Facing complexity through varying the clarification of the design task

How a multi-contextual approach can empower design engineers to address complex challenges

Kersten, Wouter; Diehl, Jan-Carel; van Engelen, Jo

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Wouter Kersten, Jan Carel Diehl and Jo van Engelen

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Abstract

Today, most challenges designers face are complex. One way industrial design engineers have learned to deal with this complexity is to simplify the problem early on—for example, by focusing on one particular context, e.g. user group. Variations are typically addressed, but preferably inside the simplified design task or even after initial success has been achieved and a path has been set out. A range of authors have suggested ways to address variations during the design process. This paper contributes to exploring this notion of variation by presenting an approach that emphasises contextual variation early on, clarifying the design task before the design process, in a narrow sense, begins. This enables designers to seize opportunities that reveal themselves before a final path is set. Based on real-life cases and discussion of existing literature, the value of this approach for an industrial designer's arsenal is explored and guidance for next steps is offered.

Keywords**:** context variation, complexity, design arsenal, variation of the design task, design approach

Introduction: Background, purposes and structure of the paper

In this paper we expand on the thoughts we presented in a previous working paper (Kersten, Diehl, & Engelen, 2017) and an associated presentation at Relating Systems Thinking and Design (RSD6), which was organised in October 2017. Based on evolving insights and dialogue since then, the framing and some emphasis of the key points have shifted and are now more thoroughly substantiated. The key points have not fundamentally changed. However, driven by these shifts and the ongoing dialogue, we do feel that it is opportune to first explicitly explain the leading thoughts behind this paper, what it adds to our previous work (Background) and what it does, and does not intend to, accomplish (Purposes), all of which is further clarified by outlining the paper's structure (Structure).

Background

This paper's focus is on designing in the face of complexity. Many authors have contributed their thoughts on this topic in the (recent) past. With our work, we intend to contribute to that ongoing dialogue. In previous work (Kersten, Diehl, Crul, & Van Engelen, 2016; Kersten, Diehl, & Crul, 2017; Kersten, Long, Diehl, Crul, & Van Engelen, 2017) we have presented first explorations and empirical results of using an approach that can contribute to helping designers work with complexity. This suggested approach most notably revolves around *intentional early contextual variation*, or, in seminal design engineering terms (Beitz & Pahl, 1996; Pahl, Beitz, Feldhusen, & Grote, 2007), 'when clarifying the design task'.

In this paper we build on our first explorations and more thoroughly discuss the academic angle. Real-life examples, used throughout this paper, help to illustrate what problems industrial design engineers can face, as well as the results of addressing these problems in different ways. Some of these examples, or parts thereof, have been used in other publications, but that does not reduce their value. All examples have, to a large extent, been anonymised because the details of the products, countries, etcetera, are not essential for the paper's purposes, and disclosure may hurt the interests of the, often small, case-companies.

In addition to previous work, we intend to strengthen the interplay between theory and practice by further scrutinising empirical findings, and, through the lens of others'—evolving—academic contributions, we reflect on whether our own empirical findings are coincidental or not. We thus create a firmer basis for discussing in what ways the use of *intentional early contextual variation when clarifying the design* might enrich the arsenal of industrial design engineers. We like to emphasise that exploring this enrichment is, by no means, intended to imply that other approaches are suddenly superfluous. Such enrichment would just imply that the suggested approach has merits and, therefore, is worth consideration. Such consideration would represent an attitude that is advantageous to further scientific discovery in any area (D'Souza & Renner, 2014).

Purposes

Fuelled by the ongoing discussion since our previous publications, we address three key aspects in this paper. First, the core question we explore both, in a practical and an academic sense, is whether the main principle of engaging in contextual variation early in the design process when clarifying the design task indeed adds value for industrial design engineers addressing complex problems. To do this, we first identify and discuss a brief history, and the present state of affairs, of how industrial design engineering is addressing complex problems.

Secondly, a related key aspect we reflect on is the general attitude required in the face of complexity. Particularly, we reflect on the discussion of whether the high level of uncertainty that characterises complex situations implies that we should 'muddle through' with small, incremental, opportunistic steps (Norman & Stappers, 2015), or whether there might be alternatives worth considering.

The third key aspect we discuss is what level and type of guidance should be offered to designers when they intend to work with an approach that is not yet known to them. It is obvious that there should be some clarity of purpose when suggesting the use of any approach. However, it is less evident how much codification, in the form of detailed process guidelines, instructions and blueprints, is required and how much such codification represents the attitude necessary for effectively approaching complexity. While it may be claimed that novice designers will always need detailed guidance to get started, we open the discussion to whether this is the case or whether the feeling of control is more of an illusion (Flach, 2015). In particular, we are curious as to whether (junior) designers do prefer the feeling of being in control or, alternatively, the autonomy that allows their own creativity to flourish (Langer, 1975). We reflect on this point at the end of the paper.

In this introduction we now provide a concrete, real-life example that represents a situation we found to commonly occur in practice. This example illustrates the types of problems that have thus inspired our research. At the end of the paper, we discuss how our line of research, together with that of other academics, suggests that alternative approaches, other than the one described in this example, are possible.

Example case

A company set out to introduce a renewable energy system in an emerging market (country). After several iterations based on the paradigm of 'fail early, learn fast', they concluded that they had found the proposition (product features and business model) that would gain sufficient traction in their target market. This proposition provided them with the basis to attract funding to enter the production and implementation stages. The funding was obtained using the result of the eventually successful pilot as a guideline for S.M.A.R.T. targets. This acronym commonly refers to Specific, Measurable, Attainable, Relevant and Timely and are used as default standard to set as concrete as possible goals and thereby facilitate monitoring and accountability. Additionally, some funding was reserved for exploring changes that might be required, but were expected to be minor, to enter a second market (country) to enhance the company's financial viability prospects.

