Co-evolution and emergence in design

Kees Dorst, Faculty of Transdisciplinary Innovation, University of Technology Sydney, Broadway, NSW 2007, Australia

The notion of co-evolution has been widely adopted as a useful descriptor of one of the key aspects of designerly thinking: the re-interpreting of a design problem in the light of an exploration of possible solutions until a good 'fit' between problem and solution ('an idea') emerges. In this paper we pick up the discussion by considering co-evolution within design projects, in the briefing process and across projects. Aspects of the process to get from problem space to solution space can be captured with design models, but in considering the 'jump' from solution space to problem space we enter largely uncharted territory.

Keywords: co-evolution, emergence, framing, innovation

The notion of co-evolution, which was introduced in the design research discourse in the late 1990s (Maher, Poon, & Boulanger, 1996), has been widely adopted as a useful descriptor of one of the key aspects of designerly thinking: design practitioners commonly change the design problem in the light of their exploration of possible solutions, until they can create a good 'fit' between problem and solution ('an idea' that bridges between problem and solution) (Dorst & Cross, 2001). While the early papers on co-evolution remain widely referenced, there has been very little follow-up research or discussion to critically asses and/or further detail the notion (with the noted exception of the detailed empirical studies by Maher & Tang, 2003; Wiltschnig, Christensen, & Ball, 2013) and Crilly and Moroşanu Firth (2019).

In this paper we pick up the discussion by describing co-evolution in more detail: the key insight that co-evolution can take place in design is probably beyond reasonable doubt, but Figure 1 shows co-evolution as a series of unarticulated 'jumps' that bridge the gap between the problem space and solution space. In this paper we explore what is happening inside these jumps, seeking to develop closer models of what happens in such transitions. We will see that the 'downward jump' from problem space to solution space (transition (A) in Figure 1) can be captured with some of the existing models of design, but that in considering the 'upward jump' from solution space to problem space (transition (B)) we enter largely uncharted territory.

Corresponding author:
Kees Dorst
kees.dorst@uts.edu.au

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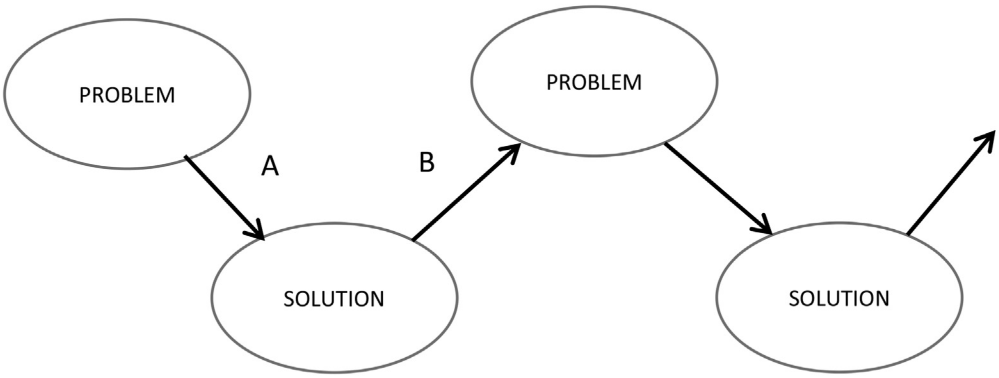

Figure 1 The co-evolution between problem and solution (after (Maher & Tang, 2003))

The reason to seek further detail in the modeling of co-evolution practices lies in the fact that co-evolution, as the quintessential open form of design reasoning, is now becoming newly relevant to fields beyond design. Organisations are realizing that as the problems in the world are moving from being very complicated to truly complex, our ways of addressing them should shift accordingly (Snowden & Boone, 2007). Organisations need to move from problem solving to a much more designerly way of thinking: truly complex problem situations require a thoughtful exploration by (repeatedly) proposing interpretations of the problem situation, creating and testing possible interventions until a good 'fit' between problem and solution emerges. Thus co-evolution, the reconsidering of the problem, is a key part of dealing with complexity. Nowadays, co-evolution lies at the core of creative practice – not just in design, but in other disciplines as well (Dorst, 2017).

1 Co-evolution in design

The challenge for design research is to identify the principles of co-evolution, describe the key practices that drive this process, and create methods and tools that can help make co-evolution a deliberate and thoughtful process for design and for professions beyond the designing disciplines. In order to achieve a finer granularity than earlier co-evolution research – in which co-evolution was introduced as a conceptual idea, a 'jump' between the articulations of function and form – we need to carefully consider the terminology used to describe this phenomenon. The "problem space –solution space" terminology, introduced in the seminal paper by Maher is firmly based on Simon's modeling of design as a rational problem solving process (Dorst, 1997).

