



Science Arts & Métiers (SAM)

is an open access repository that collects the work of Arts et Métiers Institute of Technology researchers and makes it freely available over the web where possible.

This is an author-deposited version published in: <https://sam.ensam.eu>
Handle ID: <http://hdl.handle.net/10985/10229>

To cite this version :

Philippe BLANCHARD, Patrick CORSI, Hervé CHRISTOFOL, Simon RICHIR - On the effectiveness of experimenting with C-K theory in design education: analysis of process methodology, results and main lessons drawn - In: 19th International Engineering Design Conference "Design for Harmonies" (ICED), Corée du sud, 2013-08-19 - ICED 13 - 2013

Any correspondence concerning this service should be sent to the repository

Administrator : scienceouverte@ensam.eu



ON THE EFFECTIVENESS OF EXPERIMENTING WITH C-K THEORY IN DESIGN EDUCATION: ANALYSIS OF PROCESS METHODOLOGY, RESULTS AND MAIN LESSONS DRAWN

Philippe Michel BLANCHARD (1,3), Patrick CORSI (2), Hervé CHRISTOFOL (1), Simon RICHIR (1)

1: Arts et Métiers ParisTech, France; 2: IKBM Sprl, Brussels, Belgium; 3: L'école de design Nantes Atlantique, France

ABSTRACT

This paper experiments a transdisciplinary design innovation way in educational contexts through workshops implementing a C-K Theory-based co-evolution between Concepts and Knowledge spaces. At l'école de design Nantes Atlantique EDNA, a 'posture for humans' concept subject was prescribed to students working half time in industry as a preparatory phase to the development of a contemporary day bed. The workshop permuted halfway C-K groups' yields: cross-contents swaps brought ruptures in groups' bias and enabled locating and addressing cognitive fixations. A log scale expressed relative ΔK increments in mobilized knowledge. Groups' innovation capability was graded on innovation capability maturity levels relative to C constructs. Engineering students often opened large K gaps while designers amplified C jumps even if bounding K operations. The process improves C-K implementation processes for small organizations and hybridizes competencies. With its primary power to orderly address the known and the imaginary, C-K Theory helps going beyond known design innovation approaches and supports educational settings not far from what is possible about everywhere in all specialty domains.

Keywords: innovative design, design education, creativity, design methodology, C-K theory

Contact:

Philippe Michel Blanchard
Arts et Métiers ParisTech
Lampa Lab
Angers cedex 01
49035
France
p.blanchard@lecolededesign.com

1 ELABORATING A NEW EDUCATIONAL RATIONALE FOR CONDUCTING COMPETENCE TRANSFERS

Education transcends teaching as meant to provide methods with transdisciplinary value. This paper is ontologically positioned within the spectrum of creativity methods incorporating distinct group interactions and tunable steering mechanisms. Correspondingly, it draws on specific design innovation experiments in order to suggest ways to rise above classical creativity methods in education.

1.1 Where innovating means going past innovations

How do we envisage *innovation*? Change processes happening in today's socio-economic environment may or not induce pervasive transformations. And actuating them consciously requires both experimenting and stepping back from action (Choulier, 2008). Clearly, innovation may be seen either as the *outcome/result* of some action or the observable *process* leading to it. Yet, this dual view isn't powerful enough: as we consider the process –explicit or tacit– of targeting an innovating object, we may as well *operate on the process* for a novel variety of target knowledge objects (Fig.1). This is a capacity level poised to innovate process innovation, leading to 'fresh' value (Corsi et al., 2011).

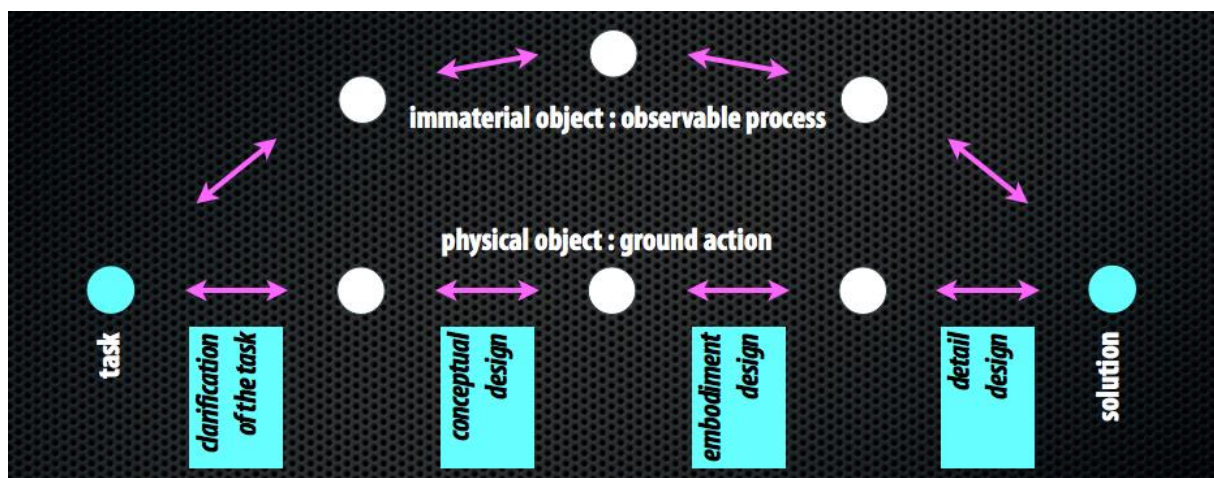


Figure 1. Yielding design innovation competencies in post-modern education calls for a 'beyond innovations' capacity level. There, a task isn't 'being solved': it is redefined.

