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# *That was fun, now what?: Modelizing knowledge dynamics to explain co-design's shortcomings*



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*Co-design workshops seek solutions to complex, multi-stakeholder issues. These ephemeral encounters bring together designers and uninitiated individuals who embark in a facilitated process that mobilizes a range of simplified design tools and methods. Despite co-design's benefits in terms of representation and acceptability, these workshops also come with limitations and often fall short of their intended goals. Proceeding from stylized facts informed by both our experience and the literature, this study investigates why co-design struggles at maintaining engagement and fails to consistently deliver innovative output regardless of the number of participants involved. Namely, we employ a model-building strategy to illuminate the main knowledge dynamics during workshops and to highlight a constrained 'reactive expansion' mechanism that explains known co-design's shortcomings. Implications for workshop facilitation and planning are offered in closing.*

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*Keywords: co-design, design cognition, C-K theory, stylized facts, model-based science*

## *1 Introduction*

Introduced in the 1970s, the term 'co-design' was first used to describe architectural and design choices made to ensure the optimal performance of new products (Burkhart et Ittelson, 1978). For example, Wolf (1994) explained how planes' engines and fuselage had to be designed concurrently to fully support each other. By contrast, contemporary definitions describe planned meetings in which professional designers engage with external actors (Sanders, 2002). The emphasis is placed on the many benefits—be it in terms of novelty or representation—of opening up the design process to stakeholders, most of whom are not designers by training, as well as on the

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increased acceptability of solutions conceived in a more participatory manner (Steen, 2013).

Specifically, co-design meetings or workshops are typically short-term, punctual engagements led by professional designers and involve different participants with little to no prior relational history and with limited design experience (Sanders & Stappers, 2008, 2014). As Sanders (2002) explains, co-design allows for controlled encounters between designers and ‘ordinary folks’. Facilitated by the use of playful tools and methods, these workshops pursue innovative solutions to a range of complex, multi-stakeholder problems (Sanders, 2000; Steen et al., 2011). This includes, for instance, designing new public policies (e.g., Blomkamp, 2019), health care services (e.g., Heiss & Kokshagina, 2021), organizational change strategies (e.g., Dubois et al., 2016), or education curriculums (e.g., Severance et al., 2016). However, opening up the design process also implies less control and more complexity (Steen, 2013), and is not without shortcomings and barriers. These include uneven power dynamics (e.g., Burkett, 2012), a lack of shared understanding (e.g., Kleinsmann et al., 2007) or dedicated processes (e.g., Kleinsmann & Valkenburg, 2008), priorities misalignment (e.g., Blomkamp, 2018), wavering motivation (e.g., Farr, 2018; Trischler, Pervan, et al., 2018), or mitigated results from a novelty and feasibility standpoint (e.g., Bradwell & Marr, 2017; Pirinen, 2016). Thus, despite their many benefits and undeniable popularity, co-design workshops may not always be the most effective or efficient approach to designing solutions (Evans & Terrey, 2016). While co-design may actually be an inherently flawed approach, and that expectations regarding its outcomes should be ‘calibrated’ accordingly (Lloyd & Oak, 2018), it has also been argued that much remains to be understood about how participants interact and how best to structure workshops. Indeed, better understanding the downsides and benefits of co-design, when and why to use it, as well as improving both its process and outcomes, remain ongoing conceptual and practical challenges (Bradwell & Marr, 2008; Steen et al., 2011).

In particular, previous work has called for more systemic analyses of co-design dynamics that would allow for the simulation of different participant and facilitation configurations (Trischler, Kristensson, & Scott, 2018). To that effect, we note that the co-design literature generally describes a mechanism that relies on “the sharing and combining of knowledge and [the development] of a shared understanding” (Steen, 2013, p. 16). Kleinsmann et al. (2007) also explicitly mention knowledge sharing and pooling as the core activities that underpin co-design, while Taffe (2015) explains that the goal is to get participants to contribute their knowledge jointly towards creative artefacts. Specifically, co-design workshops aspire to bring together the “abstract space” of professional design work with insights from the “concrete space” of everyday life Lee, 2008.

Hence, proceeding from three stylized facts on co-design’s shortcomings (e.g., [Cont, 2001](#); [Kaldor, 1961](#)), this paper uses a model-building strategy that depicts core knowledge dynamics during workshops and attempts to shed light on co-design’s underlying mechanisms. These stylized facts that relate to the ephemerality of engagements, the lack of innovative results, and the presence of issues irrespective of the number of participants, are both informed by our extended experience with workshops and supported by the co-design literature. Namely, this study asks: what are the main knowledge dynamics and variables at play during co-design and what inherent limitations do they reveal? Drawing from C-K theory (e.g., [Hatchuel et Weil, 2003, 2009](#)), which describes knowledge exchange and creation in design, our minimalist model shows a uniquely restricted and ephemeral “reactive expansion” system that not only accounts for all three stylized facts but also highlights its limitations and potential ways to overcome them. In the process, this study answers calls for more research on participants interactions in co-design ([Blomkamp, 2018](#)) and on the nature of ideas that arise during workshops ([Hirscher et al., 2019](#)). Last, we conclude by identifying practical implications for facilitation as well as potential directions for future research.

