Part 2: historical cases of inventions of design theories - German engineering design and Bauhaus industrial design

The analysis of the historical emergence of past design theories reveals an interesting interplay between creativity issues and design theory. Two main propositions emerge from this history:

P1: creativity issues are symptoms of the limits of existing design theories confronted to new innovation issues. They emerge at the borderline of established design practices and evolve over time

In the 1850s creativity issue is the fixation by existing, already designed objects; in the first half of the 20th century creativity issue is the fixation by existing design rules and machine elements, leading to non-relevant reuse of existing knowledge; in 1920s in the Bauhaus, creativity issue was the "clichés" and the limited perception capacity.

P2: design theories emerge to overcome contemporary fixations and extend generative capacities.

In the 1850s, ratio method help to use relevant rule for designing context-sensitive products; in the 1950s, systematic design proposed to design according to pre-ordered languages (functional, conceptual, embodiment, detailed design) to enable divergence and the production of knowledge at the right moment and hence to propose constantly improved products. In 1920s Bauhaus theorists renew theories of forms, colors and materials to enable generative super-imposition.

These design theories also provide interesting ways to deal with the issues of innovation management.

P3: design theories invent new ways to use knowledge for innovation

Each design theory provides sophisticated and original ways to make use of knowledge while overcoming knowledge fixation. Redtenbacher ratio method conterbalances the tendency to use the knowledge on existing objects by creating a "context-sensitive" algorithm that is based on stabilized models of the object and lead to use the right knowledge at the right moment. German systematic manages knowledge creation to avoid that designers steadily reuse obsolete design rules. It is based on wide ranging knowledge maps that help identify the "holes" to focus creativity where it is relevant. Bauhaus theories build enriched models of material, forms, colors, contrasts, to disentangle them and support generative super-imposition.

P4: design theories invent new ways to combine divergent thinking and convergent thinking in innovation processes

Redtenbacher ratio method is highly convergent but keeps divergent at well-identified steps. In German systematic convergence is created by the progressive instanciation of pre-ordered languages of the objects, each new language being also a step for temporary divergence. In Bauhaus theories, the emergence of the "organism" results from the super-impositions of dimensions (forms, material, color,…) and this super-imposition itself is also an opportunity of divergence.

P5: design theories invent new ways of combining autonomous creative teams and control.

Redtenbacher ratio method leads to distinguish the rule-maker and the rule-user (initially the professor and the technician). In German Systematic, a distinction emerges between the project team with a clear target and a clear framework and the engineering department, in charge of controlling knowledge reuse and knowledge production. Bauhaus led to invent a form of "self-assessed" collective creativity, in interaction with an inspiring leadership, based on some constraints ("use industrial processes and design rules") and the designation of expansion areas (new objects).

We summarize these results in the table below.

Table 1. Summary of the main results

Creativity issues	Theory	Knowledge management	Innovation process	Organisation	Type of innovation output
Fixed by existing products	Ratio method (Redtenbacher, 1850s)	Method to use the right rule at the right moment, based on stabilized, synthetic model of the object	Context sensitive algorithm insuring convergence towards a satisfying solution and divergence at critical moments	Work division between rule-maker and rule-user	Adapted, varied products.
Fixed by the reuse of non-relevant design rules	Systematic Design (Hansen et al. 1950s, Pahl & Beitz 1970s)	Knowledge creation at well-identified steps; identify "holes" (residue) to focus creativity where it is relevant	Convergence and divergence by pre-ordered languages to create the object;	Project leader framed by a clear, specified target; engineering department heads controlling the relevant use and creation of rules	Variety, continuous innovation, continuous knowledge production
Fixed by "cliché"	Bauhaus school (Itten, Klee,… 1920s)	Abstract knowledge (on form, material, texture, color,…) to disentangle clichés; generative super-imposition	Convergence and divergence by super-imposition	Self-assessment of a group of creators; inspiring leader designating areas of expansions	New grammar of objects

4. Part 3: Design theory and creativity today? Testing our framework

These propositions can be tested by looking at recent advances in creativity studies and design theories, two fields of research that grew very fast in the last decades. A comprehensive study of the advances is out of the scope of this paper. We simply would like to underline what our proposals lead to look at in literature.

Following proposition P1, our question is: what are the new forms of fixations identified in the literature? Prolonging the seminal works and experiments of Smith et al. (Smith et al. 1993) and (Jansson and Smith 1991) on fixation by recently activated knowledge, recent studies have identified several types of fixations: fixation by the representations of things (Ward 1994), fixation by knowledge too "contaminated by the specific goal and task" (Finke 1990), fixation by the limited capacity to use knowledge very far from the task (difficulty to use metaphor, to connect with different types of knowledge) (Burkhardt and Lubart 2010), fixation by emotions (Zenasni and Lubart 2009), fixation by images and metaphors (Chrysikou and Weisberg 2005), fixation by organisational and social relationship in firms that are not "creativity-experts" (Stewart and Stasser 1995; Sutton and Hargadon 1996). These newly identified forms might be the new challenges for design theories.