1.1 Co-evolution in design-as-problem-solving

Within this paradigm, the design activity has been described as a process that roughly looks like Figure 2 (This is a gross generalization that does not do justice to the subtleties in the many variants of models in design as a problem

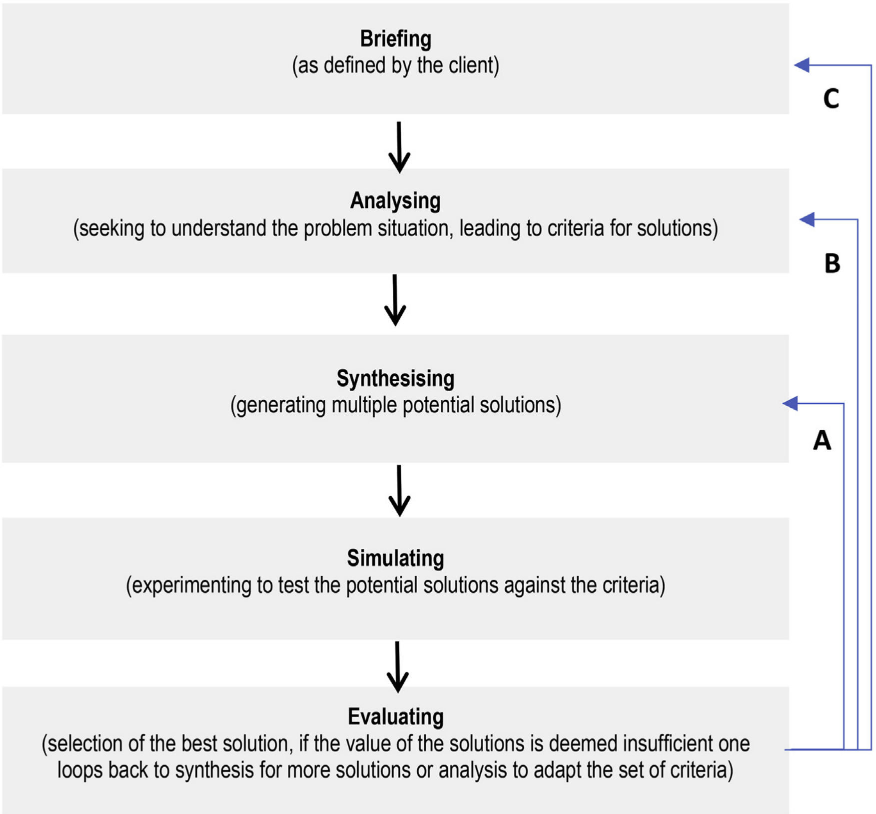

Figure 2 A design process modelled from a Rational Problem Solving perspective (after the 'basic design cycle' (Roozenburg & Eekels, 1995))

solving, and to their sophistication – but for the purpose of this paper, the rough brush-stroke is enough):

The rational problem solving modelling of design has led to influential phase models and project management models for design, as well as early AI modelling of design reasoning processes for automation. In these models design is considered to be a search process, with the designer seeking out good solutions from among many options. Quality in design processes then lies in optimising the search, the shorter the path the better (while avoiding local optimums). This theoretical model was adapted to more closely describe human design in practice (in which we have to deal with human cognitive limitations), by introducing the notions of 'immediate problem space' and 'immediate solution space' (Simon, 1973) (Dorst, 2019). Unlimited computing power would – in principle - do away with these limitations (see (Maher and Tang, 2003) for a subtle exploration of the differing strengths between humans and computers). Co-evolution described in these terms is an iterative process, with designers honing the 'immediate problem space' (the set of objectives and criteria under consideration) based on what is seen as feasible in the perceived 'immediate solution space'. Ideas are propositional (…if…then) statements, bridging a proposed problem and a proposed solution. In problem solving descriptions of designing, the design is simulated (prototyped) and evaluated – when the solution is not good enough (not 'satisficing') the process iterates: back to solution alternatives (arrow (A) in Figure 2), or possibly back to analysis (arrow (B)) when there is a perceived need to introduce new criteria (Kruger & Cross, 2006). For an extensive real-world data study of this type of co-evolution see (Wiltschnig et al., 2013) – they stress the importance of analogising and mental simulation for this feedback loop.

Because in this paper we seek to support co-evolution in complex practices (within and beyond the design domain), where reconsidering the problem itself is an integral and key part of dealing with complexity, we will focus on high-level co-evolution looping back from the evaluation of the proposed solution to the design problem itself. This means that not only can problems shift under the influence of a reprioritising/adding highlighting of different criteria (loop (B) in Figure 2), there can also be a deliberate reorientation on the problem itself (loop (C)), a redefining of the brief. As we do this our mental model of the problem shifts, and moves from 'single-loop learning' to 'double loop learning' (Argyris, 1977). This creates a completely different dynamic, a process in which problem brief and solution are both in flux until a matching problem–solution pair emerges.

Let's road-test this modelling of iteration and high-level co-evolution by using an example of a design project from professional practice, and map the steps taken through the lens of design-as-problem solving. This will help illustrate the qualities and limitations of this description of designing.