The research issue discussed in this paper is then twofold: 1) 'In what sense an appropriate methodology can serve as an integrating education factor in the face of today's disjoint education tracks' and 2) 'Which would be some initial parameters and advices to propose to practitioners?'

1.2 Where design activity is more than just design

Objects are more than objects, they are *meaning* (Findeli et al., 2005). Beyond usage or functional identity, objects embody and carry with them a context that permeates all the relationships they may have with past, present or future environments. An object is like a holon¹ that speaks of its belonging ecosystem; which transcends space and even time. Therefore, designing an object is the deep act of plotting a spatio-temporal binding with other objects and between the object and e.g. people at large.

As we deal with educating design professionals, our aim is to found design activity on explicable, yet limitless reasoning. This includes all forms of known knowledge plus any make-believe, fanciful, imaginary things; in mundane terms, both the ordinary and the unreal (Hatchuel, 2006). The authors posit that *design is the art of fully exercising thought*. Whereby such interpretation requires methods and tools, we will task the using of C-K Theory for mandating such all-inclusive use of thinking.

1.3 Whereby fusing design and innovation will alter education

A convolution of design activity with innovation shall result in a double shift with a consequence:

- A process innovation capacity displaces factual *status quo* and also creates surprises, i.e. opens the eyes to the unknown, even the imaginary (Schön, 1983). This enables the person –trainee,

¹ A *holon* is something that is simultaneously a whole and a part, expressing environmental interdependence.

student or professional– to shift from plain knowledge to ‘*a priori not impossible*’ concepts.

- A creative design activity leads to beyond-the-ordinary cognitive configurations (Brown, 2008). This can subject the person to a reverse shift from concepts to novel knowledge.

The combined effect is more than the sum of the two shifts: a synergetic process that engages say engineers to create, enables say designers to engineer and free say architects to manipulate (Driver et al., 2011). Each becomes a craftsman: to reason *and* conceptualize; create *and* implement; imagine *and* realize.

1.4 Selecting education targets for implementing design education

To engage the above gears, we selected three disjoint yet complementary educational environments:

- Students of design², given that their design curriculum manifests a social engagement. They would for instance learn how to explicit reasoning, Much of this paper elaborates on the experiments conducted with them (EDNA).
- Engineering students³, based on their natural bias to bring up technological novelties (ISTIA). They would learn e.g. how to design drawings and representations that have global meaning.
- Business school students⁴, according to their propensity to value objects on markets (ESSCA). They would learn e.g. how to balance and smoothen the previous two cultures with the perception of what markets may assimilate.

Then we observed each of their dynamics in their capacity to go past their nominal specialty. Table 1 summarizes the corresponding educational units involved in the experiments.

Table 1. The students’ units involved in the experiments and their characteristics (all workshops were conducted by P. Corsi, with help from P. Blanchard for the EDNA ones).

2012 Sessions	Organizations and levels	General contextual theme	Timings and groups
Sept. & Dec.	ISTIA - Master 2 2012-2013	‘An innovative concept that does not exist’ - 8 themes	2 days - 8 groups 30 students
Nov. & Dec.	ISTIA - Master 2 Opt. Pharma-AgroBio 2012-2013	‘BIOFUTURE Workshop’ Science Fiction & Health, Environment, AgroFood, Biotechs	2 + 2 days - 3 groups 10 students
Jan. & Jun.	EDNA - 4 th year 2011-2012	‘Operating on the Sitting Posture’	2 + 2 days - 4 groups 18 students
Dec.	EDNA - 4 th year 2012-2013	‘Co-Working 2.0’	2 + 2 days - 4 groups 20 students
Oct.	ESSCA - 4 th year 2012-2013	‘A market that doesn’t exist’ 8 themes	2 days - 8 groups 54 students

Such profiles crossings are no extraneous concerns: e.g. designers could natively be dubbed ‘marketers of form’, marketers ‘engineers of markets’, and engineers ‘designers of systems’. Yet, we postulate that, by making each of the three targets more conscious of the ‘reasoning approach’ of the other two, we can later gain a new and useful synergy, possibly a capacity to build transdisciplinary education leaping beyond traditional approaches (often still inter disciplinary, if not multidisciplinary). However, reaching such a goal requires a powerful approach and we indeed saw in C-K Theory (Hatchuel et al., 2003), (Ullah et al., 2012) a most fitted vehicle for consciously nurturing cross-disciplinarity. For four reasons:

1. It exerts the capacity to pose and pro-pose items, concepts and knowledge.
2. It *explicitly and traceably* supports the finding of things that do not exist (Agogu e et al., 2013), hence transcends learning upwards towards educating: instead of stressing the piling up of notional (knowledge) items, the C-K Theory supports the making of unknowns continuously. Each above three target publics can benefit from this possibility.