Proposition P2 invites us to analyse how recent design theories propose to overcome these new fixation effects and extend generative capacity. Let's just briefly look at three theories or methods: TRIZ, C-K theory and Infused Design. TRIZ (or ASIT) intends to help user overcome fixation caused

by relying on usual solutions to a problem; it proposes wide databases (wider than the classical libraries of systematic design) and a smart "browser", the matrix of contradictions, to find "creative" solution principles to problems (Altshuller 1984; Rasovska et al. 2009; Reich et al. 2010). C-K theory (Hatchuel and Weil 2003; Hatchuel and Weil 2009) supports the revision of object identity by the dual expansion of knowledge and concept. It has been shown that it is relevant to counterbalance fixation effects, in particular for teaching designers (Hatchuel et al. 2011b). Infused Design (Shai and Reich 2004a, b) supports rigorous relationships between different scientific objects (truss, mechanics, cinematic,…) to increase the capacity of designers to make use of very heterogeneous disciplines (Shai et al. 2009). It has been shown that it supports the identification of "holes" in certain disciplines (relative velocity in cinematics has no equivalent in mechanics), leading to the creation of new scientific objects (face force) (Shai et al. 2009). It has also been shown that C-K theory and Infused Design increase generative capacities (Hatchuel et al. 2011a). Hence these design theories tend to address (some of) the fixations listed above,…

Do these theories suggest new ways of dealing with knowledge for innovation processes? (P3). We can just underline here how TRIZ precisely proposes new ways of "browsing" for technologies; C-K theory supports rule-breaking in the knowledge base, expansion of knowledge driven by the imagination, the creation of new definitions of things, as well as "knowledge re-ordering" required for "preservation of meaning" in the new world and new forms of absorptive capacity based on structures of the unknown (Hatchuel and Weil 2007; Le Masson et al. 2011). Infused Design aims at identifying "holes" in knowledge bases and "filling" these holes by using "complementary" knowledge for design (Shai et al. 2009).

Do these theories suggest new ways of dealing with convergence and divergence in innovation processes? (P4). Methods inspired by TRIZ like ASIT maintain a strong convergence, in particular by making a "closed world assumption" that avoid too many explorations and tend to focus on the minimal "break" out of the "closed world" (Moehrle 2005; Reich et al. 2010). Processes derived by C-K theory are characterized by interdependent exploratory design paths, meaning that each new design step can provoke unexpected expansions and these expansions open new, unexpected paths for convergence in the growing tree of paths (Elmquist and Segrestin 2007; Elmquist and Le Masson 2009). Infused Design suggests a distinction between fast convergence by making use rigorous correspondences between multiple disciplinary models and divergence to explore the "holes" revealed by these correspondences.

These theories and methods can also inspire or support new forms of organization for innovation (P5), balancing creation and control. TRIZ method supports the intervention of "creative commandos" called by the classical project organisations to solve "extraordinary" problems unexpectedly emerging during the project process (Engwall and Svensson 2001). C-K theory has helped to characterize new forms of organizations, when firms are shifting from R&D to RID, organizing departments dedicated to innovative design (Le Masson et al. 2010). In these design-oriented organizations (DO2), two levels are clearly distinguished: design spaces, where focused explorations and knowledge acquisition are done, and value management, that designates and launches design spaces, coordinates explorations, manage interdependencies and repetitions, and progressively elaborates a design strategy that simultaneously and synergistically accelerates innovation outputs (convergence) and enables more and more disruptive explorations (Hatchuel et al. 2005). Infused Design leads to new forms of interdisciplinarity, in which rigorous disciplinary correspondences push to be more creative and creative explorations enrich scientific disciplines.

4. Further research

Our study on the historical interplay between creativity and design theory is still exploratory. It shows that 1) design theory is in direct relation with creativity and 2) as a support for overcoming fixations, design theories open ways to think on innovation management. This would require further research, at least on three topics: what are the processes that lead from creativity studies to design theories? What are the processes that lead to establish new design practices based on new design theories? What is the relationship between these new practices and the identification of new fixations?

It leads to a new framework to analyse different forms of innovation management. For each form, our framework consists in:

- identifying creativity issues, ie types of fixation, that have to be addressed
- analyzing design theories addressing these fixations and the related design capabilities, ie the way to deal with knowledge, processes and organization
- clarifying types of performance (and measures) to be reached by this form.

This work paves the way to new forms of research on innovation. The use of design theories could help to propose:

1. new frameworks for comparative studies: a study of different types of fixation and different types of "innovation" over time. The identification of new fixations might call for new design theories whereas new design theories might cause new fixation that will be identified by creativity studies. What are the future fixations of the today emerging design theories?
2. new frameworks for analyzing data: recent studies have precisely use design theories to analyse absorptive capacity in radical innovation situations (Le Masson et al. 2011), front end management in drug design (Elmquist and Segrestin 2007), project failure or success (Elmquist and Le Masson 2009) or exploration and exploitation in innovation (Gobbo and Olsson 2010).
3. new frameworks for generating data: through experimentations (Agogué et al. 2011; Savanovic and Zeiler 2009) or in research-industry partnerships (Gillier et al. 2010)…
4. new framework for reinterpreting historical data, from famous inventors or famous engineering companies

Finally by encouraging the interplay between creativity and design theory, by focusing creativity studies on the limits of existing design theories, by supporting the development of new design theories to overcome fixation effects, research on creativity and design theory would contribute to the invention of new forms of innovation management.

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