1.1.1 Designing a child safety seat

In the late 1980's, the advent of new safety norms for child seats on bicycles led to a new generation of products. Until then, most child seats were simply attached to the pannier (the little luggage rack) above the rear wheel of the bicycle. But under these new rules, to achieve the coveted safety approval sticker from the testing institute, manufacturers needed to embark on a radical redesign. The problem was that as panniers are not safety approved (and can become quite rickety with wear and tear), any child seat attached to the pannier would also be deemed unsafe and fail the tests. To avoid attaching the child seat to the pannier, as all the earlier products had done, the new generation of child seats would need to be directly attached to the frame of the bike itself.

Accordingly, the brief, as provided to a design consultancy by one of the main car/bike seat manufacturers, was to (1) design a seat for carrying kids on the back of a bike that could be used on all types and sizes of adult bikes, and was *to be attached to the frame of the bike. A key constraint (2) was cost: these new seats would require their own frame for attachment to the bike, rather than the simple clamps and bolts that were used before to attach the earlier generation of seats to the pannier. Such a construction could easily double the manufacturing cost, and significantly increase the sales price of the new seats compared to the conventional ones. Market-wise this was uncharted territory, and there was great apprehension as to whether parents would be prepared to pay the higher price.*

In the ensuing design process, the design agency arrived on a solution (3) in which the bike seat was attached to the bike frame at three points: the main stay of the bike frame (under the saddle) and two fixation points on the stays at either side of the rear wheel (see Figure 3, on the left). Prototypes were built (4) and in early static testing the design looked stable and secure. However, dynamic testing of the prototype (5) with the maximum expected load of 18 kg (a six-year old) showed an unexpected problem: while the bike seat and its supporting frame were solid, the full weight of the seat actually bent the rear stay of the bike frame itself (see Figure 3, center) in some bikes. The problem was that the full weight of the seat and kid hit the rear stay in the middle, just where it is most vulnerable … with the benefit of hindsight, this problem could have been expected: of course bike frames are optimized for minimum weight, and none of the tubes is bigger or thicker than it needs to be. Suddenly placing an extra sideways force on an optimally thin tube is a recipe for disaster.

The feedback loop from the design test and evaluation went back to the analysis step (6), and criteria pertaining to the dynamic stability of the whole bike-and-seat system were added. New design proposals were generated (7), and out of the alternatives the solution to lengthen the down tube of the bike seat frame - so it would attach to the rear stay of the bike much closer to the wheel axle — was put forward for prototyping and testing (8). This solution turned out to be structurally sound, provided the bike seat was attached in the intended manner (9). To ensure proper attachment, instructions and warnings were added in the manual.

Figure 4 shows the development of the child seat, modelled from a problem solving perspective. The line between the ‘problem space’ and ‘solution space’

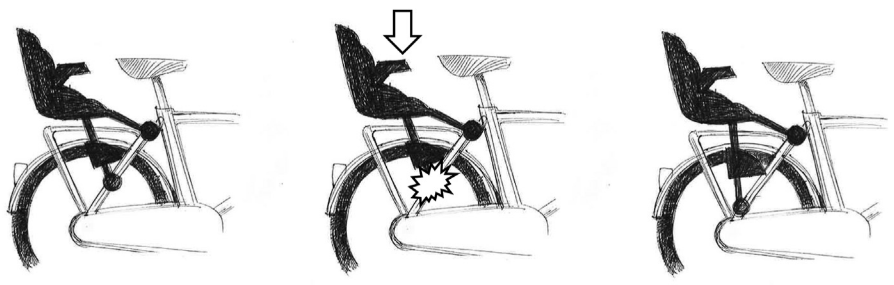

Figure 3 The child seat, original design (left), the problem of bike frame deformation (center) and the redesign (right)

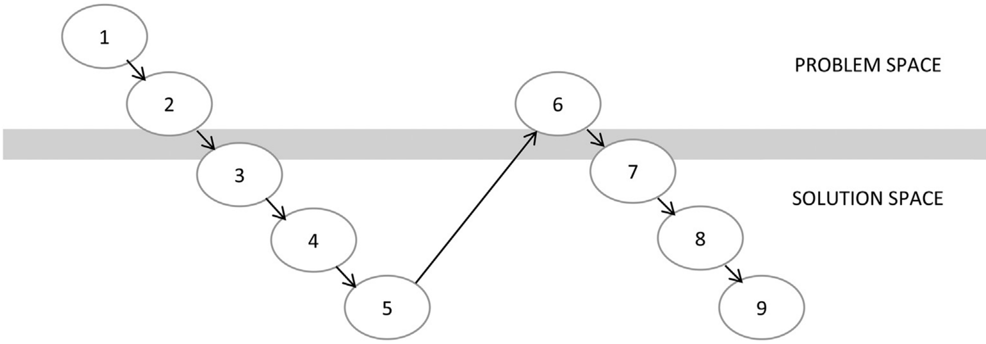

Figure 4 The child seat development process described from a problem-solving perspective

has been intentionally blurred, to highlight the phenomenon that it is often unclear whether a propositional design step (that has implications for both problem definition and possible solutions) would belong to either one or the other.

Interestingly, in this case the moment of acute crisis (the proposed solution is failing) was enough to spawn a second branch to the design project, effectively splitting it in two tracks: in addition to the iteration back to criteria in Figure 4, and a deeper reconsidering of the briefing and its underlying values (see Figure 6).