² At L’ cole de design Nantes Atlantique in Nantes (EDNA), France : introduction to innovative design.

³ At Institut des Sciences et des Techniques de l’Ing nieur d’Angers, ISTIA, Angers University, France (first innovation institute in France, est. 1976), dedicated to innovation engineering.

⁴ At  cole Sup rieure des Sciences Commerciales d’Angers, ESSCA, France : business innovation.

3. It leaves an important part to *varying intention/motivation* (a key mental disposition for students) contrary to classical innovation methods (Hatchuel et al., 2011). The C-K Theory frees a designer's natural thrust to *intentionally* draw various designs, an engineer's to intentionally reason in *various ways* and a marketer's to intentionally *vary* market/products couples. Moreover, the C-K Theory makes intention explicit and *a posteriori* traceable.
4. It can serve as a *common* methodological ground for the above targets, as it is a horizontal mean, backed by theory, and that remains independent of specific disciplinary knowledge.

2 A BRIEF INTRODUCTION TO THE C-K THEORY IN THE CONTEXT OF THIS PAPER

2.1 On one founding principle for using the C-K framework

We used the C-K Theory, so far employed mostly by *engineering* practitioners and within the larger firms' *engineering* environments. Its resulting scientific and technical preponderance -or perhaps sometimes dominance- may be amply justified by the daunting amount of knowledge underpinning about any new technology, plus the technological intensity of today's product innovations. However, the fundamental purpose of the C-K Theory does revolve around the art of *designing* innovation.

2.2 What about the formal C-K Theory framework?

C-K Theory inherits from the creative power of modern mathematics (axiomatic set and category theories etc.). It is a powerful approach for discussing design phenomena. This paper does not detail the actual implementation of that theory, instead points at the results obtained.

A C-K process is made comprehensible and interpretable thanks to a co-generation referencing between two spaces: **C**oncept and **K**nowledge. Interactions between these two antagonized spaces are monitored and enriched continuously as the expansion of the **C**oncepts space progresses. More elaborated concepts (through adjoining attributes that authorize to expand previous concepts) may happen to gain a logical status within the **K**nowledge space. Conversely, the knowledge mobilized helps adjoining attributes based on properties in **K** for the purpose of expanding the **C**oncepts space.

This process is a design reasoning method and its mechanism is only briefly exposed here below (for a more elaborate explanation, see references). It starts from a (yet to undertake) C_0 root concept that stands beyond the perimeter of the known **K**—this being called a disjunction (Hatchuel et al., 2003). The **C** space is creatively developed through partitioning and expanding progressive tree-structures where nodes are properties-added concepts. Information, data, prototypes, tests, protocols etc. constituting the evolving **K** space stage are piecewise called on duty exactly as the whole **C-K** reasoning necessitates and goes: on demand and as established (both *ex ante* and *ex post*). The **C-K** process goes on through interacting formal operators between **C** and **K**. A design process is supposed to end when a 'junction point' is found between **C** and **K**, i.e. a concept is validated in **K** or for which specifiable R&D can be performed. The obtained object becomes decidable: it can be described in **K** (e.g. Corsi, 2013 in the context of designing futures).

3 A MULTIPLICITY OF AIMS FOR A PROCESS-BASED EXPERIMENT

This paper intends to depart from, and ideally offset, any single *métier* bias. It proposes to unfold a stepwise, non-linear C-K-based process by observing the performance of the target publics above and, for the EDNA design school, by coordinating the performance of four students' groups.

3.1 Operational aims

All the above arrangements took account of the need to satisfy the various and independent material constraints set by the three backing independent institutions. Yet, the research focus of this paper is to be found through the fuller experiment conducted at the EDNA design school. With reasons:

- Designers are interestingly more often exposed to the producing of breakthrough concepts (Bouchard, 2005) while it may be less true for engineers, except when bringing radical innovations. Marketers are customarily faced with the ongoing challenge to curb ruptures and mold continuity solutions that don't disrupt markets for obvious reasons monitoring markets.
- Designers' reasoning is essentially conceptual, less technical. The C-K Theory proposes a particularly efficient way to achieve innovation design (Garel et al., 2012). Yet, it was built

within an engineering environment with the collaboration of large industrial groups. Our motivation is to bring it to designers plus SME environments (EDNA designers students are half-time working with innovative SMEs), an opportunistic and necessary move.

Our research also aims at determining the acclimation and efficacy constraints of the C-K Theory within unprepared environments: to what conditions designers are able to assimilate the C-K approach profitably so to operate in their field better; how SMEs can accommodate unsought theories?