## 2 Stylized facts

Stylized facts (SFs) are widely used in economics as theoretical simplifications of complex phenomenon for the purpose of model building ([Arroyo Abad & Khalifa, 2015](#)). According to [Kaldor \(1961: 178\)](#), they “concentrate on broad tendencies, ignoring individual detail, and proceed on (...) a hypothesis that could account for these stylized facts, without necessarily committing on the historical accuracy, or sufficiency, of the facts or tendencies thus summarized”. Simply put, SFs are “empirical regularities in need of explanation” ([Hirschman, 2016, p. 606](#)). In the present case, prolonged observation, participation, planning and occasional facilitation, as well as informal discussions with a range of stakeholders over the course of a two-year period<sup>1</sup> have allowed us to identify three broad empirical phenomena in co-design. Most of the workshops we were involved in were day-long (or less) facilitated engagements that followed a typical divergence-convergence design sequence. Throughout these experiences, we also got to develop a first-hand appreciation of co-design’s inherent strengths and weaknesses. The resulting SFs do not adequately depict all co-design occurrences and we recognize that they do not fully account for the field’s richness and variety. Rather, our decision to focus on a few “common denominators among the properties observed” ([Cont, 2001, p. 224](#)) is motivated by the desire to crack open the black box of co-design and to study its underlying mechanisms. We trust that those who have experienced similar-built workshops before will relate to these dressed down shortcomings and that those who have not will appreciate their plausibility. That said, we also note that all three SFs— *ephemeral engagement*, *underwhelming outputs*, and *size does not matter*— described below are also

extensively supported by prior research and are not mere anecdotes. Thus, while typically not expected from work that proceeds from SFs, we still saw fit to support our own interpretations with the relevant literature.

### *2.1 SF #1: ephemeral engagement*

Co-design workshops often present themselves in a creative and informal format, and rely on a range of fun ‘game-like’ tools and methods (Trischler et al., 2019). The stated objective is to make design work more accessible and engaging to laypeople. It implies giving voice and making the engagement enjoyable for all (Ornekoglu-Selçuk et al., 2023). Workshops also tend to be short-lived encounters—a few hours, perhaps a day or two—and, as such, have been said to carry the risk of being seen as mere attempts to pacify clients and stakeholders (Abrassart et al., 2015). Over the years, we have seen many participants, some more willingly than others, embark in a process often too limited or too ambitious from the start, only to wrap things up a few hours later and never return to it. Despite its ludic nature, such co-design can generate disappointment, scepticism, and outright frustration (Pirinen, 2016). When that happens, not only are potential benefits unlikely, but these limited encounters risk yielding tokenistic collaboration and mistrust (Burkett, 2012; Evans & Terrey, 2016). From a participant standpoint, what often remains of co-design is a fairly pleasant, yet superficial meeting that leads to unfulfilled expectations (Hasu et al., 2011). Granted, voices have been heard, connections have been brokered, and embryonal ideas have emerged, but only to subsequently suffer from a lack of ownership or next steps (Kleinsmann & Valkenburg, 2008). As a result, initial enthusiasm tends to fade away quickly (Dubois, 2015). If recruiting participants for a single workshop is often said to be challenging (Trischler et al., 2019), finding ways to motivate them to partake multiple times becomes daunting, no matter how fun it might be.

### *2.2 SF #2: underwhelming outputs*

In as much as discussions on needs and aspirations are worthy activities, co-design workshops also typically seek tangible and original results (Piller et al., 2005). Yet, innovative outputs in co-design remain elusive (Trischler et al., 2019). Based on our experience, tangible realizations that stem from workshops are indeed hard to come by. In fact, research suggests that sponsoring organizations seldom implement ideas often deemed useless (Trischler, Pervan, et al., 2018) or that workshops lack the appropriate facilitation to achieve innovation (Trischler, Kristensson, & Scott, 2018). The output is often seen as underwhelming, impractical or market-ready, and in turn tends to be as short-lived as the workshops themselves (Evans & Terrey, 2016; Pirinen, 2016). Hence, without consistent results to show for, co-design has become associated with more upstream innovation activities