1.2 Co-evolution in design-as-reflective-practice

To describe the second branch of design activities in this project, we will first introduce an alternative of way describing design that highlights (and hides) other aspects of the complex design activity. As a reaction to perceived bias in the rational problem solving description of designing, Schön (1983) created an alternative descriptive framework in which professional practice – in this case: design - is seen as a learning process in which practitioners explore options by reflecting-in-action (implicit, direct, embodied) and reflecting-on- action (explicit, deliberate - see Figure 5). The reason to introduce this alternative view of designing here is that it potentially renders more detailed descriptions of the early stages of the design project, around the creation of the design brief (in the problem solving description of designing, the creation of the brief remains largely unarticulated, the brief is seen as a 'given' (Dreyfus, 1992))

Design processes are then modeled in terms of naming, framing, moving and reflecting (Figure 5).

It is important to note that in this modeling of designing, the object of reflection is the designer's action – the designer is judging whether the action (the

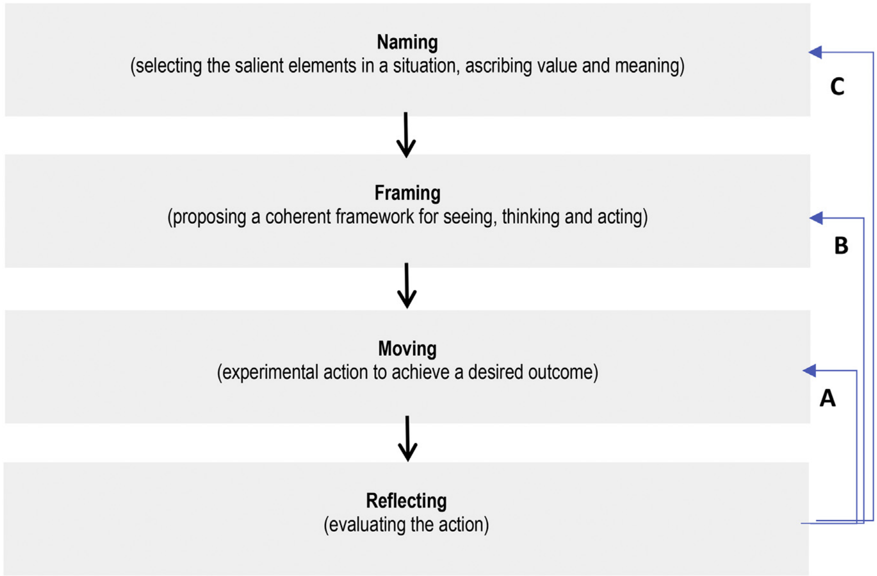

Figure 5 Modelling design as reflective practice (reflection-on-action)

naming, framing or moving) itself is fruitful or not (for instance by opening rather than closing possibilities, etc). In this way, the designer thoughtfully explores different directions and through multiple reflective loops learns his or her way towards a solution.

Iteration in design is captured through feedback loop (A), going back to moving, and possibly to feedback loop (B), to reframe the problem (although the theory is a bit ambiguous on this point). The type of high-level co-evolution we are interested in here is the iteration back to naming elements in the problem situation (C), and prioritising them by ascribing value and meaning.

Let's revisit the child safety seat example and describe the second leg of its development in these terms.

1.2.1 Designing a child safety seat (continued)

…The crisis also led to a more fundamental rethinking of the design brief, away from its initial technical compliance focus (Figure, 6 (a)).

The design agency engaged in a much broader discussion on the moral responsibility of a manufacturer for risk and child safety across the whole lifetime of the product (b). This led to several changes in the design. One of these (c) was the redesign of the fixation points to make sure the parent could clearly see when the seat was not properly attached, and another (c) was the redimensioning and improving the coating of some critical parts of the structure to better resist wear & tear, and to protect them from the weather. The original design was

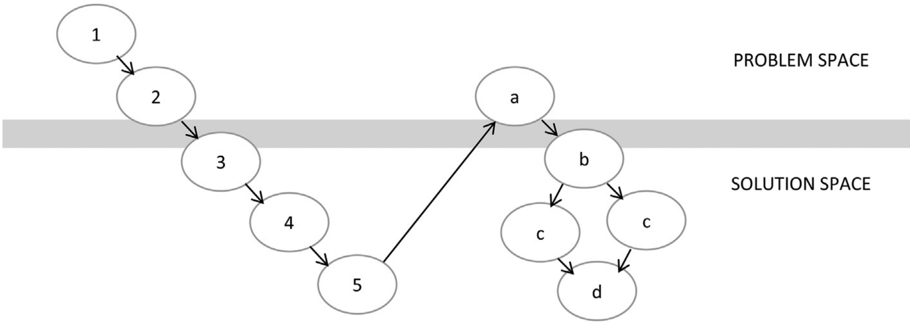

Figure 6 The rethinking of the child seat brief, modelled as reflective practice

made to last X number of years (the calculation was based on demographics data: how many children are there in a family, born how many years apart on average?), but this does not take into account the huge second-hand market for such products once kids have outgrown them. In this case, there even is a third-hand and fourth-hand market, extending the use of such a product to up to 20 years. Although the warranty has long expired by then, there is a moral imprimatur to ensure a product that is sold on the promise of providing safety for the child (endorsed by a safety sticker from the government testing institute) is made as safe as it can be within economic constraints (d). The broader thinking on providing lasting child safety in transportation led to other products being developed in the range (a smaller seat for the front of the bike, a range of car seats for different ages, etc).