3.2 Methodological aims

Our approach was to propose to a panel of designer students an initiation to the C-K Theory then measure the results obtained through a carefully planned protocol involving various operational configurations. In this way, the experiments may lead to hypothesize the transplanting the C-K Theory out of its initial context. Conditions of the ‘cutting’ have been and will continue to be rigorously analyzed and transcribed into good practices recommendations.

4 WHAT A STATE-OF-THE-ART CAN TELL

The literature dedicated to the applications of the C-K Theory tackles experimentations in small firms only very partially. The seed authors of the theory have engaged into numerous collaborations with large industrial groups, e.g. Seb, St Gobain, Alcatel, PSA, Renault, ESA-CNES, RATP, Thales, Volvo, Areva, Safran... (Hatchuel et al., 2009). Yet, SMEs are seldom mentioned in their literature: the Avanti firm for a nail holder device (Hatchuel et al., 2004). Our option is to study what a methodological process backed by the C-K Theory can bring here. One direct reference found that touches educational issues is Hatchuel (2008), which relates two applications in design education context. The first one was conducted in Nancy, France as a joint program (Artem) of a school of art, a school of engineering and a business school. No specific design school was there concerned. Students tended to follow two distinct project phases: ‘co-elaboration’ where they all played a similar role and ‘co-operation’ where a work division occurred. The second application took place with students already trained in C-K Theory from engineering design, industrial design, and management schools. Given such paucity, we focused on experimenting the C-K Theory for designers students who aren’t purposely prepared and hypothesized that a structured approach may yield many results in faster time, with the aim to set guidelines for fielding the C-K Theory: trainer’s guidelines facilitating peer usage when fielding and conducting classical K/C/P workshops in the future.

5 THE EDNA EXPERIMENTAL PROTOCOL AND ITS CONSTRAINTS

For all three targets, the field experiments that were conducted invited a new type of design innovation process where a dose of creativity regeneration is needed. In this section and in the following, we will only explicit the EDNA experiments: all others are methodologically equivalent.

5.1 Background facts about the main target EDNA design school

‘L’école de design Nantes Atlantique’ was created in 1988 and is well known for its 5 years designer curriculum. A Master degree curriculum including alternating periods totaling half time in industry was opened in 2011 with the specific objective of mastering Design Management and Innovation. Its first year’s 18 students were divided in 4 groups. An experimental protocol was purposely designed. The three production steps were clearly identified: 1) *Initiation*, lasting 16 hours; 2) *Progression*, lasting 8 hours and held later; 3) *Cross-workshop*, lasting 8 hours.

A first phase (*Initiation*) comprised an introductory conference on the potential of the C-K Theory, then a 2-days workshop was focused on working out a specific theme and was using the Blue Ocean™ strategy (Chan Kim et al., 2005) for creating new market spaces. The four groups then presented their conclusions in plenary with an ad-hoc external jury.

A second phase (*Progression*) followed as an advanced formalization of the findings after a latency period of a semester (other classes and in industry). We observed that this approach enriched both teachings and field experience. The original students’ groups extended and completed their earlier results during one day plus another plenary feedback.

On the basis of the latter roundup that enabled each group to appropriate all the four extended realizations (positioning, viewpoints, bias...), a third phase (*Cross-workshop*) was organized that lasted the following day and consisted in swapping actors, a crossing that enabled each group to re-open the general theme possibly with a fresh view and development.

By analyzing and synthesizing these experimentations, we could propose a number of performance improvements when fielding the C-K Theory in unprepared environments.

5.2 On the thematic orientation chosen for the experiment

The chosen theme for the workshops was part of a partnership process with the national Tapestry craft organization (Groupement des Artisans-Tapissiers de France). As a preparatory phase to the development of a contemporary day bed, the *posture* subject theme plus its surrounding characteristics were defined. Various ways to express the notion of posture were formulated (oxymoronic and not formulations) with a view to trigger the C-K Theory process.

6 DESCRIBING THE MEASURABLE FIELD EXPERIMENTATION AT EDNA

(Hatchuel & al., 2011) evidenced the measurability of a C-K process yield and the interest for educating students in creative thinking. In order to be able to quantitatively qualify the respective groups' yields, two indicators were defined. A first (**CA**) takes into account the innovation capacity of each phase production and marks the innovation **CA**bility where five possible levels are given by the Innovation Capability Maturity Model (Corsi et al., 2011). (NB. The five innovability levels are: 1) 'making do', 2) 'repeating', 3) 'coordinating', 4) 'managing', 5) 'sustaining & evolving'. Only the first three are relevant here). A second indicator measures **Knowledge** as an entity and plots it logarithmically (**log K**). The idea of logarithm for basing a value measure was afterwards found in cited in (Reich, 1995). This measure is believed to be homomorphic to the data but a definition still lacks explicating the relation to the performance of the system holding the knowledge being measured. In essence, it is a rapport to quantity (the number of knowledge elements) that filters out the extensive list of those elements. It is considered as a measure general to the whole set of groups and not an ad-hoc one because the process for the construction of knowledge was common to all.

