


The Design Society Chat Room  
Design Theory SIG  
26th October 2021

## The interplay between design theory and creativity

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Chairmen of the Design Theory SIG of the Design Society

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## The Design theory SIG

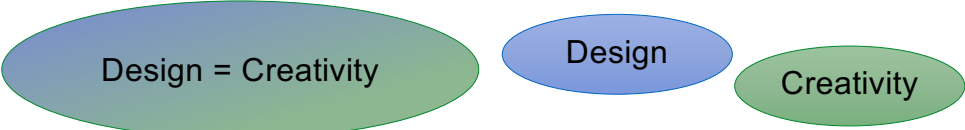


- A large community : >100 participants each year; more than 300 people connected to the SIG; more than 35 institutions represented...
- Under the auspices of the **Design Society**
- Support an strong renewal of research on Design Theory and Methods for Innovation
- **Strong interactions with other SIGs, in particular creativity SIG (presentations by T. Taura, Y. Nagai, G.Cascini...)**

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## The interplay between design theory and creativity

- In professions: creativity, a curious landmark for design professionals:
  - Commonplace on designers: creativity = design!
  - Commonplace on engineers: creativity begins where engineering science (optimization, decision...) ends? But also authors claiming: 'there is creativity in engineering' (von Engelmeyer 1895, Pahl & Beitz 1977, Howard et al 2008, Taura & Nagai...)
 ... hence maybe not so separate? **Provide a common language?**



(industrial) Design begins with creativity?

Creativity begins where (engineering) design is ending?

- In academia: Design theory and creativity research, two separate academic fields, with different approaches: engineering design vs psychology
  - ... but finally two (scientific) ways to look at similar phenomena, namely creativity thinking? ... and uncovering different facets? ... and hence interacting fruitfully??

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## The interplay between design theory and creativity: creativity as a (critical) test for design theory?

Level of the models of thought

- develop formal models
- tests them (consistency, explanatory power, predictions,...)

At the level of models of thought: **does design theory, as a formal model of thought, account for creative thinking?**

...DT inspires methods, measures, organizations for...



Level of models of collective action

- Same logic: models / tests
- DT as a resource for new models of action that go beyond (decisional, optimization) rationality (see PSI – Reich et al. 2015)

At the level of models of collective action: how can DT help develop new models of creative collective action?

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## The interplay between design theory and creativity

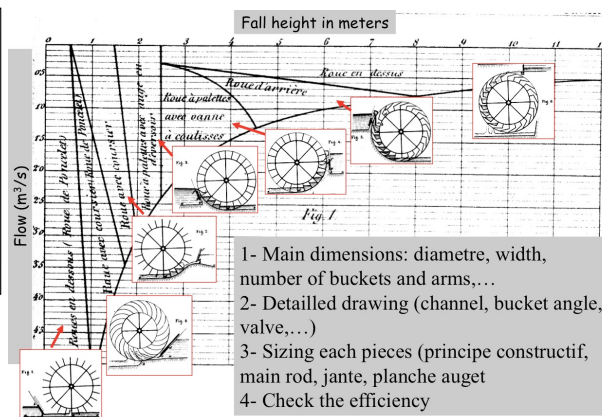
1. Lessons from history: Design theory to overcome identified lack of creativity - uncovering a dialectical relationship:
  - 1840s Redtenbacher, 1920s Bauhaus, 1950s Systematic Design
  - Creativity diagnoses poor performance and raises the question of methods for improved creativity performance
  - Design theory as a way to overcome these limits.
2. From creativity issues to contemporary design theory: design theory as a model of creative thought
  - Expectation on design theory from the point of view of creativity
  - The generic mechanism of creative power in C-K theory: expanding partitions and knowledge expansion
3. Two lineages of works on how design theory addresses contemporary creativity issues
  - Overcoming fixations
  - Impact of knowledge structures on generativity
4. Key drivers and perspective of the research on design theory and creativity

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## Historical moment 1: Redtenbacher 'ratio method', Germany, 1840s


- Statement: technicians always rebuild the same machine(s)
- Goal of the « ratio method »: help technicians to « invent » machines adapted to their context



A great success: method taught in all engineering schools in Germany and used until 1920s!