such as issue framing, idea generation, creativity, and imagination (e.g., [Steen, 2013](#)), rather than downstream applications of more fully fleshed out outputs ([Bradwell & Marr, 2017](#)). In fact, according to [Stewart and Hyysalo \(2010:58\)](#), workshops have this tendency to “focus on design work prior to market launch and to neglect (...) actually getting the finished product to work”. [Taffe \(2015\)](#) further explicitly questions co-design’s ability to yield tangible artefacts, pointing out that it may be better suited for exploration and discussion, while [Pedersen \(2020\)](#) mostly sees workshops as forums for negotiation between conflicting visions. Why then, we ask, call it design and entertain claims about what it can produce from a novelty standpoint? Such disconnect between sought-after outcomes and actual evidence further undermines co-design ([Cash et al., 2023](#)). As for professional designers and experts in attendance, these workshops often feel like labour-intensive brainstorms that rehash known issues or solutions and are made worse by superimposed facilitation that seems simplistic or overdone ([Dubois, 2015](#)). Some even argue that such unwarranted mingling with non-designers actually ruins design outcomes ([Taffe, 2015](#)).

### *2.3 SF #3: size does not matter*

Gathering as many stakeholders as possible and assembling as diverse of a knowledge base appears to be an established premise for hosting co-design workshops ([Nguyen & Mougenot, 2022](#)). The complexity of the topic at hand, the number of people impacted, and the desire to find a positive outcome for all call for such enlarged and unconventional groups of designers. The workshops we took part in generally involved amateur designers such as students, clients, parents, employees, government officials, citizens, or simply curious individuals, often gathered around the same table for the first time. It remains, however, that important challenges come with getting large groups of lay people to engage in design. For one, many of them lack basic design skills and/or subject-matter expertise, which in turn is bound to make their contribution to the workshop uncertain at best. Indeed, the knowledge level of participants, or lack thereof, is widely cited as one of co-design’s main shortcomings ([Jagtap, 2022](#); [Trischler et al., 2019](#)). In addition, while these workshops may actually seek to foster trust and collaboration, pre-existing ‘baggage’ or lack of coordination mechanisms between participants, be they amateur or expert designers, are all bound to inhibit engagement and execution ([Bradwell & Marr, 2008](#); [Farr, 2018](#)). Similarly, in our experience, we find little evidence that co-design work better with bigger groups, nor with more experts present. In fact, we posit that the engagement (SF#1) or innovation (SF#2) issues occur irrespectively of participants. The prevalent ‘the more people the merrier’ mindset seems misguided: workshops, large or small, all inevitably end up losing steam, some quicker than others.

### 3 *Modeling co-design's knowledge dynamics*

This paper seeks to create a simple co-design model and to highlight knowledge dynamics during workshops to explain the three SFs. Investigating any complex process, such as participants interacting during co-design, is said to be best achieved by first modeling its underlying system of action (e.g., [Bachimont, 2007](#); [Le Moigne, 1995](#)). Model building allows for the indirect study of real-world systems and, in the present case, for abstract properties to be captured in a mathematical representation ([Weisberg, 2012](#)). This well-marked strategy in many fields, including biology and psychology ([Godfrey-Smith, 2006](#)), involves first specifying the variables and model system, and then proceeding to discuss the similarity between the model and the phenomenon itself ([Gieryn, 1988](#)). Describing the main content variables as well as how they are structured and interact is also said to be the first step to assessing the performance of a given design method ([Cash et al., 2023](#)). It also enables to explore how modifying a given model variable might lead to real-world changes.

To do so, we chose to rely on design theory that intertwines a theory of knowledge with a theory of creation and accounts for the effects of knowledge exchanges in design situations. In what follows, the terms 'knowledge' and 'concept' stem from our use of C-K theory ([Hatchuel & Weil, 2003](#); [Le Masson et al., 2017, 2020](#)) as a guiding framework. This theory is considered to be a reliable model of generative processes based on knowledge ([Hatchuel and Weil, 2009](#)). Namely, it describes a design reasoning by distinguishing between the Knowledge (K) mobilized and the emerging Concepts (C), as well as the interplay between the two ([Agogu e et al., 2012](#)). This theory has been applied to a wide range of topics, including idea generation and organizational configurations ([Boudier et al., 2023](#); [Gillier et Piat, 2011](#)). The Knowledge space groups together logical propositions that an individual possesses. The statements in K are said to be "decidable", that is, they may be true or false depending on the available knowledge ([Hatchuel et Weil, 2003](#)). The Concept space includes propositions for which initially there exists no logical status (i.e., not possible to tell if true or false based on available K): they are deemed "undecidable" and create an impetus to solve them. Accordingly, an initial concept ( $C_0$ ) should serve as the starting point for design activities which, in turn, should seek to render it decidable ([Hatchuel et Weil, 2009](#)).