Time on the horizontal axis represents the phases held during the whole workshops process (Fig. 2). The first two workshops are done in continuation and the third comes after swapping groups' C-K records.

Each group chose a code name⁵. Here follows an account of the four groups' progressions.

1. The *Apostrophe* Group decided to elicit the concepts of future mobility, new behaviors and well-being, out of the *posture* problematic. Its root concept C_0 is 'an object that adapts to the body and sustains it.' The tree structure ends up with the *Body Moov*' concept (a moving body activates the product and heats up the body while adapting to its shape). As gels exist that heat up upon mixing, this represents a conjunction between the **C** and **K** spaces. During its second approach, *Apostrophe* experienced the need to draw up two syntheses leading to amplifying the expression of the initial C_0 in more general form from 'an object that adapts to the body' to 'a reactive sitting object.'

Students reckoned social contracts whereby it is man who adapts to a chair and mobilized **K** relevantly (the rapport body/matter, adaptation and support) but no new concept, thus justifying the *Body Moov*'.

Drebbel Group took over this result for phase 3 (*Cross-workshop*). The latter C_0 concept from *Apostrophe* (an object for interactive sitting) was varied around five propositions. From a bipolar *object+user* view, *Drebbel* introduced a third term: the *environment*. Here, the relative knowledge explores perception and movement sensor-based systems plus environment, autonomy and command related notions. The resulting concept aims at describing a sitting device that interprets external factors and adapts them to man. Still, the progress promise wasn't confirmed as $C \rightarrow K$ and $K \rightarrow C$ operators are loosely explicated and there isn't any surprise found. Overall, the **K** mobilized by *Atmosphere* is richer than for *Drebbel*. Still, *Drebbel* sustained *Atmosphere*'s innovation capacity quite well.

2. *Drebbel* Group posed C_0 as 'a body support without prehensile matter' during the first phase. It examined the prehensile proposition as untouched/touchable without sensation or untouchable with **K** being essentially physical and perceptive (states of matter, structure, mechanics, magnetism, fluid dynamics, sensation mechanisms...). One expansion envisages levitating the body through balancing forces. The conclusive concept describes 'a flux of matter as body support' and is illustrated by a person floating on a water stream. *Drebbel* wished to imagine a new virtual formalism for describing

⁵ Groups compositions as follows. *Apostrophe*: É. Caron-Bernier, S. Miet, N. Tollens-Szelag, J-Ch. Wielfaert. *Drebbel*: F. Butour, J.-Ch. Denier, Th. Le Touze, F. Li, F. Tai. *Reverso*: P. Ariaux, C. Arnaud, A. Chasle, J. Delaigue, V. Madelin. *IKA*: M. Bertho, S. Bluet, C. Hansen, É. Simon.

movements between **C** and **K**. The result is different yet not necessarily more explicit. The second (*Progression*) phase changed the initial C_0 (*'body support without prehensile matter'*) to *'sitting without matter.'* A somewhat unsatisfactory idea to illustrate the **C** and **K** columns in non-standard form was transformed in more conventional illustrations in phase 2. Nevertheless, the operations $C \leftrightarrow K$ lack declarative power. In the third phase *Apostrophe* took over. As it appreciated the results carried over (a high variety of concepts in **C**), it pointed to the weak knowledge mobilized and to a feasibility dead end. Hence completely revisited the notions of perception and matter! Its new concept was to make matter invisible by trumping senses: the armchair *does* exist but its presence is *not* perceived! An interesting result that convinced *Drebbel*, who nevertheless regretted that the C_0 was unchanged. Once more, the spread of knowledge mobilized is rather weak. A list of invisibility technologies would have been wise. Still, on the knowledge or innovation capacity angle of view, the crossing of groups has shown highly profitable.

3. *Reverso* Group chose *'swimming in the air'* as the first phase (*Initiation*) theme. The knowledge mobilized concerned fluid mechanics and suspension in gas lighter than air. A bio-based mimicry of mucus-covered scale of fish led to the concept of a second skin. It examined research on technical textiles that embed active capsules. An embodiment enabled to consider *'a textile jump suit with scales (composed of helium capsules) facilitating air penetration.'* Still, the characteristics of helium (1m³ lifts 1kg) are invalidating. During the second phase, *Reverso* 'inverted' its C_0 (i.e. *'swimming in the air'* became *'flying in water'*). New knowledge was taken into account with elliptical wings and shark's skin. At last, concepts were more widened than deepened, but a *'textile with active capsules'* projective concept remained to be improved. During the third phase, *IKA* took over and, with a rather stable knowledge, the number of operations $K \rightarrow C$ significantly increased, resulting in *'a swimming pool filled with gas heavier than air'* new concept. *Reverso* appreciated this enriching as highly conformant to their own logic. However, an inventory of probable situations and application contexts would have been wise. The knowledge quantity and innovation capacity indicators evidenced a strong increase and without loss during the cross-transfer: the cross-workshop exploited the initial work well.