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## Historical moment 2: Bauhaus, Itten, Klee - education to overcome clichés, Germany 1920s

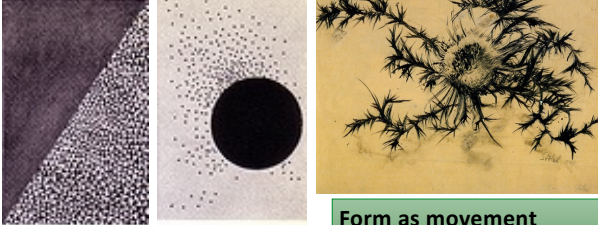


- Statement: « imagination and creative ability must first of all be liberated and strengthened »
- « the objective laws of form and color help to strengthen a person's powers and to **expand his creative gift** »

« Improve perception and representation »


**Theory of colors** = « liberate the study of colors harmony from associations with forms », discover « expressive quality of the colors and the color contrast »

Work on Old Master: « this study can do damage only on the absence of watchful self-criticism » – Issenheim Altar




**Theory of contrast** = open a new world to students

**Form as movement**

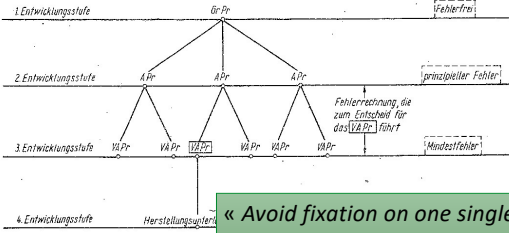

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## Historical moment 3: systematic design, Germany, 1950s





- Statement: composition with well-known building rules is too limited
- Goal of the systematic design: support systematic exploration of alternatives at well identified levels (functional / conceptual / embodiment / detailed design)



« Avoid fixation on one single solution » (Ehrlenspiel 1975)

Another great success: systematic design as the « model of thought » of worldwide R&D!



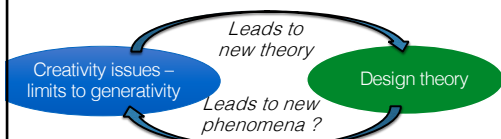

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## A dialectical relationship between creativity issues and design theory?

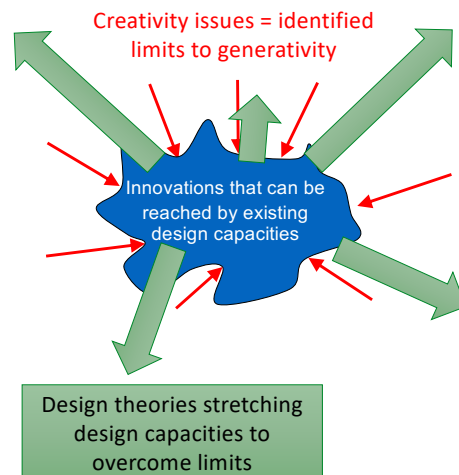
Common pattern in these 3 moments:

- Creativity diagnoses poor performance and raises the question of methods for improved creativity performance → uncover the « box » out which it is difficult to go!
- Design theory and methods: models of thought to overcome these limits (teachable models!)



Questions:

- What are the limits of today?
- How does contemporary design theory address them?
  - ... at the level of models of thought
  - ... at the level of models of action



Le Masson, P., Hatchuel, A., et Weil, B. (2011). "The Interplay Between Creativity issues and Design Theories: a new perspective for Design Management Studies?" *Creativity and Innovation Management*, 20, (4), pp. 217-237.

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## The interplay between design theory and creativity

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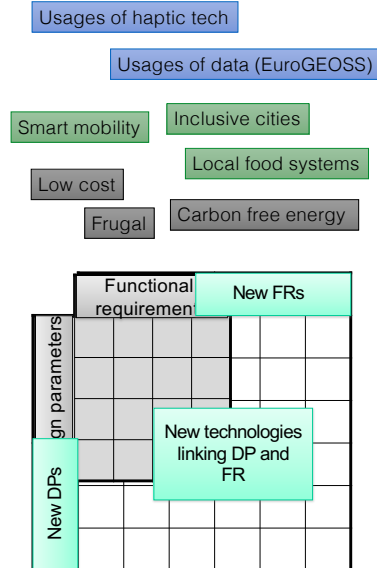


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## 2-1 Expectations on design theory – where are we missing creativity?