In addition, C-K theory models the two different operations that make it possible to move from one space to the other ([Figure 1](#)). First, any statement that lacks a logical status and creates a break in terms of Knowledge is called a 'disjunction' (K to C). In innovative design, the subsequent examination aims to refine this statement and acquire the necessary (logical) Knowledge to endow it with such status — be it true or false — and thus carry out a 'conjunction' (C to K). Expansive operations can also occur within a single space (K to

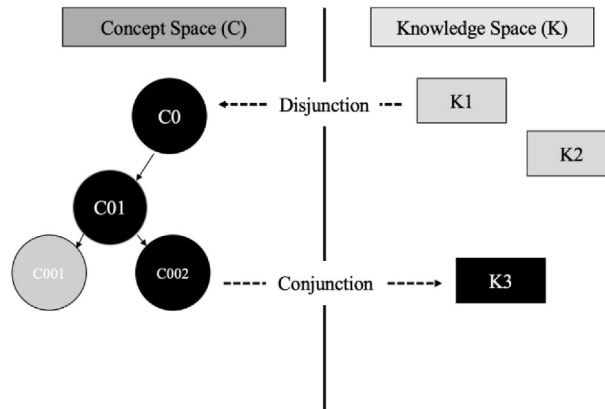


Figure 1 C-K theory spaces and operations

K; C to C). The former describes the acquisition of knowledge that may or may not inform concepts, but that nonetheless enriches the K space. The latter refers to the addition of undecidable properties to a concept which in turn triggers knowledge activation and acquisition (Hatchuel & Weil, 2009). Innovative design requires both spaces to undergo expansions which, while not necessarily symmetrical, ought to be progressively enriched. In short, it is not sufficient to generate concepts without gathering relevant knowledge to support them nor to simply ‘pile up’ knowledge without clear direction or purpose.

Based on C-K theory, we can now deduce a model for the phenomenon described by the three SFs, using as little variables as possible to explain K and C operations in co-design. This means that the model is a minimalist idealization that only captures co-design’s main causal properties and omits other less central features (Weisberg, 2012). First, this model ought to account for the fact that these punctual and ephemeral encounters typically operate as a closed system, meaning that participants bring their own knowledge to workshops and are not systematically brought to gather additional knowledge. In fact, Trischler et al. (2019) explain that workshop organizers will even purposefully limit the amount of new information made available to avoid overwhelming participants. Thus, in spite of sustained efforts to further verbalize participants’ initial knowledge, it remains that all the work still often occurs within a finite knowledge base. Facilitation and tools, as good as they may be, are indeed generally geared at externalizing the lived experience, tacit knowledge, and latent needs of those in the room (Sanders and Stappers, 2014).

Hence, let us consider that each participant possesses discrete knowledge building blocks or elements at the beginning of the co-design workshop. Through facilitation, tools, and methods, participants are brought to combine

## Modeling knowledge dynamics

the different building blocks they have. C-K theory tells us that the combination of knowledge (i.e., propositions from the K space) can in general result either in new knowledge ( $K \rightarrow K$  operator) or in a concept without logical status ( $K \rightarrow C$  operator). This is exactly where design theory is useful for it accounts for situation where knowledge exchange can result in creative propositions and clarifies in which situations the knowledge combination might instead result in concepts. In its simplest form,<sup>2</sup> the initial knowledge has to be independent. If there are independent elements, there is no way to deduce one from the other and thus all knowledge is considered to be undecidable (see [Hatchuel and Weil, 2009](#); [Le Masson et al., 2016](#)). In other words, they create a proposition that is neither true nor false and, as such, should be considered a concept (C). Hence, in our minimalist model, we suppose that a participant A possesses knowledge of type  $i$  noted  $K_i$  and participant B of knowledge of type  $l$  noted  $K_l$ . We also posit that  $K_i$  and  $K_l$  are independent and that their combination is unknown to A and B (i.e., is a concept for both participants). When these participants come together in a co-design workshop, or more precisely when they decide<sup>3</sup> to combine the knowledge  $K_i$  (K of type  $i$ ) of A and the knowledge  $K_l$  (K of type  $l$ ) of B to yield the concept  $C_{il}$ , we can express in the following way:

$$K_i \otimes K_l \rightarrow C_{il}$$

We note with  $\otimes$  the interaction that creates a concept. It depicts the reaction between the participants' knowledge  $K_i$  and  $K_l$  resulting in a conceptual expansion. Workshops allow for 'conceptual socialization': it is the facilitated social relation ( $\otimes$ ) that yields concepts. We call that a "reactive expansion" in the sense that two knowledge bases react (like two chemical molecules) to create a new entity that is not new knowledge but rather a concept, and hence is an expansion.

