The C-K theory: a model for creativity

The C-K theory encompasses methods widely implemented in the industrial world and that have achieved several notable successes. Ultimately, this theoretical breakthrough has revolutionized our approach to design.

28 April 2017 Pascal Le Masson

Paris Innovation Review – The C-K theory was developed more than 20 years ago, at a time when the now central idea of "innovative design" was still in its infancy. Where did this breakthrough come from?

Pascal Le Masson – Let's start with the present situation. A competitive company is no longer merely improving its products: it is also constantly modifying their definition. These changes in an object's identity – something everybody witnessed when mobile phones became smartphones – are spreading across all products. It is a structural transformation.

This new model of design has been implemented over the last twenty years. It uses new methods, quite different from those of engineering offices of the 20th century. In this sense, it is an industrial revolution that extends to all activities. However, in the 1990s, when this system began to emerge, engineers and researchers were both confronted with an enigma. How does one account for the paradox that innovation can produce something with an identity different from everything that existed before, while being formed by bricks of things that already existed?

Solving this puzzle – with the advantages of a good theory: rigorous rationale, control over reasoning, explanation of facts, light on hitherto unseen phenomena – could provide a better understanding of the fundamental phenomena described under the terms "creativity" or "invention". It could also provide a real assistance to engineers and designers faced collectively to the implementation of effective and rigorous "innovative design" processes.

In the 1990s, the challenge was quite real and the initial draft of the C-K theory emerged in response to the crisis of traditional innovation. Imagine the research department of an automobile company at the time: not 500 engineers, like in the 1960s, but 10,000. A factory full of white-collar workers with an unused potential: they know how to improve what exists but they have a hard time inventing breakthroughs that will make their business sustainable.

Armand Hatchuel and Benoît Weil were among the few researchers who perceived the crisis of traditional industrial innovation and its related scientific issues. This diagnosis convinced them of the need for a theoretical bet that would later prove quite fruitful.

Until then, the theories of knowledge and of creativity were strictly separated. Armand Hatchuel, soon joined by Benoît Weil, noted that these somewhat blurry objects – whether a designer's "brief," a technological bet, an architect's vision – were in fact propositions of the same type, both rational and rigorous, that the nascent C-K theory would label as "concepts" (C). A concept has a unique feature that distinguishes it from knowledge (K): it has no logical status. One cannot say whether the statement is true or false. A concept, for example, is: "there are chairs without legs."

Such propositions are different from those that have a logical status. Therefore, the C-K theory is based on the idea of making a distinction between two separate worlds: in the first, propositions have a logical status (K space); in the second, they are undecidable (C space). The great discovery is that these spaces, while presenting different structures, interact according to invariant and "expanding" mechanisms: they produce simultaneously new objects and new knowledge.

This distinction between C and K acts as a "wedge" (like in tree-felling) that will help open a space for innovative design, explore methodically both worlds and enable their interactions. The world of creative

ideation, of chimeras, of the "desirable unknown" (the C space of concepts) is in a systematic dialogue with the world of knowledge, of modeling what is known, of laws and beliefs (K space). Innovative design cannot be reduced to a mere exercise of creativity or to increasing knowledge of what already exists. The C-K theory models the process of dual expansion of the unknown and the known. One stimulates the other: knowledge stimulates creation and creation stimulates knowledge.

The intellectual implications of the C-K theory have never stopped expanding since its formulation. But the stakes were also operational. The C-K theory implies a paradigm shift for engineers and managers: the shift from *decision* to *design*. The question is no longer to decide "correctly" (i.e. optimize) among all the existing alternatives, but to generate new and better alternatives. The manager is not only a decision-maker but also a designer (or at least, a driver of design). Management sciences are entering a "post-decision" paradigm. The rationale underlying this paradigm is no longer about decision-making or criticism alone, but also about design.

In businesses, we need to move from R&D to RID, where "I" stands for the function that organizes innovative design i.e. the regeneration of the identities of techniques and products. This model, which we have described since the late 1990s, announced the directions of innovation which differ from R&D. But above all, the tools inspired by C-K theory were about to provide these new innovative features with methods and processes crucial to their effectiveness and credibility: exploring the unknown with rigor and efficiency is neither easy, nor intuitive.