1. **Lack of creativity to face innovation challenges** - beyond optimisation and problem solving:
  - New usages for emerging technologies (techno push) (see data,...)
  - Products and services on « innovation fields » (without clear requirements)
  - Design under strong innovation constraints (see transitions)
2. Lack of « radical originality » (Boden 1990), ie need to account for the **modification of « generative rules »**:
  - Rule breaking, rule creation
  - New definitions of objects + re-ordering
  - ... revising rules of systematic design! (FR, DP)



## 2-1 Expectations on design theory – cognitive obstacles identified by creativity studies

3. A « productivity gap » phenomenon → **cognitive cause = fixations by knowledge**

How to make a square by moving ONE match?

Cognitive fixation on « square » :  
Square = geometrical shape  
Square = mathematical operation (2x2)

Fig. 4. Examples of creative solutions developed by subjects in the control condition (see Starbuck 1981, for (a), and under (c) conditions of Experiment 2).


Fig. 5. A sketch of a model of working memory in relation to problem-solving. It shows a person's brain connected to a computer, illustrating cognitive processes.

Finke, Ward, Smith,... ; Janson & Smith...

Crilly, N. (2015). "Fixation and creativity in concept development: The attitudes and practices of expert designers." *Design Studies*, 38, pp. 54-91.

## 2-2 Model of creative thought – limits of available models...

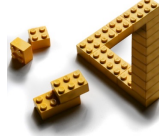
**Decision theory**




*Programming, optimization, combinatorics ...*

Decision theory (optimization, search...) = models of thoughts, based on knowledge, but **without generativity**

Design theory = advances were required to meet the expectations:  
 Expectation 1 = new innovation challenges  
 Expectation 2 = revise generation rules  
 Expectation 3 = help overcome fixation



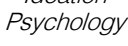


**Creativity theory**



*Ideation Psychology*

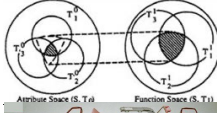
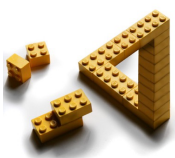
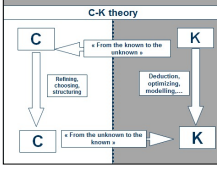
Creativity research: generativity measures, studies of generativity phenomena but... **knowledge background remains too implicit**, leading to aporia:  
 > CT vs DT? False creativity in DT vs creativity in CT?  
 > role of expertise: source of fixation vs source of creat?




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## 2-2 Design theory – a quest for generativity

**Classical professional language:** technical, functional, emotional,...

INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED11  
15 - 19 AUGUST 2011, TECHNICAL UNIVERSITY OF DENMARK

**A SYSTEMATIC APPROACH OF DESIGN THEORIES USING GENERATIVENESS AND ROBUSTNESS**

Armand Hatchuel<sup>1</sup>, Pascal Le Masson<sup>1</sup>, Yoram Reich<sup>2</sup>, Benoit Weil<sup>1</sup>  
(1) Mines ParisTech (2) Tel Aviv University

**Abstract relational language:** concepts, unknowns, desires,...

**General design theory (Yoshikawa 1981)**




**Axiomatic Design (Suh 1988)**

**Coupled design Process (Braha & Reich 2001)**

**Infused Design (Reich & Shai 2001)**

**C-K theory (Hatchuel & Weil 2002)**

...  
**(other proposals: C-K/Ma, PSI, design creativity models...)**




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## C-K theory – creative power: K-expansion and C-expansive partitions

2-  $K \rightarrow C$ : knowledge support C-partitions – either in a 'restrictive way' (rely on usual knowledge) or expansive way: the use of original (independent) knowledge (**expansive C-partitions**)

1-  $C \rightarrow K$ : C-exploration will provoke **knowledge expansion** – imagination supports knowledge creation

Expectation 1: DT = situation where there is **unknown** by reference to some knowledge - **AND the knowledge reference can be very rich and complex** → integrates Knowledge background, works for multiple creative issues

Expectation 2: regenerate design rules via K-expansion AND C-expansions

Expectation 3: K as a source of fixation – to be controlled by rigorous design reasoning.