We suppose now that we have  $n_P$  participants and, to simplify, that each participant A disposes of a number  $n_K$  (the same number for all) of knowledge elements noted  $K_{iA} \dots iA \dots n_K$  such that each knowledge elements  $K_{iA}$  of any participant A is independent of any knowledge elements  $K_{lB}$  of participant B.<sup>4</sup> Here, we only count the discrete knowledge elements that are unique for each participant (different from all the knowledge bases possessed by all the other participants). In a co-design workshop, the combinatorial possibilities ( $\alpha$ ) of concepts built by mixing one (independent) knowledge element provided by each of the  $n_P$  participants are therefore of the order:

$$\alpha = n_K n_P$$

Where  $n_P$  is the number of participants and  $n_K$  is the number of independent knowledge elements. Granted, there can be plentiful concepts created this way. Yet this remains a finite number: the number of different K

combinations is still technically limited. In C-K terms: there is a change in the C space (which gained new concepts through reactive expansion), but not in the K space.<sup>5</sup> In short, because co-design workshops typically operate as closed systems, the interaction between participants' knowledge can only produce a limited number of concepts. And, based on our experience, no new knowledge is later injected so this number becomes de facto a maximum.

We now factor time in our model. We consider that a workshop at time  $t$  leads to the formulation of  $\alpha_t$  concepts. In theory, there are  $\alpha$  possible combinations at the beginning of the workshop ( $\alpha$  of the order of  $n_K^{n_P}$  – see equation (2)). As work unfolds,  $\alpha_t$  concepts are discovered and there remains  $\alpha - \alpha_t$  concepts to be formulated. Over time, the number of already-formulated concepts increases; under these conditions the odds of finding new ones decrease. Sustaining the reaction would normally require an influx of knowledge to compensate for the emerging concepts. While the process might be fun initially (easy creation of new 'ideas'), it is arguably also bound to feel pointless sooner or later (SF#1). A blocked K space inherently limits discovery, surprise, and learning, not to mention that even if each new concept contains knowledge that are novel to some participants, it also necessarily contains only knowledge that is part of the initial collective knowledge base, which means that it might not appear innovative for some participants (SF#2). Last, inviting more participants, even with independent K, could delay the exhaustion, but never prevent it so long as the system remains closed (SF#3). Hence, the model accounts for all SFs:

- *Work gradually dries up the pool of original propositions and begins to feel useless (SF#1)*
- *Outputs seem hardly innovative because they only rely on pre-existing knowledge (SF#2)*
- *Having more knowledge at the beginning does nothing to alter these mechanisms (SF#3)*

To better understand this model, let us illustrate the operations described above by means of a simple example. Let the word 'water' be the  $K_i$  of participant A, and 'land' the  $K_j$  of participant B (and consider that one is independent of the other: participant A did not use land before and participant B did not use water before). During a workshop, the combination of  $K_{iA} \otimes K_{jB}$  can only yield 'water-land' (or 'land-water'). This is not new knowledge: this is a concept which is bound to remain a concept without subsequent knowledge acquisition. Given that neither of them could ever independently formulate this concept, the participants might experience initial amusement or satisfaction. It is worth noting that the knowledge of the word 'water' is not the knowledge of everything related to water, and that the same goes for 'land.' Participants would only be able to propose more sophisticated combinations of water and land if they possessed extended knowledge *a priori* (e.g., mud,

archipelago, wetlands, etc.). Yet, while the number of potential disjunctions would be greater, it would still technically be limited. Here, we suppose ‘water’ and ‘land’ are the only knowledge that were independent for the participants A and B, once the ‘water-land’ concept emerges, participants can no longer generate original combinations without further K expansion. Reactive expansion is thus exhausted: there are no more K for new concepts and no way to operate conjunctions. As a result, ‘water-land’ remains ‘undecidable’. [Figure 2](#) summarizes this example.

Through this minimalist model, we can also discuss the necessary conditions for reactive expansion to (continue to) occur. This implies highlighting which variables in the equations above, when removed or nullified, effectively render the model inoperable. We identify these conditions as follows: 1) the heterogeneity of knowledge; 2) the creative purpose of the interactions between participants; 3) the independence of knowledge; and 4) the continuity of interactions in time. All four conditions are required for the reactive expansion to begin and endure; said differently, reactive expansion stops when interactions cease (condition 4), when participants no longer seek concepts (condition 2) either because their initial knowledge is strictly similar (condition 1) or is not independent from one another (i.e., knowledge can be deduced from another) (condition 3).