It is no coincidence therefore that this theory was developed in an engineering school specialized in training decision-makers…

The theory was first exposed in a class. In 1996, an optional course titled "Engineering of Design" was offered by Armand Hatchuel, with Benoît Weil, Jean-Claude Sardas and Christophe Midler. The aim was to present state-of-the-art theories of design: German systematic theory, axiomatic design by Nam P. Suh, problem-solving theory by Herbert Simon, etc. Armand and Benoît planned to present a few research avenues toward a more universal and "generative" theory at the end of the course. However, one hypothesis, detailed by Herbert Simon, likened design rationale to *search* within a known *problem space*. This assumption can be found, implicitly, in all other theories. Rejecting this premise (proposed by Armand) required to reason on an "unknown space", opening a theoretical alternative with stimulating effects. During its presentation, this theory generated a great deal of enthusiasm among students and was quickly adopted for several graduation projects. This rupture triggered the definition of a space of concepts (partially unknown) and the possibility for the emergence of new knowledge. In a way, the first formulation of the C-K theory emerged during a course aimed at engineering students.

But this formulation was also consolidated by research conducted with industrialists exploring new approaches to innovative design: first, Renault and Tefal (SEB Group) and later, RATP (wich is operating the Paris subway network) and Thales. We must insist on the autonomy and support provided by Mines ParisTech to its researchers, and the stimulating effect of the partnership between research and industry. One could take the risk of confronting the enigma of creative and rational reasoning – or of innovative design. Ultimately, the close link between research and teaching offers an great space for theoretical prototyping.

How does the academic development of theory work?

It wasn't until 2009 that the first complete academic paper on C-K theory was published in a refereed journal. But the international academic world discovered the theory in 2003, at the Congress of the Design Society, in Stockholm.

The story is worth telling… In 2001, a manager from Saab Aerospace did a global benchmark of research in design and discovered our work. He became strongly interested and offered us a partnership. The 2003 Congress took place in Stockholm and the organizers invited the Vice-President of Saab Aerospace – a figure of R&D, in Sweden, who had closely followed our work – to the inaugural conference. And in front of 2000 researchers, he announced a new theory which contributed to understanding the innovations of Saab Aerospace in a very useful way for its future projects. The next day, Armand and Benoît presented the theory in a crowded room!

However, many experts had trouble understanding that the theory also models the mechanisms of invention. Not to mention the abstract nature of its essentials. To convince a larger audience, it still needed to showcase an ambitious and illustrative application.

In 2003, a student named Michaël Salomon joined a CNRS team at Orléans to apply C-K theory to the study of magnesium-CO_2 engines for Mars missions. The results were beyond all expectations. After six months, he and his colleagues published a paper titled "Mars Rover vs. Mars Hopper" focused on a new vehicle that would enable new modes of travel to Mars. The theory clearly fulfilled its promises. The student even obtained a doctoral fellowship at Berkeley. The academic reception of the C-K theory was firmly consolidated.

In the 2000s, the C-K theory begun to circulate in the industry. Did this contact improve it?

Yes, and in major ways! After the first partners, several other industrialists joined in, starting with STMicroelectronics and the SNCF – but also middle-market companies such as Urgo or Nutriset. We worked together to implement the method, identify its conditions of use, train the managers. Books such as *Les Processus d'Innovation* (Processes of Innovation, 2006) also contributed to this dissemination.

Innovation managers are looking for new methods but what they are usually offered boils down to project management or brainstorming methods. Thinking with C-K allows to extend and assess more rigorously all projects: one can appreciate the variety of alternatives, the originality of breakthroughs, the value created etc.

The partnership with RATP was crucial. The company has a strong tradition of foresight and innovation, with great scholars such as Édith Heurgon and Georges Amar who promote new paradigms of mobility. Georges Amar asked us to reflect on a collective approach, inspired by C-K theory, which would mobilize experts from many different backgrounds on topics such as the design of the "metro of the future."

It's a real challenge. With groups of 50 to 60 experts, it is impossible to follow all the subtleties of the theory. Our response will be to seek the best "linearization" of C-K reasoning i.e. a method that preserves the generativity of the process. This is where KCP comes in, by inverting the logic of traditional brainstorming.

First difference: according to brainstorming, you need to "remember what you know." KCP prescribes the exact opposite: "first exchange on what you know and especially what you do not." Move from the state-of-the-art to the *state-of-the-non-art*.

Second difference: brainstorming prescribes to "produce ideas, even in a messy order." KCP intends to guide you "on tracks where you would never go unless you receive help." There are no such thing as "ideas in total disorder". Ideas always follow an implicit order. This brings us to the so-called "fixation" highlighted by the psychology of creativity. Allowing individuals to act "freely" will introduce a considerable bias due to common knowledge. KCP imposes a methodical exploration of the unknown and therefore calls for moving beyond fixation.