CIRP Journal of Manufacturing Science and Technology  
journal homepage: www.elsevier.com/locate/cirp

On some unique features of C-K theory of design  
A.M.M. Sharif Ullah\*, Md. Mamunur Rashid, Jun'ichi Tamaki

Hatchuel, A., et Weil, B. (2003) "A new approach to innovative design: an introduction to C-K theory." *ICED'03, August 2003, Stockholm, Sweden*, 14.

Hatchuel, A., et Weil, B. (2009). "C-K design theory: an advanced formulation." *Research in Engineering Design*, 19, (4), pp. 181-192.

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## From creativity issues to contemporary design theory –DT as a model of creative thought

- **Design theory is today a model of creative thought**  
(at the same level of rigor than decision theory for decision making thought)
- Some critical tests:
  - The internal consistency of the theory
  - How the theory addresses the above mentioned 'creativity' issues
- Going on with the interplay between design theory and creativity...

Leads to new theory

Leads to new phenomena ?

Creativity issues – limits to generativity

Design theory = model of creative thought

How does contemporary design theory provide grounds and **perspectives for new studies on creativity phenomena?**

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## The interplay between design theory and creativity

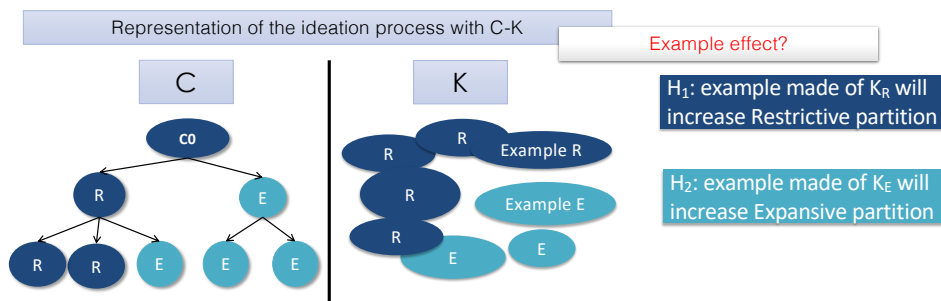
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### 3-1 Overcoming fixation – illustration of a design theory based experiment

Agogué, M., et al. (2014). "The impact of type of examples on originality" J. of Creat. Beh., 48, (1), pp. 1-12.

- Research question: do examples fix or defix in creativity processes? Unconclusive literature (apparently contradictory experiments)
- Design theory based experiments:
  - Clarify hypotheses → Design theory enables to formulate specific hypotheses

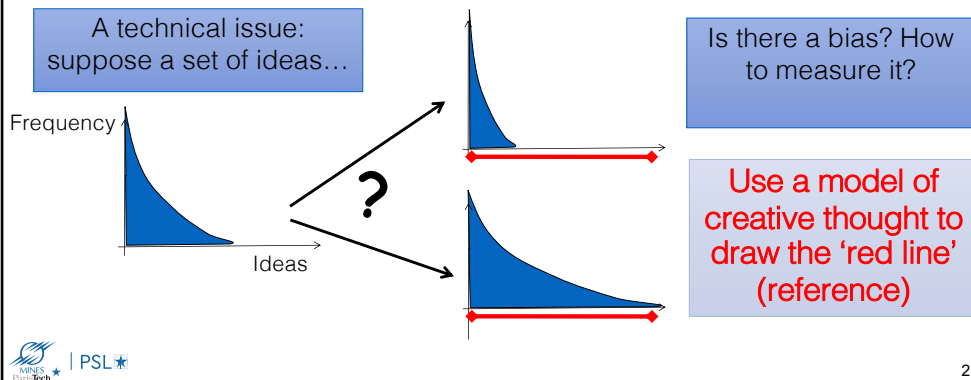


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- Research question: do examples fix or defix in creativity processes? Unconclusive literature (apparently contradictory experiments)
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  - Improve experimental setting → Design theory enables the development of new measurement methods