To explain these conditions, let us again turn to equation (1):  $K_i \otimes K_l \rightarrow C_{il}$ . This contrast with other cases where two elements of knowledge will not yield a concept, as explained by C-K theory:

- 1) Considering that combinations of strictly identical knowledge amounts to the same knowledge as opposed to a concept, we note that the equation above only works if:

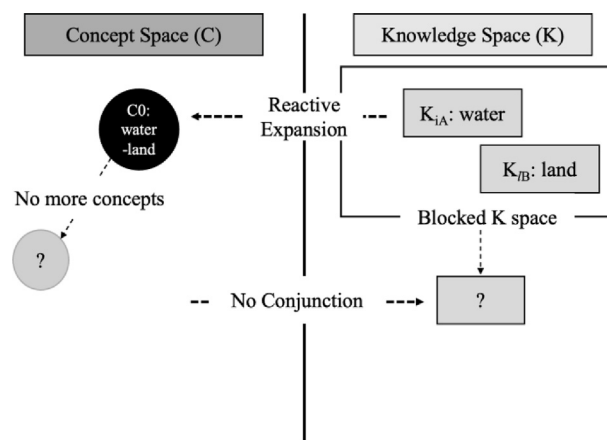


Figure 2 C-K tree for ‘Water-Land’ example

$$K_i \neq K_l$$

That is, the model implies that *reactive expansion requires that the participants' knowledge is heterogenous*. While the rationale for more participants is often based on the benefits of involving stakeholders and increased acceptability, the model makes the case for heterogenous knowledge from a mechanical standpoint: too redundant of a knowledge base impedes reactive expansion.

- 2) The second condition refers to the fact that the combination between knowledge is geared towards generating 'creative', not previously known proposals. We can write this condition as:

$$K_i \otimes K_l \rightarrow C_{il} \not\subset K$$

Specifically, the combination of K must purposefully seek a disjunction. In other words, reactive expansion requires that the interactions between participants remain of 'conceptual' nature. The process stops when participants no longer look for creative concepts or begin focusing on known solutions (i.e., proposals that are feasible, valid, etc.) instead of undecidable proposals.

- 3) Third, for reactive expansion to (continue to) occur, participants must possess independent knowledge—this condition is, technically speaking, a more precise (restrictive) version of condition #1. In C-K terms,  $K_i$  and  $K_l$  are deemed independent when there can be no K to K operator between them – which also means that this cannot correspond to deduction or inference (considering that experimental knowledge creation is a K to K operator) (Ullah, x 2020).

*$K_i$  and  $K_l$  must be independent*

In short, if  $K_l$  can be deduced from  $K_i$  or are somehow related, combining them will actually only amount to pre-existing knowledge (e.g., a form of syllogism:  $K_i$ : there is a man named Socrates;  $K_l$ : I know that men are mortal;  $K_i \otimes K_l$  = there is a man named Socrates and he is mortal).

- 4) Finally, expansive reaction supposes interaction. This fourth condition is as follows:

*$K_i$  and  $K_l$  must interact*

Reactive expansion mechanically stops when interactions ( $\otimes$ ) cease. The generation of concepts comes to a halt when participants do not have further opportunities to combine their knowledge. In summary, the conditions of co-design's model of reactive expansion are as follows:

1. *Participants' initial knowledge must be different*
2. *Participants' interactions must seek out concepts (disjunctions)*
3. *Participants' knowledge must be independent*
4. *Participants must be able to interact*

## 4 Discussion

While our experience with co-design over the years has often impressed us by its ability to involve people in design, it has also left us fairly unconvinced of its efficacy. We chose to sum up our reservations, which all find echo in the literature, into three broad SFs and attempted to explain them through a model of the core knowledge dynamics during workshops. In doing so, this study offers a basic framework to understand participants interactions in co-design (Blomkamp, 2018) and further explains the nature of the proposals that stem from these interactions (Hirscher et al., 2019). It also highlights C-K theory's capacity to uncover complex mechanisms and contributes to the literature on design-based social dynamics (Gillier et al., 2010; Reich & Subrahmanian, 2020).

The reactive expansion model not only accounts for all SFs, but also provides insights on co-design's costs and benefits (e.g., Bradwell & Marr, 2008; Steen et al., 2011). First, with respect to participants: a) design newcomers will generally be keen on co-design in the beginning: the model shows how disjunctions through a reactive expansion in C, albeit hardly original, might indeed be initially pleasant (good benefit, low cost); yet also that b) experts are less likely to gather new independent knowledge during workshops (cost increase, benefit decrease). In short, the model explains the known ambivalence of experts or experienced designers who may have already had the knowledge or are attending the *n*th workshop where the same concepts get formulated.