4. *IKA* Group chose to develop *'lying on the ceiling'* as root C_0 , which was partitioned into *'being attracted to the wall'* and *'not being attracted to the wall'*, two concepts opening differing views with complementary knowledge. A first view proposed *'to be fixed by strategic contact points to sleep well'* and a second *'to fix on the wall through a reversible scratch system.'* The validity of the potential innovation capacity was analyzed with the Blue Ocean™ method (Chan Kim, 2005). During the second phase (*Progression*), *IKA* abandoned its paper-board constructions and used Post-It™ paper on an erasable white board plus photos as the recording method of the evolution history. Sometimes, a single Post-It™ triggered filling an entire board. *IKA* widened the initial *'to be lying on the ceiling'* C_0 to *'augmenting the freedom of movement'*, thus freeing from the notion of wall. The knowledge envisaged then becomes rather complex for a relatively simple concept. Solutions as the Ballule™ or new man-machine interfaces were evoked. During the third phase (*cross-workshop*), *Reverso* took over and its expression medium was to take one of the latter made photos and retouch it (Fig. 2). The acknowledged widened C_0 was seen as not contradictory enough and thus the group proposed *'beyond gestures limitations.'* Then, consequential **C** expansions proposed the notion of transplant, limbs prolongation (either pushing the limits towards the external side or augmenting one's own capacities from within). During this phase, an initial loss in appropriating anterior results was observed. Yet, the **K** was noticeably completed and the innovation capacity increased strongly.

7 THE LESSONS DRAWN FROM THE EXPERIMENTS

7.1 General observations from the five workshops

To succeed in conceiving workshops deployable in SME environments means: accelerated dynamic, less total calendar time, a more synthetic approach yielding exploitable results sooner ('quick wins' and other direct or indirect tangible results), the evaluation of the quality and quantity loss that may result as a consequence in terms of richness of designs and the capacity to create lineages.

The experience drawn from our workshops with students tends to make such objectives realistic. For one, students demand an equivalent speed and quality, as well as seeing concrete achievements. Even if EDNA students are alternatively busy half of their time in industry -sometimes using C-K- we cannot extrapolate further for SME besides the fact that these workshops have opened the

understanding of how contextual professional determinants (engineers, designers, marketers...) are able to adopt approaches founded on the C-K Theory.

The protocols followed indicate adoption ways in SME environments: 1) precise guidance and timed monitoring, 2) guided getting of conclusive concepts and 3) competences and cultural de-biasing (the crossing enables operating at intersection of disciplines or crafts). Table 2 below accounts for the main lessons drawn that set future educational guidelines.

7.2 Observations pertaining to the C-K Theory

As a general orientation, the C-K approach has also been used with a view to curb linear thinking processes and regenerate creativity (Agogu  et al., 2013). However, the constraint imposed by the initial choices (start concept C_0 , properties and attributes, etc.) remains a determining factor all along the process. A chief reason why we used specific mechanisms to de-bias mental fixations observed during it (cf. cross-workshops at EDNA). Such mechanisms may although have, if not properly monitored, time and cost impacts.

Table 2. Overall view on the main lessons learnt in each specific workshop. Many of these become guidelines for future education and experimentation within SMEs.

Target	Workshop type	Main lessons learnt
ISTIA-1	Introduction workshop to C-K Theory for engineers	<ol style="list-style-type: none"> 1. Dominance of technical logics with respect to conceptual logics (always) 2. An effort to overcome linear logics and reasoning is necessary: it is useful to hybridize teams of engineers with designers and/or marketing competencies 3. It is useful to complete the C-K approach by evaluation tools
ISTIA-2	An integrated Futures and Innovation workshop. It offers the symbiosis innovation, futures studies, and an early requirements definition for an innovation project Structuration with three steps K/C/P	<ol style="list-style-type: none"> 1. When processed by C-K Theory, a « science fiction » problematic resembles less to science fiction! The K supposedly pertaining to the fiction field are as many relations to projector concepts C that may be relevant 2. A better capacity to define projects that are really innovative (i.e. that trigger breakthroughs). The forcing the rupture and the new K not yet acquired constitute a natural alignment with the C-K approach 3. Enables overcoming limitations of present K islands frontiers 4. Unites the innovation approach with the futures studies approach (that becomes a new field of interest): futures bearing thematic, unthinkable - impossible – undecidable – plausible – possible – feasible relations) 5. Delivery of futurist concepts, of associated implementation parameters: democratization of the futurist approach
EDNA-1	Introduction workshop to C-K Theory for designers	<ol style="list-style-type: none"> 1. Shows how designers may appropriate a breakthrough innovation approach 2. It is fundamentally possible to ‘contract’ cognitive bias thanks to the cross-workshops. Early made fixations are lowered in the reasoning. Tends to work out ecosystems rather than homogeneous groups in any professional C-K workshop 3. Dominance of conceptual logics with respect to technical logics (always!)
EDNA-2	Structuration in three steps K/C/P	<ol style="list-style-type: none"> 1. The K/C/P phasing clearly contributed to the perception of the ‘innovative project’ dimension by designers 2. The effort to overcome purely linear logics and the anchoring in knowledge spheres remains necessary
ESSCA	Introduction workshop to C-K Theory for marketers	<ol style="list-style-type: none"> 1. The marketing culture seems to anchor neither in C space nor in K: a suitable balancing concepts-knowledge is possible 2. However the major relative sensitiveness to (market) value tends to reduce the normal systematic exploration in C and K