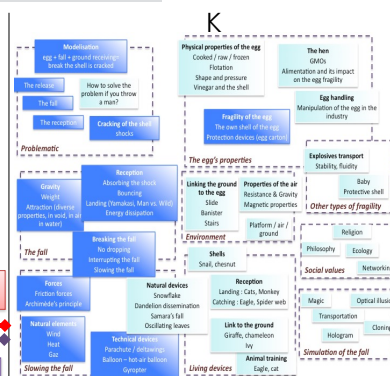
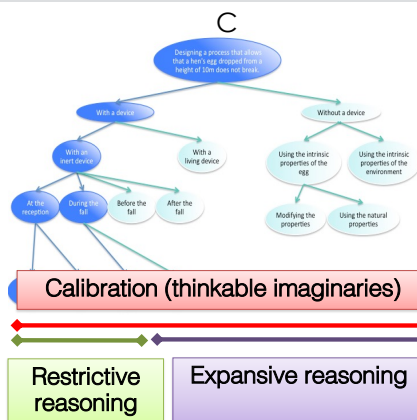
### Experiment protocol

#### 1- Define a design task

“You are a designer – propose as many creative solutions as possible on the following design issues (without example)  
 Make that an hen’s egg launched from 10m height doesn’t break”



#### 2- Prepare the referential




## Experiment

**1- The design task**

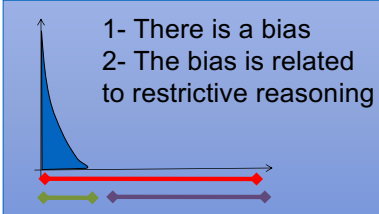
You are a designer – propose as many creative solutions as possible on the following design issues (without example)  
*Make that an hen's egg launched from 10m height doesn't break*

**2- The referential**

**3- The experience (without example)**



1- There is a bias  
 2- The bias is related to restrictive reasoning



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## Experiment


**1- The design task**

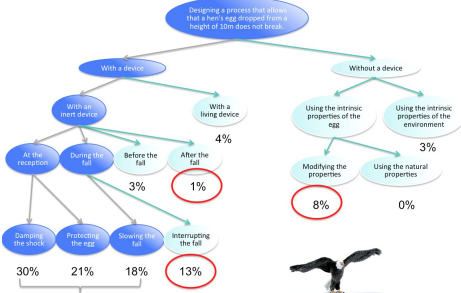
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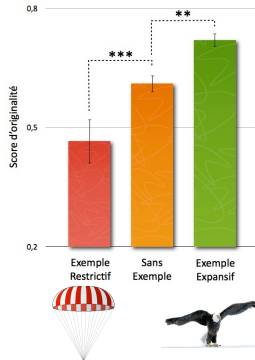
**2- The referential**

**3- The experience (without example)**

**4- Testing hypotheses (experiment with example)**







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### 3-1 Overcoming fixation – illustration of a design theory based experiment

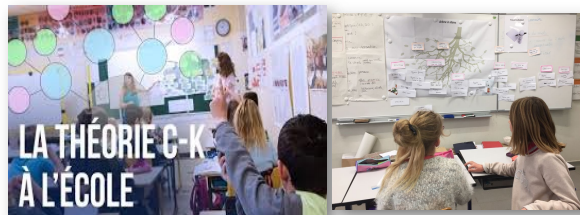
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- Research question: do examples fix or defix in creativity processes? Unconclusive literature (apparently contradictory experiments)
- Design theory based experiments:
  - Clarify hypotheses → Design theory enables to formulate specific hypotheses
  - Improve experimental setting → Design theory enables the development of new measurement methods
- Hypotheses are verified
- Open new frontier for research: theoretical framework and instruments to study how to overcome fixation... see some results below...

### 3-1 Overcoming fixation – further developments...

- Similar experimental protocols to test teaching methods to improve creativity (children, biomimeticism)

Experiments by Anaelle Camarda et al, ANR Idefix



Freitas Siqueiredo, C., Hatchuel, A. (2016). "Beyond analogy: A model of bioinspiration for creative design." *AI EDAM*, 30, 159-170.  
 Picaparti, et al. (2020). "Engineering Design Innovation through C-K theory based templates." *Journal of STEM education*, 21, (1), 58-63.