The company's main resources were used for implementation in the initial market. The parallel exploration in the second market soon revealed that, to get sufficient traction, the company would need a different business model (i.e., leasing instead of selling) and would need to make fundamental changes to some physical design features to support that business model. Company representatives informally discussed the leasing-option with possible customers in the initial market as well. Many of these potential customers indicated that they would have preferred the leasing option over buying the product. However, due to the funding agreement that was based on S.M.A.R.T. targets, including a target on number of units *sold*, there was no space to change the business model in the first market. Working on the required changes for the second market would also take away too many resources from the initial implementation.

Following the chosen path resulted in the second market not being served because of the changes that would be required and the customers in the first market being underserved, which dampened revenues. This, somewhat ironically, endangered achieving the S.M.A.R.T. targets. While the market for a sell-buy model did exist to an extent, the company had used that knowledge as argument to not investigate whether other business models would have worked out as well, or better. The strategy to create quick success in the initial market had created a path dependency and funding lock-in from which, in practice, it was not possible to diverge.

Key observations in light of this paper:

- *Variations for different markets (contexts, countries) were considered late in the process, after crucial decisions had been made regarding design, production and business model;*
- *Optimisation for the short term created a path dependency that erected serious barriers for the longer term (expansion);*
- *The company had a plan that was (implicitly) based on assumptions that were obtained in the initial market, but that insufficiently took into account the possibility of different scenarios;*
- *The quick success, i.e. alleged proof to make choices that would create a successful business model, kept the company from exploring more options and from considering informed, alternative scenarios;*
- *In short, the complexity of the design challenge as being a multi-contextual one, had either not been recognised as such or was considered low priority. The resulting design space was, therefore, limited. While it was based on discussions with multiple stakeholders (prospective customers, possible partners, government), these were all positioned only in the initial context.*

Structure of the paper

Having explained the main background and purposes of the paper, as well as having provided an example of the type of situations we encountered and thus wanted to address, we now provide a quick overview of the paper's structure. For extra navigation purposes, the section titles are added in parentheses and underlined.

We continue in the next section by providing a brief reflection on some main, past contributions in the industrial design engineering domain, particularly pertaining to complexity (*Where does IDE come from?)*. This serves as a logical warm-up to reflect on where this currently leaves design engineers when addressing complex multiform problems (*What is the current state of affairs?)*. We gravitate towards discussing the notion of 'variation' in the design process. Next, we briefly discuss the main problems that industrial design engineers encounter—as we observe them in practice—when trying to tackle the type of problems we talk about (*The problem: Possible consequences of insufficiently addressing complexity*). There are many ways that these consequences might be mitigated or prevented. We are far from the first to recognise this room for improvement, so we discuss ingredients in existing academic literature that represent relevant explorations regarding the use of design process variations (*Which current alternatives do exist?).* We, however, consider these ingredients, not as end-points, but as invitations to continue such explorations. They thus serve as inspiration for the approach that we consider to be a logical consequence; we describe this approach, and especially its application in real-life cases (*Travelling onwards: Intentional early contextual variation*). The reflection on these experiences (*What might this approach add to designers and others?*) then feeds the final section. There (*In summary and towards next steps*) we first discuss the findings through the lens of the paper's purposes, including how our work has both benefited from, as well as feeds back to, the work of others. The paper ends with suggestions for academics and practitioners on how to move forward.

With this introduction, we intend to convey how we have stood both on the shoulders of, as well as shoulder-to-shoulder with, others' work. Thereby, we send the message that no suggested approach can be a total novelty, so that is not the intention in this case either. It also is explicitly not our intention to introduce a formalised method or tool. After all, a complex situation, by its nature, cannot be solved by blueprinting. With this paper, we mainly intend to share insights about the demonstrated and perceived value of the proposed approach in practice, and, by means of reflection through the lens of literature, argue why that value is not a coincidence, but is also not a given, as demonstrated by our experiences.

Where does industrial design engineering come from?

In this section we briefly look back on where the industrial design field has come from and touch on the other two main topics we presented in the introduction, i.e., an underlying attitude and level of codification. At the end of the 19th century, industrial design revolved around shaping forms and producing artefacts (Fallman, 2008; Latour, 2009; Nelson & Stolterman, 2002). In the course of the 20th century it also included solving problems, first purely technically oriented, late 20th century also more societal. combined with the art of defining these problems better in the first place. This development brought designers closer to being better positioned to address more complex challenges.

While some authors from the design domain have claimed that designers, by virtue of their way of thinking (i.e., design thinking), are automatically well positioned to tackle complexity, (Brown, 2008; Buchanan, 1992; Cross, 2001; Dunne & Martin, 2006; Nelson, 2007) it is not necessarily evident whether this always occurs in real life. There is even less clarity on whether non-designers who use simplified design tools (Antle, 2017) are, in reality, tackling complexity correctly. Unthoughtful use of such tools, by designers and non-designers alike, is a manifestation of an attitude that revolves around early simplification of a challenge. *When and if* that is indeed the dominant attitude, the design process is driven by reductionism (Nelson, 2007), analytical decomposition (Diethelm, Flannery, Giuliani, Flournoy, & Pfeifer, 2016) and desire for manageability and control (Chen & Crilly, 2016). This provides a feeling of being in control of the process and, therefore, of the result (Backx, Hilberath, Messenbock, Morieux, & Streubel, 2017).