To describe these developments in terms of design-as-problem solving: the briefing for the project was altered in consultation with the manufacturer to include these systemic considerations.

2 Co-evolution in the creation of design briefs

The above example highlights how a design process can be derailed, and the designer forced into a reconsideration of its starting point. The crisis helped questioning the current design on different levels, and redirected the design process to become more value-driven and user-centered, rather than focusing on the technical problem of constructing a device that would be strong enough to carry the child safely. The system border of the design situation was extended to include a longer (generational) timespan, an extension that led a to whole new range of solutions being considered. This design strategy is often associated with higher levels of design expertise (Lawson & Dorst, 2013).

Yet to really inform how fields can use co-evolution to deal with the complex problem situations they are facing, we need to look beyond this type of co-evolution that is rooted in such crisis management: there is an element of passivity in co-evolution that results from the derailment of a design process. How can we understand co-evolution as a *deliberate, proactive* process of questioning the problem as it has been formulated in its original context (Wiltschnig, Christensen and Ball, 2013, p531) How does one co-evolve on purpose? Let's turn to a brief example to see how this might work, picking up a case that has been described before in Design Studies (Dorst, 2011). The letters between brackets in the text below refer to the overview of this process in Figure 7.

2.1 Alcohol-related violence in Kings Cross

The late-night problems in Kings Cross, an entertainment district in the city of Sydney, have been labeled "alcohol-related violence" in the media and in public discourse. This statement names the important elements of the situation (a) and contains the frame (b) that safety and security should be assured by combatting violence – and that the violence is causally related to alcohol consumption. The obvious way forward is then to reduce alcohol consumption because, through that step, violence will also decrease. This can be done (c) through legislation, and increasing the police presence to enforce the new rules. Crime prevention partnerships with stakeholders in the area support this direction, and special 'drunk tanks' were created for the intoxicated. This is a clear and convincing path to action, with an almost inescapable rationality, except that on reflection (d) the actions taken no longer lead to greater safety in the area.

A reframing of the problem is necessary, and the Designing Out Crime research center was approached to take a fresh look at the problem situation. After going through the Frame Creation process (blackboxed here as it is beyond the scope of this paper[1]; for a detailed step-by-step description of this case study see Dorst, 2017), one of the most fruitful frames (e) was built on the metaphor of seeing the area as a music festival. This is a radical reframing of the problem situation, miles away from seeing it as a crime problem. Elements of the situation newly emerge as significant (f) and the new value set to strive for includes a vibrant, night time economy. The design directions (moves (g)) to achieve this are varied and can be drawn from many professional fields (e.g., event management, behavioural psychology, economics, visual communication, education, fluid dynamics). For instance, the violence and misdemeanors can be managed by making sure there is appropriate transport out of the area late at night, providing enough public toilet facilities, diversifying the entertainment offerings, creating "chill-out" spaces, rerouting traffic, improving management of taxi queues, having "Kings Cross Guides" welcome the party goers into the area, creating safe spaces for sobering up, etc. These measures have been shown (h) to reduce frustration, boredom, and violence (Dorst, 2015, 2016). Over the ten years of the University of Technology Sydney's Designing Out Crime center's involvement with the area, other frames have been applied to the problem situation (seeing the identity-forming activities of the groups of young men as a rite of passage, looking at

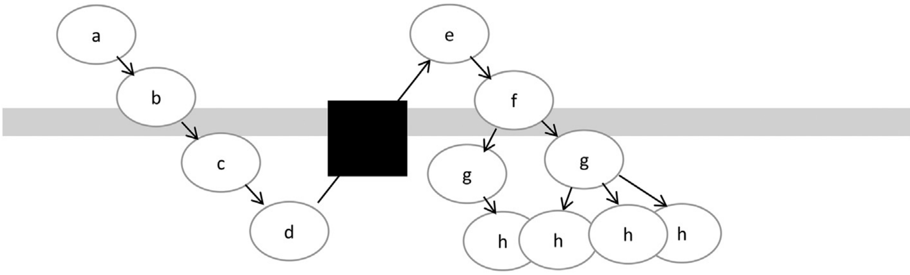

Figure 7 Reframing the problem situation at Kings Cross

the difference between daytime and nighttime use of Kings Cross as a Dr.Jekyll-and-Mr.Hyde like transformation, etc) and the complexities of the developing problem situation will certainly demand more frames in the future. This is very much in line with the realisation that in a situation of true complexity, one can't create one-off 'silver bullet' solutions, but should seek to create interventions that bring the whole system into a more desired state (see (Stacey, Griffin, & Shaw, 2002) on 'transformative teleology').