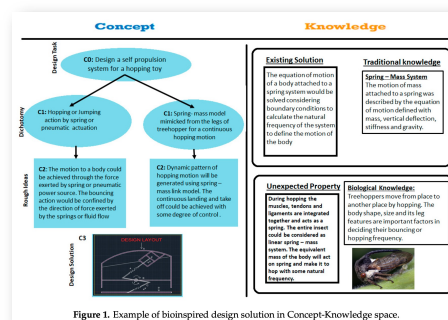


Figure 1. Example of bioinspired design solution in Concept-Knowledge space.

### 3-1 Overcoming fixation – further developments...

- Similar experimental protocols to test teaching methods to improve creativity (children, biomimetism)
- Similar experimental protocols to study defixating leadership: systematic exploration of how 'leaders' might help ideators

Ezzat, H., et al. (2016). "Solution-oriented versus Novelty-oriented Leadership Instructions: Cognitive Effect on Creative Ideatio." DCC.  
 Ezzat, H., et al. (2017). "How minimal executive feedback influences creative idea generation." PLOS ONE, 12, (6), pp. e0180458.  
 Ezzat, H., et al. (2018). "Specificity and Abstraction of Examples: Opposite Effects on Fixation for Creative Ideation." JCB, 54, (1), pp.

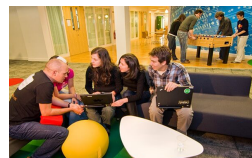
Ezzat PhD, special mention at the PSL thesis award (2018)

New ANR project (J. Boudier PhD thesis)

#### Usual suspects for "leader for creativity"



The innovator



The facilitator

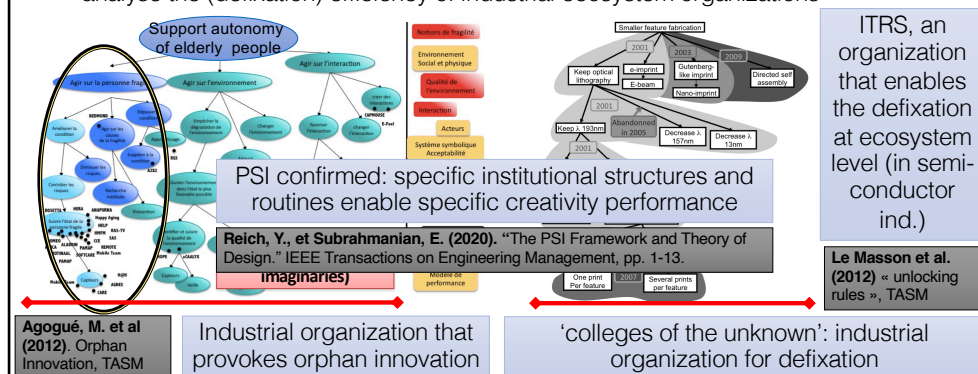
Other types?

→ How can a leader defixate his/her team with good initial instructions?



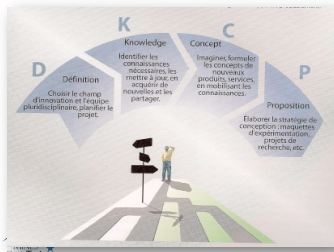
### 3-1 Overcoming fixation – further developments...

- Similar experimental protocols to test teaching methods to improve creativity (children, biomimetism)
- Similar experimental protocols to study defixating leadership: systematic exploration of how 'leaders' might help ideators
- Similar protocols to analyse fixation / defixation at the level of industry ecosystems – analyse the (defixation) efficiency of industrial ecosystem organizations



### 3-1 Overcoming fixation – further developments...

- Similar experimental protocols to test teaching methods to improve creativity (children, biomimetism)
- Similar experimental protocols to study defixating leadership: systematic exploration of how 'leaders' might help ideators
- Similar protocols to analyse fixation / defixation at the level of industry ecosystems – analyse the (defixation) efficiency of industrial ecosystem organizations
- From theory to method for collective creativity: KCP in companies: beyond brainstorming



Elmqvist, M., et Segrestin, B. (2009). Int J of Automotive Technology and Management, 9, (2), pp. 229-244.  
 Hatchuel, A., et al. . (2009) "Design Theory and Collective Creativity: a Theoretical Framework to Evaluate KCP." ICED'09, Stanford CA.