Although designers allegedly do not fall for such temptations (Cross, 2001; Dorst, 2011), early simplification would result in limiting the design task's scope so that it becomes more manageable. Therefore, it might be realistic and beneficial to not *assume* that designers are fully immune to the temptation of control, especially if they are actively part of an environment where control is important (Mundy, 2010) and allowing for ambiguity and intuition (Verganti, 2017) less so. A reduced scope is consistent with the control span that people in managing positions still expect to be held accountable for, or that can give them a sense of sufficient certainty to inform their decisions (Mundy, 2010). Such an attitude is often encouraged by emphasis on a specific output and an efficient process, driven by demand for early success and achieving SMART targets on clear components (Doran, 1981; Piskurich, 2015). This, however, also means that reality is not fully acknowledged, since, in real life, interrelations may be more important than the components themselves (Monat & Gannon, 2015). Recognising such interconnections in design terms can influence important design decisions.

One field attempting to address humanity's challenges, but not immediately jumping to simplification, is systems thinking (Ackoff, 1971, 1973; Meadows, 1997, 2002). Systems thinking can potentially contribute to supporting designers and other professionals in gaining a better understanding of complex systems. However, as several authors have argued, many designers did not receive well the formalised and normative way systems thinking was initially presented to them (Collopy, 2009; Sevaldson, 2014; Sevaldson, 2017). Proponents of methodologies like systemic design (Jones, 2014, 2015a) and systems-oriented design (Sevaldson, 2013, 2017) have, in recent years, attempted to merge the fields of systems thinking and design in an evolving process. One conducive factor in that process might very well be the RSD symposium series. These developments do not necessarily mean that we now have one proven, universal way to 'solve complex challenges'. Importantly, complex and wicked problems, by their very nature, do not have solutions. This 'feature' of complexity was put forward decades ago (Rittel & Webber, 1973) and was later explained in the design context (Buchanan, 1992).

A noteworthy observation in line with the above is the realisation that, to address complexity, it is wise to be openminded about the knowledge types and, therefore, perspectives that might be required. Relying on deep expertise currently still has relevance, particularly when facing complicated problems, the land of 'known unknowns' (Snowden & Boone, 2007). However, complex situations are the land of 'unknown unknowns', which implies that broad and diverse, rather than deep, knowledge is required to ascertain what is happening. There are no clear solutions, and even the exact question is not always clear and may never be fully clear. In those circumstances, designers seem more likely to benefit when they have, or make, room to appreciate the complex richness of the opaque, real-life situation—for example, by building rich, holistic pictures, instead of obsessing over a clear, tangible result (Checkland, 2000; Lewis, 1992).

What is the current state of affairs?

Our research was, and is, mainly driven by observing how—in practice, not in theory—complex design engineering challenges are frequently addressed. In particular, we are talking about the types of cases we have actively experienced—complex, multiform, globally relevant, basic-quality-of-life problems with many local manifestations. These problems are simultaneously experienced by many different people, often in different contexts, and in different ways. Examples of relevant themes are sanitation, clean cooking, energy access, waste, and financial inclusion. The term 'context' can refer to any demarcation between sets of requirements that is used to provide focus for the designer. Obvious contextual boundaries can be observed between countries, affluence levels or, more generally, user groups.

We observed that, for such cases, designers with different experience levels often zoomed in on one manifestation of the problem in one specific context. This choice may have been driven by the well-intended goal to work in a user-centric way. Early simplification enabled them to focus and develop a solution that worked with the particular user group in mind. That solution was then based on contextual intelligence (Khanna, 2014), i.e., deep knowledge of a specific context.

By reasoning in this way however, a system that is open was simplified into a closed system that can be controlled much better because of its limited scope. Such reductionism and de-contextualisation seem to have some practical merit but do carry many risks. When living in an interconnected world, we also need ways of thinking that can productively feed this off interconnectedness (Morin, 2008), even if this means facing more uncertainty. After all, uncertainty characterises real life (Flach, 2015). The relevant questions, then, become how can one embrace this complexity as an opportunity, and how might acceptance of not-knowing (D'Souza & Renner, 2014) result in evolving insights? Other practical questions then appear concerning how much uncertainty is still workable and when actual decisions can be taken to move towards next stages. One school of thought advocates that, in the face of this continuous uncertainty, all we can do is take very small, even opportunistic, steps and then, based on what happens, constantly adjust our course, i.e., 'muddling through' (Norman & Stappers, 2015). We will return to this later, to discuss whether alternative lines of thought might also make sense.

In terms of the currently prevalent industrial design engineering process, we observe that the range of uncertainty is mostly 'controlled'. Allowing systematic variation in several process design steps attempts to address the reality of uncertainty. Figure 1 below shows where, in a regular design engineering process—as suggested by, for example Pahl et al. (2007) and Roozenburg & Eekels (1995)—this room for variation is reserved. The activities typically receptive to systematic variation are shown in the form of Δ-symbols. The core design principle of variation goes hand-in-hand with three other core design principles that are also represented in Figure 1 and explained more in depth below. This set of four core design principles has been described before (Muller, 1999; Leenders, Van Engelen, & Kratzer, 2007). Note that these principles are all used within the design task as it is established in a narrow sense.