Third difference: according to brainstorming, "only the most interesting idea must be selected among all the ideas produced." As if we were forced to choose between several investment opportunities. But ideas are not mutually exclusive! Choosing one single idea among 350 means we exclude 349 others. But what if, among these 349, one could help us develop the idea we selected in first place? By excluding them, we could have killed the very idea we had chosen to keep! The C-K theory shows that all ideas originate from the same roots and are related to knowledge shared by a collective. Hence, they are highly interdependent. Therefore, we need a design strategy that takes into account all the possibilities we had imagined… as well as the initial budget!

Impossible? Not necessarily: today we have many resources to extend the knowledge space – strategic monitoring over competitors and labs, contests, open innovation, etc. Even better: our awareness of these interdependencies facilitates the identification of a single missing brick controlling many ideas. Designing this missing piece will lead to a generic technology capable of reorganizing a significant part of the technical system.

KCP will soon experience a real industrial and scientific success. Teams are growing rapidly, researchers are getting involved and many theses have been launched. KCP will become a business method in the RATP and in Thales, who will send engineers and product marketing specialists for training at Mines ParisTech. KCP has allowed to identify many new forms of collective action in innovative design. In return, it has proved one of the greatest tools of insertion of these methods within organizations. Many of our partners have deepened these approaches. Technip, for instance, tested a KCP with 1,500 experts scattered around the world and connected via a social network.

The success of the C-K theory and KCP method called for a comprehensive engineering of innovation. For this purpose, we supported the emergence of consultants. Some, such as Yvon Bellec and Domnique Lafon, the founders of Cayak, had been following our research for a long time. Others are students and doctors trained in the laboratory who subsequently created companies that disseminated the theory and its methods as well as building effective tools, such as STIM, created by Benjamin Duban and Frédéric Arnoux. Our long-standing partners have supported these trades that serve as an interface between research and the industry and contribute to the growth and dissemination of innovative design methods.

Let's return to the academic development of this theory...

It goes hand in hand with its dissemination in the industrial world. The *Theory and Methods* Chair of innovative design was created in 2009 and brings together thirty researchers, supported by approximately forty firms. Internationally, the dissemination of large firms such as Airbus also contributes to the interest in the theory.

From a scientific standpoint, we had to strengthen the foundations of the theory. Armand Hatchuel noted that the space C would keep on working as a model of particular sets in which it isn't possible to "choose" any element (because we would then be able to produce a solution and the proposition would have a logical status) as long as the design hasn't been completed. Step by step, he goes back to the foundations of set theory and more specifically to *forcing*, a mathematical method that allows to generate new set models. Its inventor, Paul Cohen, won the Fields Medal for his discovery. Armand and Benoît discovered that *forcing* is a design theory that can be closely associated with the C-K theory. This is a major result: there is a "sets" version of the C-K theory! I was able to show that the conditions of forcing refer to specific structures of knowledge – consistent with the "splitting condition" – that I found in the teachings of Johannes Itten and Paul Klee at the Bauhaus, the famous design school.

In 2007, the Design Society decided to entrust Armand Hatchuel and Prof. Yoram Reich with the creation of a section dedicated to "Design Theory". Thirty researchers met in January 2008 for the First International Workshop on Design Theory. Year after year, the initiative snowballed among scientific communities.

The research community in Design Theory has been growing constantly. Around the Mines ParisTech Chair first. Akin Kazakci opens pathways to a more conceptive data science. Sophie Hooge codifies C-K charts and explores the theory of innovative collectives. Mathieu Cassotti and Marine Agogue make the connection between C-K theory and developmental psychology, opening new approaches to creativity. Anne-Françoise Schmid makes the connection with contemporary epistemology. Vincent Bontems crosses design theory and the philosophy of technology of Gilbert Simondon. In addition, the dialogue is further enriched by historians of science, but also by process chemistry, materials, biological engineering, agronomy, fundamental physics – researchers from different backgrounds who asked a question: what is design, what is "generative" reasoning? For example, for a researcher working on feeding neutrons, imagining particles, developing approximations of the Schrödinger equation, is a design object. With a good design theory, you do not conceive particles in the same way. This researcher found in the C-K theory a way to completely rethink his research program. Gradually, a new academic community was established, with hundreds of researchers.

A high-impact breakthrough has a trickle-down effect on both the industry and the academic world. In academia, we are gradually finding a place that did not exist. A complete reordering has been triggered by the emergence of an autonomous field that will, in return, feed the existing academic fields.

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