Second, in terms of planning and facilitation, the model highlights the finite nature of reactive expansion which theoretically proceeds from a pre-determined number of combinations. Clearly, the cost-benefit is more favorable at the first workshop and, *ceteris paribus* (same participants) only deteriorates with each repetition. Granted, the number of combinations might be incredibly high and facilitation does contribute to making the available knowledge base actionable. Thus, we can only assume that it is the mechanism's redundancy as well as the gradual awareness of its limitations that eventually generates disengagement. In short, participants may be skittish to invest themselves wholly in a process that so clearly exhibits limited possibilities, which explains some's reluctance to engage in multiple workshops over time. Indeed, any ambiguity about a given design method's nature or content is bound to negatively impact its efficacy (Cash et al., 2023).

Third, in terms of initial knowledge: a blocked  $K$  space makes it impossible to operate conjunctions and limits further work on emerging concepts. In short, the lack of innovation or subsequent adoption stems from the inability to determine the status of said proposals. Without built-in learning or targeted effort to acquire knowledge, co-design is doomed to yield embryonal proposals whose true potential are impossible to determine. Again, this suggests that the benefits only decrease with the progressive combination of knowledge without the acquisition of new knowledge; conversely, it shows how benefits may increase by enabling participants to learn and acquire knowledge towards solving the disjunctions they generated during the workshop. Although it has been theorized that the lack of participants' knowledge is a key issue in co-design ([Bradwell & Marr, 2017](#)), the model suggests instead that the shortcomings stem from how said knowledge is used and restrained. Given that so much emphasis is placed on gathering lots of people in the beginning, perhaps the need for additional knowledge later on, based on how the collective work unfolds, has gotten lost. Much like the importance of monitoring for both  $K$  and  $C$  expansions.

These considerations suggest new avenues to improve co-design, but also show how other potential quick fixes might actually prove ill-advised, be it enriching the initial knowledge base, adding more participants, or engaging in initial trust building. Let us analyze these three options:

- 1) At face value, the model can appear to imply that a very large initial knowledge base might delay exhaustion or make up for the lack of additional knowledge (SF#3). Yet, this also comes with the challenge of getting strangers to work together towards a common output (e.g., [Burkett, 2012](#)). Based on the model's conditions, we know that without first addressing the inability to operate conjunctions, adding people creates complexity and contributes very little.
- 2) The conditions also show how future input of knowledge necessary to sustain the reactive expansion must be different and independent: conjunctions cannot occur if said knowledge is redundant or can be deduced from what is already available. Looping back to our example, if a third participant joins and only possesses a little bit of  $K_{iA}$  (water) and  $K_{iB}$  (land), then there is no expansion for these combinations have (or could have) been exploited already. This means that there is little value in adding participants whose knowledge overlaps with others. Likewise, presentations to start workshops become part of everybody's knowledge and thus create overlap that not only limits expansion but also does very little to enable conjunctions later on.
- 3) Last, the model's conditions also show that the knowledge-sharing behaviors necessary to build trust should be of conceptual nature as opposed to being simple discussions. In fact, it has been argued that trust between participants is not always a pre-condition for achieving innovative

outcomes, but rather could be a by-product of engaging in design itself (Dubois et al., 2014). While we questioned the use of the term design to describe these encounters, the model underlines the importance of working towards disjunctions even though tangible outputs may not materialize.

## 5 *Implications, limitations and future research*

The model also carries implications for practice. For one, we understand that facilitation should continue to foster conceptual interactions and to encourage undecidability (expansion in C), all the while enabling knowledge acquisition, learning, and conjunctions (expansion in K) to maintain engagement. It suggests that any injections of additional knowledge should be done at different stages to ensure they remain critical and timely. Workshops could, for instance, encourage participants to generate novel propositions related to the topic at hand, invite them to unearth relevant K they already possess as well as gaps and open questions, and then support them in learning as they work towards making their propositions decidable. Hosting consecutive workshops with a different focus each time (first generating proposals, then mapping K, etc.) that build a growing knowledge base is also one possible way to achieve this (Lähteenoja et al., 2023). Realizing that perceptions about the mechanisms at play may undermine participants' motivation, facilitation should ensure that K acquisition happens early and often, and is made visible. In other words, allowing participants to quickly identify specific needs for additional K and enabling learning before fatigue or redundancy begin to creep in is key, much like getting them to reflect both during and after the workshop about the extent of the new K they have acquired. Workshops should also involve subject-matter experts, with the difference here that it may not be able to know who to invite to support conjunctions before the participants actually begin to generate concepts.