### 3-2 Knowledge structures and creativity

- Research question: What kind of knowledge should be taught? How to teach students to improve their creative design skills?
- Issue: clarify hypotheses → how to characterize knowledge for creativity?

#### Theoretical model: forcing & splitting condition

Forcing implies that knowledge follows « **splitting condition** »:

- The new is not determined by initial knowledge rules → design is not know-how
- The new is not a modular combination of the old rules → design is not lego



Hypothesis: a school (like Bauhaus) that aims at 'expanding creative gift' (Itten), should teach splitting knowledge

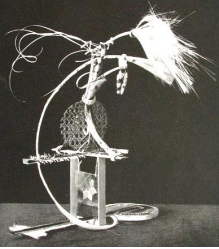
Study Bauhaus courses (Itten, Klee) to analyse how they enable (or not) splitting knowledge

### 3-2 Knowledge structures and creativity

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- Issue: clarify hypotheses → how to characterize knowledge for creativity?
- Empirical material: Bauhaus courses and material, studied with C-K

C

Phase 3: texture montages of contrasting materials



« fantastic structures with completely novel effects »  
(Itten)

K

<p><b>K on Materials (lemon exercise)</b></p> <ul style="list-style-type: none"> <li>• Wood</li> <li>• Metal</li> <li>• Glas</li> <li>• Textile</li> <li>• Sorghum</li> <li>• Wicker</li> <li>• ...</li> </ul>	<p><b>K on Texture (tactile assessment)</b></p> <ul style="list-style-type: none"> <li>• rough</li> <li>• fibrous</li> <li>• smooth</li> <li>• shiny</li> <li>• Dry</li> <li>• ...</li> </ul>	<p><b>K on Montage:</b></p> <ul style="list-style-type: none"> <li>• Rigid</li> <li>• Elastic</li> <li>• Stable</li> <li>• Slender</li> <li>• Balanced</li> <li>• Jointed</li> <li>• ...</li> </ul>
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Deterministic (necessary):  
Mat → Text

Modular (independent):  
 $T_1 + M_0 = T_2 + M_0$


Non-Deterministic:  
Mat → Text1 OR Text2

Non-Modular:  
 $T_1 + M_0 \neq T_2 + M_0$

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### 3-2 Knowledge structures and creativity

- Research question: What kind of knowledge should be taught? How to teach students to improve their creative design skills?
- Issue: clarify hypotheses → how to characterize knowledge for creativity?
- Empirical material: Bauhaus courses and material, studied with C-K
- Bauhaus creativity teaching relied on teaching « splitting » knowledge
- Open new frontier for research: investigate how knowledge structures impede / support creativity



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## 3-2 Knowledge structures and creativity— further developments...

- Uncovering the creativity logic enabled by non-verbal media: how sketching can be used to split (architect's own) knowledge.

Brun, J., Le Masson, P., et Weil, B. (2016). "Designing with sketches: The generative effects of knowledge preordering." *Design Science*,

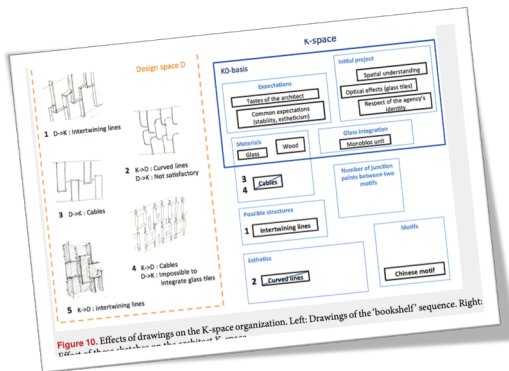


Figure 10. Effects of drawings on the K-space organization. Left: Drawings of the 'bookshelf' sequence. Right: Effects of these drawings on the organization of K-space.