The Frame Creation methodology informs the 'upwards jump' from solution to problem ((B) in Figure 1), and drives co-evolution through a stepwise approach to help professionals travel from solution to problem. The adoption of the methodology allowed the Designing Out Crime center to develop an agenda across the projects in its portfolio, seeking to evolve crime prevention practices to move away from what effectively are countermeasures to crime to understanding the upstream causes, and concentrating on tackling these (Dorst, 2016).

3 Co-evolution across design projects

It is interesting to see in the Child Safety Seat example how the design project splits in two parallel streams of inquiry, and how the need to rethink the design leads to valuable lessons for future design projects. High-level co-evolution describes such an interaction with the broader context in which design projects take place – after all, the 'design brief' is no longer just an input, a one-way interface between the design project and the outside world. Once the design brief starts to shift, the designers will need to re-engage with the broader design situation (Hekkert & Van Dijk, 2011). But how does this work? To explore this interface we will here use some observations from professional design practice, before re-engaging with the modeling of co-evolution.

The notion of co-evolution was introduced in design research through the lens of AI and clearly, it has struck a chord in design practice beyond the realm of theory. But inevitably, the theoretical notion of co-evolution does abstract from a number of realities (limitations in time, resources, a certain lack of flexibility once commitments are made, etc) that need to be taken into account if we want to use the notion to describe, model and support this practice in the real world. The following assumptions behind our current modeling of co-evolution stand out (Please note that these observations and reflections do not amount to an overview of contemporary design practice - they are incomplete, but useful in setting an agenda for further empirical and theory-driven research in the final section of this paper).

(1) As said, co-evolution can be part of a reflection process that goes across design projects: the design problem shifts based on reflections on the performance of an already existing solution (e.g. the unsafe child seats). In product design, this corresponds with the learning that happens from generation to generation of a particular product line. While the focus in design education and design research is often limited to a singular design (R&D) project, the reality of design practice is to be part of a succession of generations of solutions, more like R&D&R&D&R … The challenge for designers is to create the maximum viable amount of progress from one product generation to the next – striving to maximise the learning *within* a project, rather than across generations (Lawson & Dorst, 2013). There is empirical evidence of multiple layers of co-evolution that may occur within and across design projects (Crilly & Moroşanu Firth, 2019).
(2) In reality, design happens in situations where resources are already locked in, restricting the solution space. This can be observed on a small scale in the problem-solving scenario for the child seat design: the crisis that was sparked by the initial product test had to be addressed with minimal changes to the design. And on a larger scale we can see this in design practice where to a degree the solution is already there, and (perhaps counter-intuitively) greater flexibility is to be found in the manipulation of the problem space rather than the solution space. This is not uncommmon – designers are often challenged to create value propositions for a more or less immovable solution, for instance when an organisation is seeking to apply newly a developed technology ('technology-push') or would like to move into a new market with minimal changes to an existing design.
(3) The way co-evolution has so far been modeled seems to assume that at the start of a design project there is one (consolidated and integrated) design problem to start with. We have seen that in practice, this is not always the case. In complex design situations, multiple stakeholders may present different design problems, and the designers find themselves working on these more or less in parallel, in multiple co-evolution processes, shifting design problems and juggling possible solutions to arrive at a solution that is satisfying to all: the elusive so-called win–win. This type of parallellism (Lawson & Dorst, 2013) could be observed in the child safety seat example.

(4) The learning that designers have always had to do in their design projects is now being formalised, extended and systematised in the new practices of 'Research Through Design'. Ever since C. Frayling coined the phrase (1993) this notion has been embraced as a potential new paradigm that will deliver both new knowledge and novel practical outcomes to the world. However, the term Research Through Design does imply that within such a project, the generation of knowledge is the major goal, and design utility a subsidiary outcome (see the definition of Research Through Design as*: 'the designerly contribution to generating knowledge'* (Giaccardi & Stappers, 2017)). Yet both the terms 'research' and 'design' are very broad domains of human activity, and the possible intersections/connections between the two are multiple and varied. This becomes abundantly clear when we consider an example of a research process as a number of activities grouped in steps/phases (see Figure 8).

Many models of the research activity exist, going back to 'the empirical cycle': *observation-supposition-expectation-testing-evaluation* (de Groot, 1969). Looking at the flow of these different activities, there are clear parallels with the design process models introduced in section 2. This creates myriad opportunities to create linkages between the processes of researching and designing, to learn from one another, and to exchange methods, tools and practices. The various types of Research Through Design projects we find today can be mapped and understood through tracing where these design and research processes cross, at junctures where they have activities in common.

From the perspective of high-level co-evolution, a key linkage between researching and designing is the looping back to just above the *inductive* step that researching and designing have in common — see the feedback arrow in Figure 8 - in this step an order is proposed, a pattern of relationships is projected on the situation to be tested to see whether it elegantly explains the phenomenon under consideration (in research), or whether (in design) this approach to the problem situation creates new viable pathways to solutions.