- *Systematic variation (shown on the right side)*. This involves varying aspects of tentative results, like product features, in a systematic way to find the best overall combination. This type of variation dates back to Leonardo da Vinci.
- *Hierarchical decomposition (shown on the right side)*. When breaking down a problem into sub-problems, or sub-systems into sub-functions, make sure to clearly delineate where the 'cut' is made, so it is possible to recompose partial solutions for decomposed sub-functions. When combining partial solutions into overall functions, a tool like morphological charts can be used.
- *Discursiveness (visualised by the spiral in the middle)*. A design process in practice is discursive. This does not only mean using iterations of the same step, but also taking larger jumps, back and forth, spanning more than one step. Experienced designers may recognise this in the notion of co-evolution of problem and solution space (Dorst & Cross, 2001). Basically, all design steps will be taken at least once, and probably several times, but not necessarily in one given order.
- *Satisficing (shown specifically on the left side, bottom)*. If a problem has many different variables and (types of) requirements, it is, in practice, not possible to optimise a design. Instead, decisions must satisfice different demands; a result is good enough, from various perspectives, to move forward. The extent to which the full List of Requirements (left side) is met by the design process result must be checked to decide whether to move back or to continue. This may tentatively happen several times during the process, but it must also be done once a design concept has been finished. This final check (bottom left) is likely to require the most conscientious version of satisficing to decide whether to continue (path Yes) or still change elements of the design (path No).

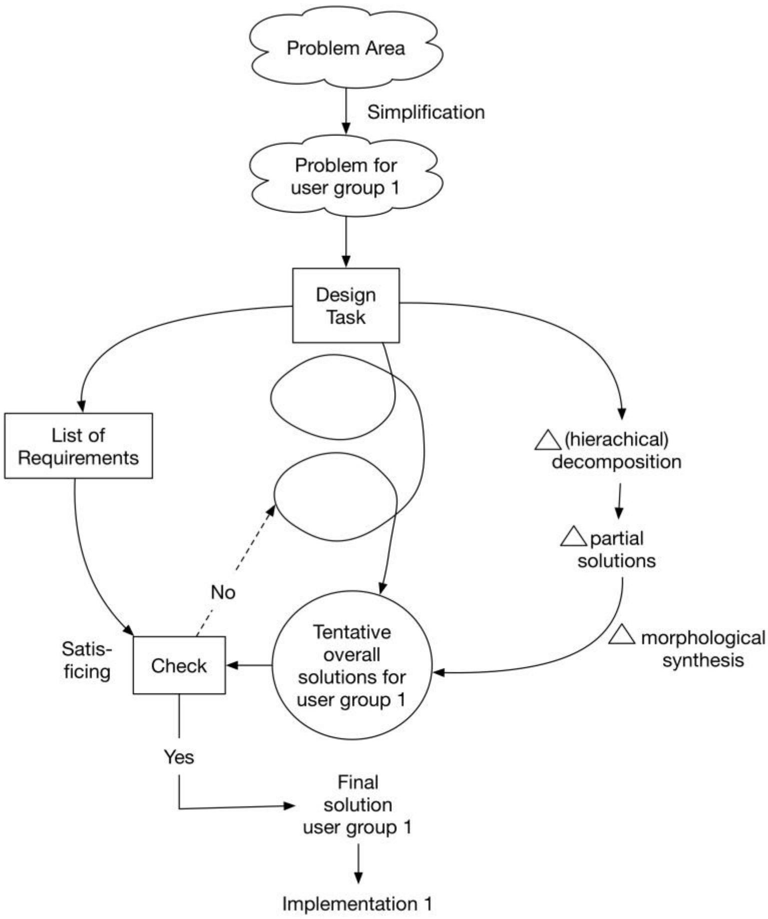

Figure 1. Seminal overview of the industrial design engineering process

As shown in Figure 1, this regular process includes room for variation, and, therefore, some uncertainty, but the main intended outcome is still a 'solution' meant for the targeted user group. The variation is performed within the simplified design task. For new user groups, slightly modified versions of the initial solution might be implemented, or the entire design process might be redone, starting by re-examining the problem for each new user group and then redefining the design task accordingly.

The problem: Possible consequences of insufficiently addressing complexity

As is now becoming clearer, the regular industrial design engineering process, as shown and illustrated above, can lead to much attention being placed on a concrete result (product). This influences the views of the design process. To clarify what the consequences are *if* designers consider a problem too narrowly—and, therefore, consider the corresponding design task too narrowly, too mechanistically or both—we briefly sketch these consequences and their drivers below. This makes it easier to understand what alternative approaches designers should strive for, which is this paper's next step. This does not imply that *all* designers currently think too narrowly and/or too mechanistically. However, we wish to show what happens if they do because it does often occur in practice.

Too much focus unduly limits the conceptual design space

The logical tendency, or even perceived urgency, to reduce variables to a number we can humanly handle is called bounded rationality (Simon, 1969). Complexity in real life problems is, however, characterised by more than a few components and interactions. Severely limiting these to immediately make the conceptual design space simpler is unlikely to respect the problems' diverse manifestations. An early *reduced (conceptual) design space* can never cater to such a diversity, and expanding that space later will likely be too late to effectively leverage possible interconnections.

Concerning the large-scale and, therefore, multiform and complex themes to which we refer, such simplification—focusing on a particular context—results in incomplete views of the whole problem. The design task is now more 'manageable', e.g., Chen & Crilly (2016), but this also leads to *heads down design* (Meyerson, 2015). Ironically, this risk is particularly alive in cases using narrow forms of user-centred design; focusing on a specific user group can quickly limit views of what else might be relevant. Thereby, a serious risk is introduced that many connections (both differences and synergies with other contexts) might get lost. The designer may not have intended this, but focusing on one user group nudges all people involved to consider only what would satisfy that group. The steps to test the ideas specifically with this user group exacerbate the effect. Again, the intention seems positive enough, i.e., testing in real-life with real users instead of in a lab. However, one not so positive consequence is that test results from only that user group dominate all subsequent steps, and this can make designers lose sight of the needs of future groups. The example in the introduction section demonstrates that this is a real-life risk, not just a theoretical one.