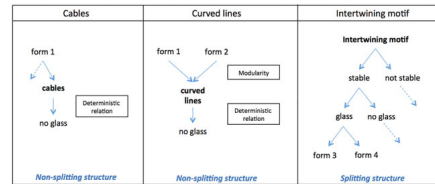


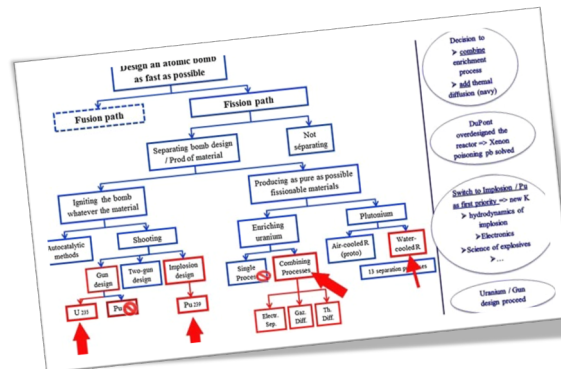
Figure 11. Avoiding modularity and determinism in building 'splitting' knowledge structures.

## 3-2 Knowledge structures and creativity— further developments...

- Uncovering the creativity logic enabled by non-verbal media
- Splitting knowledge in the organization of breakthrough innovation

Lenfle, S., Le Masson, P., et Weil, B. (2016). "When project management meets design theory" *Creativity and Innov Mgt*, 25, (3).

Manhattan = K-creation strategy = first create splitting K and then non-splitting K-base in the end (create K until the design becomes modular and deterministic)





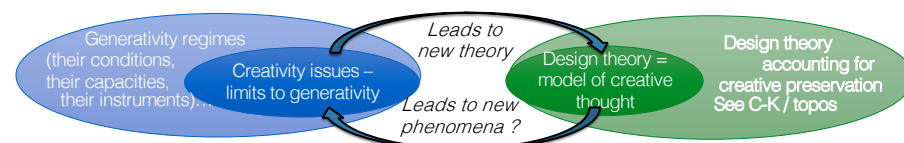
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  - The generic mechanism of creative power in C-K theory: expanding partitions and knowledge expansion
3. Two lineages of works on how design theory addresses contemporary creativity issues
  - Overcoming fixations
  - Impact of knowledge structures on generativity
4. Perspective of the research on design theory and creativity – key drivers

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## 4- Perspectives for research

- Lessons learnt from the interplay:
  - To address lack of creativity (contemporary innovation issues), design theory developed as a **'model of creative thought'**
  - Design theory, as a 'model of creative thought', proved useful to **inspire/ground models of creative collective action...**



- Many new frontiers today...
  - Overcoming fixations
  - K-based creativity
- ... leading to new interplay?
  - Generativity regimes (their conditions, capacities...)
  - **Generativity regimes with preservation:** → DT that accounts for innovation AND preservation? → model of creation heritage with C-K/topos (beyond creative destruction!)

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## Key drivers

- Interplay between theory building and empirical studies!
  - Improve formal models!
  - Improve experimentation capacities!
- This is only possible with a powerful research community!
  - participate to the SIGs and Design Society!

**SAVE THE DATE**

**DESIGN THEORY WORKSHOP**  
31<sup>st</sup> Jan – 1<sup>st</sup> Feb 2022

**DESIGN THEORY TUTORIAL**  
2<sup>nd</sup> – 4<sup>th</sup> Feb 2022

International Workshop on **DESIGN THEORY**  
Special Interest Group of the Design Society  
01<sup>st</sup> January – 1<sup>st</sup> February 2022

8<sup>th</sup> Tutorial of the **DESIGN THEORY SIG**  
02<sup>nd</sup> – 04<sup>th</sup> February 2022

**BASIC COURSES**  
Design Theory: A Contemporary Challenge  
Knowledge Discovery  
Design Method

**ADVANCED COURSES**  
The Interplay of Design Theory  
Knowledge Representation and Design Problem  
Evolutionary Design and Design Innovation  
Complexity & Design Theory

**WORKSHOPS (04<sup>th</sup> Feb)**  
Exploring your Design with Design Theory

See you next year in Paris !

The Design Society Chat Room  
Design Theory SIG  
26th October 2021



## The interplay between design theory and creativity

Pascal Le Masson – Eswaran SUBRAHMANIAN

Prof. MINES ParisTech – PSL

Research Prof. CMU & NIST

Chairmen of the Design Theory SIG of the Design Society