7.3 Measuring the concepts and knowledge obtained

The five workshops enabled to display the results as innovation capacity and knowledge creation curves with qualitative scales for each group. We now discuss various measurement results.

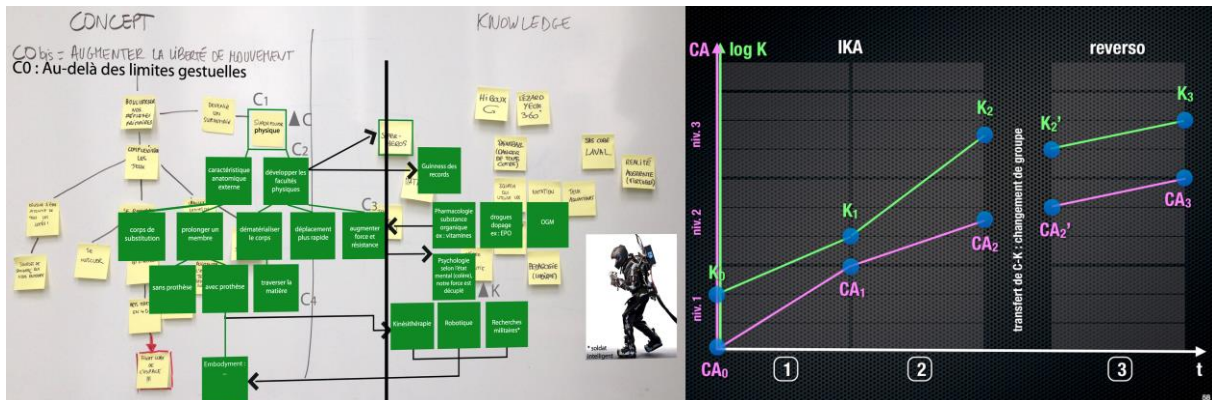


Figure 2. Measuring the innovation capacity and the knowledge creation through two curves and for a specific students' group.

7.4 The 'non-linear' operational settings brought a well-received de-biasing

Through permuting the sum of a group's yield, a forced contents crossing enabled a special rupture in the whole C-K process that revealed two interesting new phenomena in the design innovation activity:

- the surge of groups' cognitive defixation in turn revealed both further and deeper (yet unsought) fixations and surprising behavioral attitudes with respect to other parties' developments,
- groups' implementation of unexpected concepts expansions freeing original lateral thinking.

These observations lead to the need for more theoretical studies in what can be called *cross-defixation*.

7.5 Quanta of knowledge, quanta of designs

The background monitoring exerted by the animators was paramount in obtaining specific C-K properties yielding Variety, Originality and Robustness. The innovation capability grown through the whole process was plotted on a qualitative maturity scale with respect to relative ΔC constructs. The knowledge mobilized was plotted on a log scale expressing relative ΔK . We found that engineers created large ΔK gaps in all cases, marketers were satisfied with smoother ΔK and ΔC increments, while designers jumped into ample ΔC gaps even at the expense of studying K domains extensively.

7.6 Return impact on the organization

More value can be seen in delineating ways for improving a C-K implementation process towards:

- the *organization*, according to specific sizes and dynamics ranging from large conglomerates down to SMEs and even possibly start-ups, with a view to find ways to reduce the length of time usually required by practitioners to fulfill a C-K process within a K/C/P workshop series,
- *métiers* (crafts), namely here the engineer, the designer and the hybridizing their competencies,
- the *vocational* for nurturing desired innovation cultures, commencing with institutional teaching, counterbalancing with field coaching in business innovation.

8 DELINEATING FUTURE DESIGN INNOVATION WAYS

We viewed innovation as a quest having far-reaching implications since ideation or design stage. As engineers first applied C-K Theory (within the technical environments of large firms), there seems to preexist some predominance of the 'technical' angle of approach, although seed researchers belong to a 'Scientific Management Group' widely open to arts. Today, social responsibility should contribute to going transdisciplinarily. Here, C-K Theory can help: it links disciplines and joins crafts and dedicated professionals; it offers the visual interest to draw together the communities representing complex ecosystems of players; it yields substantiated and compelling arguments to engage responsible into complex projects. Because its natural power is to systematically dwell both in the known and the unknown, it goes beyond other design innovation approaches we know. This paper has shown instances of what educators can do in settings that are not far from what is possible about everywhere.