The *path dependency* created for subsequent versions of the same 'solution' for target groups in different contexts is now an almost unavoidable consequence. However, differing local contexts, including their entire ecosystems, require a more open way of approaching circumstances (London & Hart, 2004) instead of investigating how existing solutions can be made to fit new circumstances (Dahlman, Ross-Larson, & Westphal, 1987; Harrison, Graham, Fervers, & van den Hoek, 2009).

The investments and vested interests created by the first step do not encourage re-examining the problem and finding new pathways forward. Early success, in the form of a successfully user-validated proposition, has likely created buy-in for next steps. It can, however, also slow down, or even block, achieving success in multiple contexts later. The real-life example case in the introduction confirms both effects: initial, small-scale success literally created buy-in for scaling, but only for that *one specific path*, which did not allow for any variations to be seriously considered.

Process over content

An issue that refers to this paper's third purpose is to what extent designers need support in the form of prescriptive methods, tools and instructions. While providing these may seem to empower (junior) designers, there is reason to believe that the opposite might be true as well. Research has shown that telling people how to approach a situation, e.g. by giving detailed instructions, creates the perception that recipients do not have autonomy, which can feel stifling (Gulati, 2018). Lack of autonomy is a well-known factor that increases, rather than reduces, stress in difficult situations. Being pushed to follow codified knowledge in the form of specified methods and tools might easily result in designers losing trust in their own key skills, and, in the worst case, this can turn them into old-style managers (Verganti, 2017). Not being pampered with 'how to' knowledge turns out to be empowering both for experts (D'Souza & Renner, 2014) and children (Davis, 2013), so there is no reason to assume it would not be true for (junior) design engineers as well.

We can discuss the concept of (system) modelling from a similar perspective. As previously stated, the—advertently or not—normative, technocratic, this-is-*the*-way perspective, with which systems thinking was pushed into the design community, has not been overly appreciated by designers (Collopy, 2009; Sevaldson, 2014, 2017). Arguably, it is also not the type of thinking necessary for dealing with complexity. Methodologies like systemic design (Jones, 2015a) and systems-oriented design (Sevaldson, 2017) aim to overcome these mental barriers. Their use is, however, not yet fully common practice, so there is room for more attempts to try and combine the best qualities of systemic thinking with real-life design practice.

Less uncertainty feels like more control

Allowing only for a limited, focused design space, and/or being immersed in the (mechanistic) terminology of systems, can make it easier to think in terms of one particular problem definition or system model as *the* (only) right one. This starting point leaves little room for the generative dialogue required to map a landscape (Checkland, 1981) that represents the actual, multiform, multi-perspective, multi-contextual situation. The latter is an essential part of how designers operate; creativity feeds on ambiguity and interaction, and this requires a process that embraces multi-contextual diversity, not that focuses on output clarity (Lewis, 1992). Too much focus on output clarity reveals a (hidden) desire for control, which, in cases of complex problems, might not be the best driver.

Which current alternatives do exist?

As can be seen in the reflection above, some currently popular schools of thought—such as design thinking, user-centred design and systems thinking when used in a mechanistic sense—do not provide all-encompassing answers for addressing complex, multiform challenges. In other words, there is room for continued exploration. As we alluded earlier, several authors have already provided thoughts, and even methods, that suggest alternative pathways for incorporating complexity in design tasks. Such thoughts might, in traditional terms, be considered as ‘identifying and addressing gaps’. However, the word ‘gaps’ implies very clear points that need to be addressed, while, against the backdrop of complexity, it might not be as specific as that. Therefore, we prefer to use ‘room for continued exploration’.

Ingredients to inform further development

Below we include a representative, while not exhaustive, list of ingredients taken from other authors that, in our opinion, can guide further development of approaches and mindsets, i.e., can drive ‘continued exploration’. We focus on thoughts that enable designers to work with complexity by *using the notion of (systematic) variation* in some way. The reasons behind that focus were announced in this paper’s first two sections and are explained in more detail in the next section. Chronologically, identifying such ingredients and shaping our approach were intertwined. We opt to first present the ingredients, followed by the suggested approach, to demonstrate our acknowledgement that we did not work in a vacuum—that we used both our own empirical experiences, as well as dynamically evolving academic inputs, to arrive at the approach.

The ingredients are structured in three categories to create an overview. The categories are, in practice, interlinked, so these categorical divisions are not all-important. The ingredients refer to the statements of the authors, and we have not added our interpretation.

Network variation

The points below refer to looking broader than an initial problem context suggests when identifying possibly relevant sources.