4 *Co-evolution, iteration and emergence in design*

In considering co-evolution within design projects (section 1), in the briefing process before design (section 2) and beyond the design project (section 3) we have located WHERE the transition from solution space to problem space (arrow B in Figure 1) can take place.

We have not yet addressed the crucial question HOW such a jump from solution space to problem space is made, nor have we detailed how the steps up (the 'feedback loops' in the models) really work.

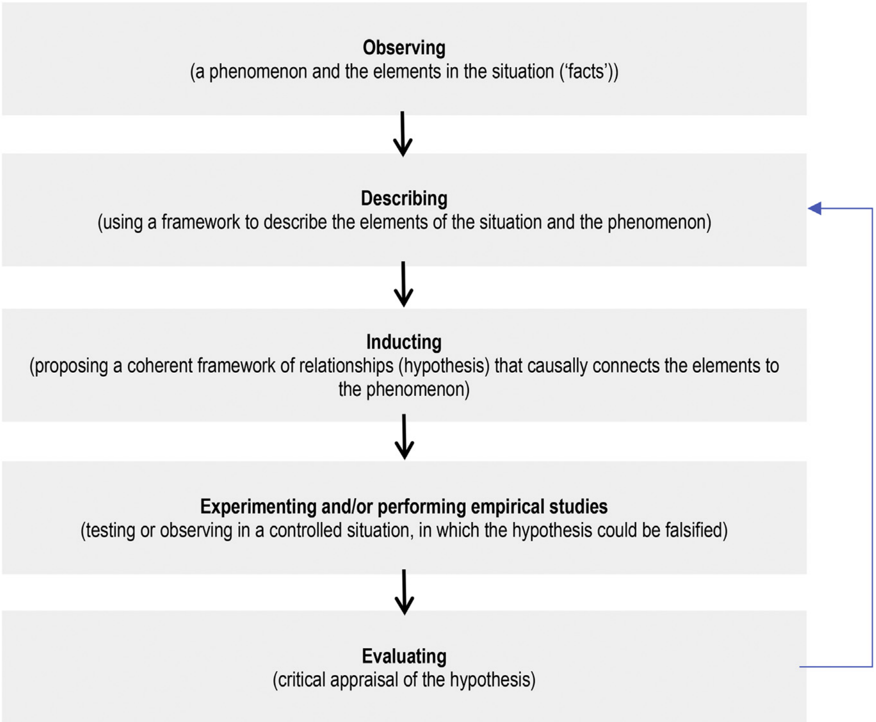

Figure 8 A model of an inductive (hypothesis testing) research project (after Popper, 1934)

Within descriptions of design iteration, the feedback loop is conventionally described in terms of an undoing of the steps from problem to solution, returning to an earlier phase in the design project ('going back to the drawing board'). This is obviously not true — we do not go back to an earlier state because in iterating, we take the lessons learned from testing the proposed solution back to the earlier activity that we need to revisit. But what are those lessons? How are they interpreted? How do they influence the ensuing activities? And how do we decide which activity (phase in the design process) to jump back to? The practices and processes that together make up these upwards jumps are, as yet, uncharted territory. This is a blind spot that needs to be addressed; further research needs to be done to observe, describe and understand design iterations within and beyond design projects to better support students and practitioners.

When we consider co-evolution - the looping back to the problem space within a design project (arrow C in Figure 1, arrows B and C in Figure 5) or beyond the confines of the design project (see sections 2 and 3) - this becomes an important and urgent issue. In co-evolution, the jump back to redefining the problem is extremely problematic. We tend to associate such shifts with progress, and see them in a positive light; after all this is design at its most free, intellectually challenging, and potentially most influential (truly strategic, in terms of the four orders of design (Buchanan, 2001a)). There is a close parallel with the notion of paradigmatic shifts as described in the history of science (Kuhn, 1970), the achievement of progress in the history of ideas (Gardner, 2011) and, in philosophy, with the 'displacement of concepts' to further our thinking (Schön, 1963). Yet in all of these, we find little guidance on how to understand in detail what Kuhn described as the 'context of discovery'. What is clear from these descriptions is that the process is driven by the 'emergence' of new order out of a complex situation. But the notion of emergence is tricky in itself, as it has a double meaning: it both refers to the 'becoming known' (of something that pre-existed — as in 'finding a solution') or the 'starting to exist' (of something that is new — as in 'creating a solution'). Within creative design, the complexity and multi-interpretability of the problem situation means that emergence is (almost) always of the latter type.

The fact that two types of emergence exist opens up the possibility of misrepresenting the jump from the solution space to a new problem definition as a 'becoming known', which introduces a fake claim to rationality (an ' … of course … ' (Lakoff & Johnson, 1999)). In the upwards jump of co-evolution we shift our perception of reality, changing the very words we use to describe and interpret the world (for instance, in seeing Kings Cross as if it is a music festival). As these words and images are the tools we use for thinking about the problem situation, their shift easily escapes critical scrutiny.