Theorizing the ephemeral nature of reactive expansion further highlights the importance of planning for future interactions (condition 4). Short-sighted planning might lead, at best, to mundane outputs, and, at worse, cynicism. Reactive expansion is valuable in that it contributes to the socialization and combination of knowledge; co-design participants gradually learn to exchange and “play” with each other's knowledge to generate propositions, which, without leading to a disjunction in K, hitherto were impossible to consider individually. In short, co-design allows for different interactions in nature between participants and supports a collective leap into the unknown. It is not, however, sufficient in and out of itself. Hence, further capitalizing on this capacity should systematically be sought after and reflected in the planning. That said, the model also calls for more flexible planning: we cannot know beforehand where the participants' exploration will take them nor how much ground they will be able to cover. As such, rather than proceeding from strict

protocols, pre-determined K inputs, and defined timeline, workshops must account for unforeseen needs for expertise and slower than expected progress that might call for more meetings than anticipated. This means fully embracing the work and that goes into realizing conjunctions and adjourning rather than settling for undecidable propositions because of time.

This study is not without limitations. For one, despite being supported by the existing co-design literature, the stripped-down stylized facts and model derived from our experience may not be fully reflective of the range of workshops' contexts, motives, and tools. Likewise, it could be argued that said experience is limited to a European centric understanding of co-design, which may come with shortcomings not found elsewhere. Our model is also minimalist by design, focuses on downsides and leaves out other contextual variables. That said, despite being incomplete, model building is still deemed an illuminating strategy (Weisberg, 2012). Having defined the main content variables and co-design's internal structure, future research could attempt a more fulsome assessment of this method's performance (e.g., Cash et al., 2023). Alternatively, there could be work geared at making this model more realistic by adding variables and causal relations. For instance, applying a more sophisticated lens and differentiating between the different types of knowledge (e.g., Ullah et al., 2012) would likely shine additional light on co-design's mechanism. The model could even be used to assess a given tool or approach's efficacy at overcoming exhaustion. We would also welcome additional research on ways to operationalize the model or that would attempt to test out facilitation techniques to overcome blocked K spaces, monitor emerging concepts, and inject new K in a more responsive and targeted manner. Last, we believe that the co-design field would benefit from looking into known strategies to sustain engagement, manage knowledge dynamics, and achieve novelty in other forms of ephemeral collaborations such as project-based work (e.g., Picq, 2011). Although the timeline may be longer and the participants less eclectic, the nature of their interactions as well as the effectiveness of this organizational configuration also depends on tools and constant facilitation by project managers.

## 6 Conclusion

This paper sought to explain some oft-experienced shortcomings in co-design workshops. Our minimalist model provides a better understanding of the core dynamics and play, the conditions under which they operate, as well as their inherent limitations. Namely, it highlights how interactions operate as a closed system and are bound to become tiresome regardless of the number or participants. That said, we believe that co-design still holds great promise and that workshops can deliver novelty. Indeed, the model also serves to identify the variables at play and how they interact to inform workshop facilitation. When geared towards learning and K expansion, co-design can prevent

(perceived) exhaustion, move beyond mere discussions and be more than just checking a box in multi-stakeholder projects. Opening up the system to enable conjunctions without overwhelming participants or watering down their knowledge is a delicate exercise that requires, as we argue, more flexible and reactive facilitation. As such, we hope that our model can inform the important work of those in charge of steering these dynamics towards novel outcomes.

### *Declaration of competing interest*

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### *CRediT authorship contribution statement*

**Louis-Etienne Dubois:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Pascal Le Masson:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Benoit Weil:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization.

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### *Notes*

1. This work was initially undertaken as part of the lead author’s doctoral research, during which he was embedded in an industry-academia co-design center in France for 2 years. This center organized and facilitated workshops on a range of topics, be it for-profit new product development or policy design, typically lasting 1–2 days and involving 15 to 150 participants. More observations were gathered at workshops in Belgium, Germany, Canada and Finland.
2. This is an extreme simplification. More sophisticated models of knowledge (e.g., [Ullah, 2020](#)) could characterize diverse co-design trajectories. Yet we argue later that these trajectories would likely have the same general patterns.
3. A reviewer rightfully noted that one should account for a ‘decision’ layer between K and C ([Kroll et al., 2014](#)). Following this line of thought, the combination of K pieces can be considered as the decision to combine.
4. Precision: to simplify we only take into account independent knowledge elements, we do not count all the cases where an element is shared between several participants or can be deducted (or inferred) one from another. We also simplify by considering that each participant has the same number  $n_K$  of unique independent knowledge elements.
5. There are however individual changes, participant A now has the K of participant B and vice versa.

### *Data availability*

No data was used for the research described in the article.

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