- There have been some efforts to engage in multi-sited ethnography—e.g., Falzon (2016), Hine (2007), Marcus (2009)—and even multi-sited design—e.g., Lindtner, Anderson, & Dourish (2011), Williams, Lindtner, Anderson, & Dourish (2014).
- Novel and view-enriching information is more likely to reside at, or over, the edge of one's network than in the centre (Sunstein & Hastie, 2015).
- By extension, the more one interacts with people at, or over, the edge of a close circle, the smaller the risk of silo-vision (Tett, 2015).
- The future is increasingly unpredictable because of society's complexity, e.g., Flach (2015), but by actively immersing in diverse environments, and not acting merely on initial impulse, it is possible to increase the odds of a better overall understanding.
- Sourcing insights from diverse knowledge areas and environments leads to better informed estimations of what might happen (Tetlock & Gardner, 2016).
- An element that may help enhance reframing (Dorst, 2015) is to include multiple perspectives (fields) by involving different types of people (Suen, 2015). A question then arises concerning how different these people should be and where they should come from, e.g., from what disciplines and geographical areas.
- To source inspiration relevant for developing creative design directions, this inspiration should neither be too close (i.e., too obvious) nor too far removed (i.e., arbitrary) from the challenge at hand (Gonçalves, 2016). According to this research, junior designers particularly—such as students—do not necessarily receive much direction on *how* to achieve this. This, then, turns out to introduce a high risk that they will be drawn to either the 'obvious' or 'arbitrary' extreme because of pragmatism or an over-zealous drive to be original, respectively.
- While thinking in terms of multiple stakeholders is by now quite common (even when dealing with topics like system resilience) these stakeholders are often still selected from one 'system' or context (Taysom & Crilly, 2017).

Scope variation
When one opens the search space with versions of network variation, a logical consequence is that it also provides more room for variation in the design task's scope, whereas little network variation provides less room.

- An attitude of early scope reduction to reduce complexity ignores the importance of a form of thinking that contextualises and connects, is self-reflective and relational, and is open to the reality of uncertainty rather than engaging in a perennial quest for certainty (Morin, 2008).
- Especially in the issue definition phase, Dorst (2015) suggests (re)framing to consider multiple views on a problem.
- Generative sensing (Sevaldson, 2014) and acknowledging the 'web of interconnections that weaves complexity' (Montuori, 2011), as well as a degree of humility on not-knowing (Montuori, 2012), are starting principles for processes that can create a better understanding of any complexity confronting us.
- Open-ended design suggests intentionally leaving several parts of the design results open, to allow for future adaptations without having to apply all resources again (Ostuzzi, De Couvreur, Detand, & Saldien, 2017).

Methods and tools that enrich the conceptual design space
Different forms of variation during the design process enrich the conceptual design space. Several methods and tools aim to accomplish this.

- Design spaces should always contain multiple interacting media. Such 'rich' design spaces are helpful for enabling designers to map the essence of complex interrelations (Sevaldson, 2008).
- Move beyond simply putting (human) users central as *the* solution, and apply more systemic thinking and systemic design principles (Jones, 2014, 2015a, 2015b) or whole systems thinking (Blizzard & Klotz, 2012) throughout.
- Tools and the processes of using them—like Gigamapping (Sevaldson, 2011), rich picture diagrams (Checkland, 1981) and synthesis maps (Jones & Bowes, 2017)—are helpful to map and connect different possible projections of a problem landscape.
- The process of reaching rich maps and pictures is, in itself, already likely to contribute to deeper understanding, independent of the exact outcome (Lewis, 1992).
- An attempt to create more dialogue between systemic thinking and design, the Systems Oriented Design (SOD) method enables designers to capitalise on the inherent systemic nature of design by considering and visualising the whole Gestalt (Koffka, 2013) and encouraging designers to use their specific design skills (Sevaldson, 2017)—including visualisations, drawing composite pictures and imagination.

Travelling onwards: Intentional early contextual variation

The above inventory demonstrates ingredients suggested by different authors, some quite recently, for using *variation in the execution of complex design tasks*. These ingredients are already helpful for many designers. What we identified from our own (industrial) design experience is that, in many cases, the potential provided by these ingredients is not yet optimally recognised or captured in practice. After some contemplation, a leading thought that emerged, partially parallel to the cited authors, was that both the type and the timing of variation seems to leave room for further development.

This resulted in initial development of an approach that could use the notions above, make some of them more explicit and suggest a different point in the process for the main points to take effect. Together, these suggestions represent one more step in the evolution to address complexity. This approach is called Context Variation by Design (CVD). It was first suggested several years ago (Kersten, Crul, Diehl, & Van Engelen, 2015) and, by now, has been used in practice, finetuned, experienced by designers and reflected upon much more. This enables us to discuss it more thoroughly.

Its key point is to address the multiform complexity of many contemporary problems by applying the base principle of *systematic variation*, not only during design task execution in a narrow sense, but instead, or rather additionally, in *shaping* the design task by involving different contextual networks to interpret and formulate the (multiform) problem. The resulting design task, then, is not focused on addressing one specific contextual interpretation but instead covers several parallel and, in principle, equally important, design tasks.

This multiplicity amplifies or intensifies the use of the three other design principles mentioned before and within Figure 1. They contribute to variations in the conceptual design space. This allows more connections and patterns to be revealed and can, therefore, enhance the multi-media aspect of rich design spaces (Sevaldson, 2008).

Figure 2 shows the new graphical representation of Figure 1's regular industrial design engineering process, this time driven by early contextual variation or 'variation when clarifying the design task'. For further clarification, the main differences are explained in depth below the figure and shown in italics. The right section of the figure is greyed out, not because it does not happen but because it uses the same principles more intensively. The key differences occur at the start (top of the figure), and as a result of the design process (bottom of the figure).