In the middle of the jump from the solution space to a new problem definition we are suspended in thin air, and our perception can easily be hijacked (advertently or inadvertently) to further the interests or values of some parties over others. Going from solution to problem in complex problem situations is always, and fundamentally, a creative step (Searle, 2003) that involves choice, judgment and responsibility.

The frame creation methodology that was used in the Kings Cross case study attempts to support practitioners in achieving creative emergence in a responsible manner. It does so by encompassing (1) the questioning of the current solution, (2) the extension of the system border to embrace the full complexity of the problem situation, (3) the (re)considering of the values at play to (4) investigate a deliberate change in the drivers (that have hitherto led to a certain type of solutions), while (5) increasing the repertoire of possible new solution directions to draw from, so new approaches can emerge. It is meant to be a reasonably safe process in moving from solution to problem as it is unflinchingly creative, broad, inclusive, and grounded in an explicit value discussion (Dorst, 2015).

5 Conclusion

The aim of this paper is to progress the discussion on co-evolution within the design research community. This has been attempted by using descriptive models of design to reflect on the processes and practices of co-evolution on a more detailed level. And the more we probed, the more questions have arisen. The modelling of what happens inside co-evolution needs to move beyond the superficial descriptions in sections 1,2, and 3. Both the problem solving and reflective practice paradigms have their strengths and blind spots, and engaging with other descriptive frameworks for design (seeing design as rhetoric (Buchanan, 2001b) (Halstrøm, 2016), as a social process (Bucciarelli, 1994) or as storytelling (Munro, 2016)) will undoubtedly lead to richer descriptions. Every description can lead us to new tools and methods to support the co-evolution process.

However, to create actionable advice to creative practitioners — within and outside the designing disciplines - we need to move beyond pure description and address the quality question. What is good co-evolution? When is it inefficient? When does it fail? The existing quality measures in design do not suffice to answer these questions. Quality in *design-as problem solving* has been defined as the attainment of a satisficing solution (relative to stated criteria) and arriving there by the shortest path. This measure does not work for co-evolution because it is based on the idea of attaining efficiency in a closed problem world (Dreyfus, 1992) while co-evolution, by definition, requires an openness to the outside world beyond the original problem space. Quality in design-as-*reflective practice* is not explicitly defined, although it is implicitly linked to the thoroughness of exploration, the occurrence of double loop learning (Argyris, 1977), and the extent to which the shift in the mental model of the problem situation has led to the resolution of paradoxes in the final outcome.

Both of these approaches seem to cover only part of the kinds of quality one might intuitively ascribe to successful co-evolution. As always, non-quality is pretty easy to articulate: a key symptom of a problematic project would be the need to loop back to the problem space late in the process, leading to the unravelling of decisions and the loss of resources that were committed to the now abandoned solution direction. Yet such learning might also be a vitally important driver for true innovation in an organisation (Hart, 1996).

Deliberate co-evolution, the designerly way to interpret & re-interpret problems, is important to creative practices across the professions. To deal with the problems and challenges of a complex and shifting world, all professional fields will need to foster a capacity for co-evolution. The ability to think between problem space and solution space is needed now, more than ever.

It falls to the design community to take the lead and show the ways this can be done.

6 One more thing

The notion of co-evolution has its roots in biology, as a concept to describe the natural phenomenon of species adapting to one another (a specific flower to be pollinated only by the bee with just the right shape) (Crilly and Moroşanu Firth, 2019). Through early cognitive science, the notion has entered the discussions on design.

On a societal level co-evolution can be used to describe the way our habits and practices change in tune with our technology (see how mobile communication is changing our culture, habits and human relations). That may be an understatement: changes in our culture are very much *driven* by the changes in technology. In the terms of this paper, this is an 'upwards jump' where the solution space (technology) influences the problem space (human culture, values and meaning). As mentioned above, this emergence of new order is potentially problematic as it is a creative process in which we change our very perception of the world - through keeping this change of perception implicit, and/or representing it as an analytical step, critical scrutiny and societal discussion can be bypassed. This compromises both our freedom of choice and our very freedom of will.

This is the dark side of co-evolution. We urgently need a strong descriptive and analytical framework to help us understand what is actually going on in the 'upwards jump' from solution to problem, and how we can safeguard against the misuse and manipulation of emergence. Design research is needed to gather deep insights into this process — not just within design, pre-design, and across design projects, but also to inform our understanding of these co-evolution processes on a societal scale. Design research has an important role to play, and no time to lose.

Dedication

This paper is dedicated to the memory of Corinne Kruger (1963–2015), artist, photographer and design researcher.

Declaration of Competing Interests

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.

Notes

1. The Frame Creation methodology supports the designer through nine steps: (1) Archeology - How did this problem come about? What has already been done to solve this?

(2) Paradox - What makes this hard? (3) Context - What is important to the current stakeholders? (4) Field - Who could be involved, and what is important to them? (5) Themes - What underlying themes emerge from this broader field? (6) Frames - In what ways can those themes be addressed/actioned? (7) Futures - What, then, are new and interesting possible outcomes? (8)Transformation - What changes are required to make this happen? (9) Integration - What can we learn? What new opportunities arise?

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