ACKNOWLEDGMENTS

The authors thank their colleagues at École des mines de Paris (Profs. Armand Hatchuel, Benoît Weil and Pascal Le Masson) for their enrichments while listening to our first results and L'école de design Nantes Atlantique management team (esp. Jean-Yves Chevalier) for a sustained collaborative support.

REFERENCES

- Agogu , M. (2013) Understanding Fixation effects in Creativity: a design-theory approach. *6th SIG Design Theory*, Paris, 4th-5th February, Paris: Mines ParisTech/The Design Society.
- Agogu , M., Arnoux, F., Brown, I. and Hooge, S. (2013) *Introduction   la conception innovante,  l ments th oriques et pratiques de la th orie C-K*. Paris: Presse des Mines, Transvalor.
- Blanchard, P., Christofol, H. and Richir, S. (2012) Exp rimentation, en Milieu Contraint, d'une M thodologie de Co-Conception de Produits Innovants, *Confere 2012*, Venice: 5th-6th July.
- Bouchard, C., Christofol, H. and Lim, D. (2005) Integration of Stylistics and Uses: Trends in Innovation Process. In Corsi, P., Christofol, H., Richir, S. and Samier, H. (eds) *Innovation Engineering*, Paris: ISTE Hermes, pp. 175-195.
- Brown, T. (2008) Design Thinking. *Harvard Business Review*, Vol. 86, No. 5, pp. 84-92.
- Chan Kim W. and Mauborgne, R. (2005) *Blue Ocean Strategy: How to Create Uncontested Market Space and Make the Competition Irrelevant*, Boston: Harvard Business Book Press.
- Choulier, D. (2008) *Comprendre l'activit  de conception*. Montb liard: Collection Chantiers UTBM.
- Corsi, P. and Neau, E. (2011) *Les dynamiques de l'innovation, mod les, m thodes et outils*. Paris: Hermes. Augmented English version to be published.
- Corsi, P. (2013) A Formal Approach for Designing Creative Futures Based on CK Theory, *On the Horizon*, Vol. 21, No. 1, pp. 54-68, <http://www.emeraldinsight.com/oth.htm>.
- Driver, A., Peralta, C. and Moultrie J. (2011) Exploring How Industrial Designers Can Contribute to Scientific Research, *International Journal of Design*, Vol. 5, No. 1, pp. 17-28.
- Findeli, A. and Bousbaci, R. (2005) The Eclipse of the Object in Design Project Theories. *The Design Journal*. Bloomsbury Publishing, London.
- Garel, G. and Mock, E. (2012) *La fabrique de l'innovation*, Paris: Dunod.
- Hatchuel, A. and Weil, B. (2003) A New Approach of Innovative Design: An Introduction to C-K Design Theory, *ICED 03*, Stockholm, 19th-21th August, Stockholm: KTH/The Design Society.
- Hatchuel, A., Le Masson, P. and Weil, B. (2004) C-K Theory in Practice: Lessons from Industrial Applications, *International Design Conference – DESIGN 2004*, Dubrovnik, 18th-21th May, Dubrovnik: FMENA University of Zagreb/The Design Society.
- Hatchuel, A. (2006) A framework for analyzing design. Adornment and wit in industrial design. In Flamand, B. (eds.), *Design. Essais on theories and practices*, Paris: French Institute of Fashion, pp. 147-160.
- Hatchuel, A., Le Masson, P. and Weil, B. (2008) Studying Creative Design: the contribution of C-K theory, *Studying design creativity: Design Science, Computer Science, Cognitive Science and Neuroscience Approaches*. Aix-en-Provence France, 10th-11th March.
- Hatchuel, A., Le Masson, P. and Weil, B. (2009) Design Theory and Collective Creativity: a theoretical framework to evaluate KCP Process, *ICED 09*, Stanford CA, 24th-27th August, Stanford: Stanford University/The Design Society.
- Hatchuel, A., Le Masson, P., Reich, Y. and Weil, B. (2011) A Systematic approach of design theories using generativeness and robustness, *ICED 11*, K benhavn, 15th-18th August, K benhavn : Technical University of Denmark/The Design Society.
- Le Masson, P., Hatchuel, A. and Weil, B. (2006) *Les processus d'innovation – Conception innovante et croissance des entreprises*, Paris: Hermes.
- Le Masson, P., Hatchuel, A. and Weil, B. (2010) *Strategic Management of Innovation and Design*, Cambridge: Cambridge University Press.
- Reich, Y. (1995) *Measuring the Value of Knowledge*, *International Journal of Human-Computer Studies*, Vol. 42, No. 3-30.
- Sch n, D. A. (1983) *The Reflexive Practitioner: How Professionals Think in Action*, New York: Basic Books.
- Ullah, A.M.M.S., Rashid, Md. M. and Tamaki, J. (2012) On some unique features of C-K theory of design, *CIRP Journal of Manufacturing Science and Technology*, No. 5, pp. 55-66.