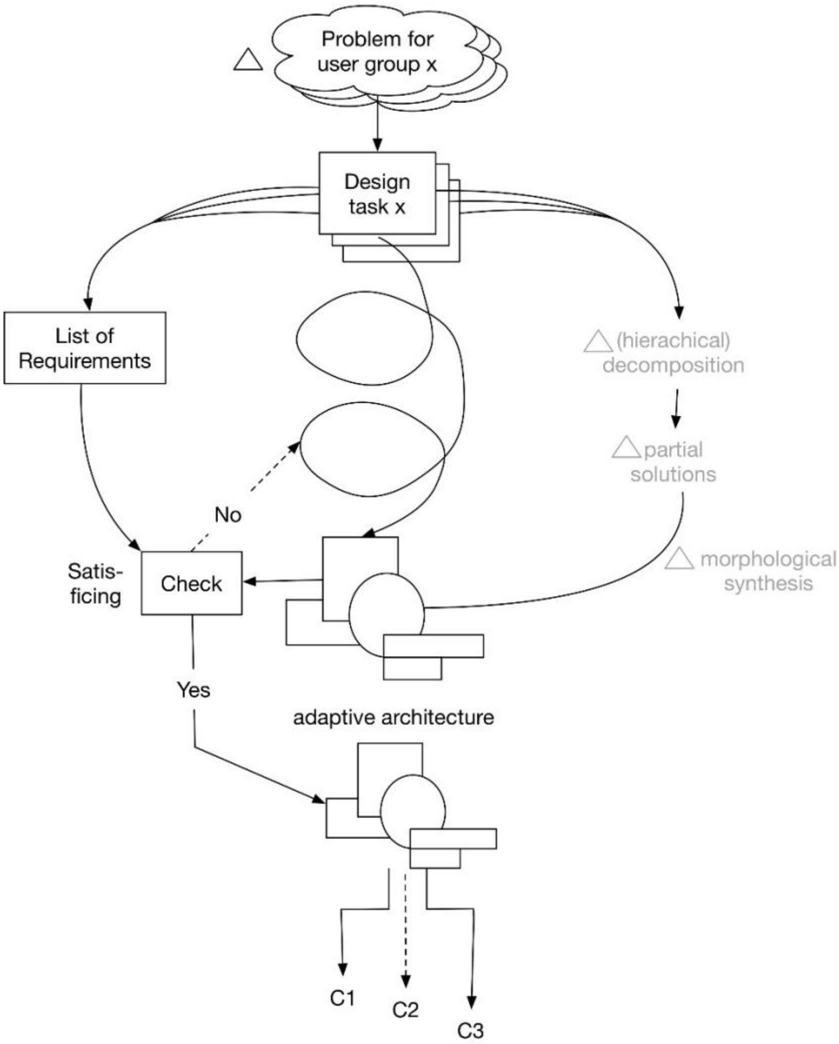

Figure 2. Industrial design engineering process driven by variation of the design task

The main differences are as follows. Contrary to the regular process, the full *problem identification and tentative problem analysis* does not occur for only one target group but, from the outset, for *multiple ones*. This results in a set of *interlinked design tasks* that are intended to cover *multiple sets of requirements* (the multiple lines leading to the left part of the figure) and feed multiple, in this case three, deeper contextual investigations (the multiple lines leading to the right part of the figure). The design process (right part) is then driven by the core design principles discussed above and within Figure 1, with more combinations and patterns now being revealed. The CVD-driven process informs composition of an *adaptive architecture* that may contain fixed, modular, adaptable, removable parts that can be used to play into contextual variations. Note that variations can occur, not only on the feature level, but also in non-physical areas, such as business model and marketing. The (continuous) use of the *satisficing* principle, with the final check at the end, should reveal whether the overall List of Requirements, covering *requirements for multiple contexts,* has been met (path Yes) or not met (path No). With the richly informed adaptive architecture as a basis, *implementations in several contexts (C1, C2, C3) are enabled*, even if not all such implementations, nor which detailed features they might require, are planned or certain.

Consequences of variation when the design task is being defined

By letting CVD thinking drive the process, as shown in Figure 2, several effects materialise. Connections and patterns that are revealed during the design process (right part of the figure) emerge by putting perspectives from different contexts together. In CVD terms these patterns are called 'shared insights'. To be clear, looking for such connections and patterns is not a feature unique to the CVD approach. Many mapping methods, such as creating rich pictures (Checkland, 1981), synthesis maps (Jones & Bowes, 2017) and Gigamaps (Sevaldson, 2011), also strive to identify patterns. A CVD mindset does, however, intentionally ensure that the diversity of perspectives that is input for such maps extends beyond the demarcation of one context.

Even more so, by explicitly thinking in terms of multiple contexts, the concrete question is raised concerning what determines a context's demarcation in the first place. For some problems, it might be a national boundary, in others gender, in yet others income level. This is not always as evident as it might seems. By mentioning 'beyond contextual boundaries', designers are encouraged to contemplate the type of boundary they are considering and may discover that they must redefine what crucially separates contexts.

The conceptual design spaces that are created by thus combining CVD with methods like Gigamapping or synthesis mapping contain rich content and can contain multiple media. Thereby, these spaces enable the design engineer to better identify patterns in the initially dispersed—and, at first sight, unconnected information—that is brought together by multiple contexts. Such patterns can be food for discussions and design decisions that would have been unlikely otherwise. In terms of complexity, observing such new connections is called emergence of 'higher order patterns from lower order informal chaos' (Johnson, 2002).

The logical result of this revised process is constructing *adaptive product architectures* instead of fixed products (though the latter could still possibly be produced with small variations). Because the designer now has much more information about actual requirements from multiple (foreseeable) contexts, it is possible to make definitive decisions on flexibility, modularity, etc. Without early contextual variation, designers might still decide to construct such an architecture, but they would have very little information to go on and could only make every single feature open-ended or modular. This means that no major design choices would be made at all. Making everything modular also poses serious problems in terms of the level of detail at which the modules would need to be designed in the absence of different requirements established for different contexts.

Cases from practice

To demonstrate how this real, but abstract, discussion of early contextual variation works in practice, we now share a number of examples from our research cases. The first example shows how early contextual variation created new opportunities, and arguably a better 'product architecture', than a previous attempt in which the design task focused on one context and postponed variation until later.

Example: Mobile sanitation units in public places in India

In a first attempt without CVD, the expected target group was involved following the Human Centred Design methodology. The sanitation units, including use-instructions, were optimised for this target group. Upon scaling the effort, it became evident that the target people, even within the same city, spoke different languages. This resulted in having to redesign instructions, training and some features. The scaling process and uptake in practice slowed down considerably and took away momentum.

This inspired the designers to start using the CVD approach in a second attempt. By involving people who spoke different languages from the start, it became obvious that the necessary move was to work more with visual icons than text. This was what, in CVD terms, is called a ‘shared insight’. By realising this early on in their attempt, different (versions of) symbols could be tried out with the different groups. One direct result was the development and validated use of a *portfolio of (variations of) symbols* that could be correctly interpreted by people from a wide variety of target groups. As a positive spin-off, illiterate people could also use the sanitation units. As Figure 3 shows, depending on text-instructions would always have resulted either in multiplication of these instructions, or omission of them entirely. By using tested and validated symbols, all foreseeable user groups could be served, including those who could not read scripts, i.e., illiterate people.

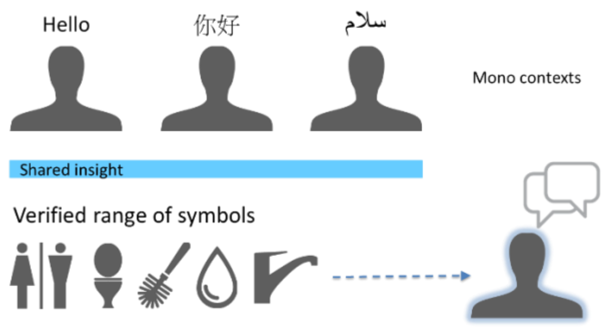

Figure 3. Early variation created a more adaptive, and inclusive, architecture

The second example shows how using CVD can, and should, go hand-in-hand with using (other) tools in the designer’s arsenal. CVD is complementary and empowering, but, though it provides the designer with rich insights to make informed decisions, it does not replace existing tools and methods in the design process itself.

Example: Charcoal based cookstoves

A charcoal cookstove producer had so far experienced problems achieving traction in more than one market. He realised that his stove might have been geared too much towards his home market. He was, therefore, open to trying out the multi-contextual CVD approach as part of the graduation assignment of a Design Engineering Master-student. To explore opportunities on another continent, two countries (C1 and C2) in Africa were chosen, both of which used charcoal as their main cooking fuel. Other than that, many—as yet unknown—differences were expected. Parallel, multi-contextual research was executed using desk research from previous projects and live field research by the designer (observing the cooking process, experiencing it herself, measuring data such as power and cooking time, discussing experiences on the spot, etc.). Figure 4 shows an overview of gathered characteristics for one country (C1). By putting overviews from both countries together cross-context patterns could be easily identified.

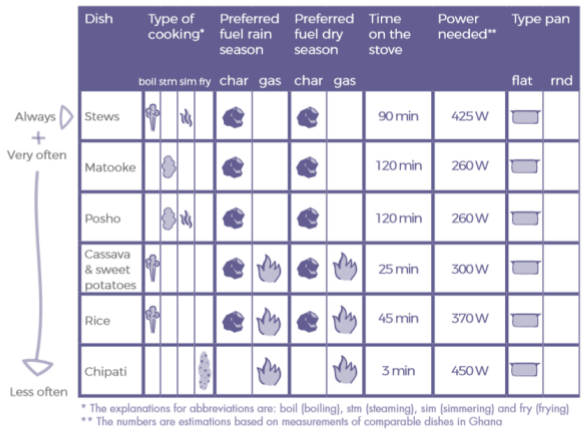

Figure 4. Cooking characteristics as basis of identifying patterns (Van Sprang, 2017)

Some important patterns, 'shared insights' in CVD terms, that were identified, and were essential input for design choices, were:

- Dominant cooking modes: low power/long duration/simmering (C1) vs. high power/short duration/frying (C2).
- Use of flat-bottomed pans (C1) vs. both flat and curved-bottomed pans (C2).
- Allowing for gas (LPG) to be connected as an alternative option during parts of the year when it is affordable, relevant for both contexts in different degrees.
- Allowing for the biochar tray to be emptied in a user-friendly manner, relevant for both contexts but articulated differently by the users.

The creation of these shared insights occurred because 'the design task' was broadened from one to two contexts. Knowing about the crucial (differences in) requirements early enough enabled the designer to, on the one hand (left part of Figure 2), define a list of requirements that covered multiple contexts and, in the actual design engineering process (right part of Figure 2), propose a stove design architecture that allowed for all of these user requirements to be actively covered. The eventual stove architecture cannot be shown in detail because of confidentiality. However, some features of the architecture, which, in hindsight, seem obvious based on the now explicit information, are: an option to connect LPG-bottles, easily attachable accessories to cater to differently-bottomed pans and a user-friendly, wide-range adjustable power-setting. Optimising the architecture for one of the context and then, before or after implementation, circling back to include requirements for the other context would, no matter which context was approached first, have required major redesign. This was exactly the problem the producer was facing before the assignment and why they were interested to try out this multi-contextual approach.

The graduate student made extensive use of a multitude of tools, including the quintessential one that is used for mapping and bringing together different variations of partial design 'solutions': the morphological chart. This step was shown on the right-hand side (bottom) of both Figure 1 and Figure 2.

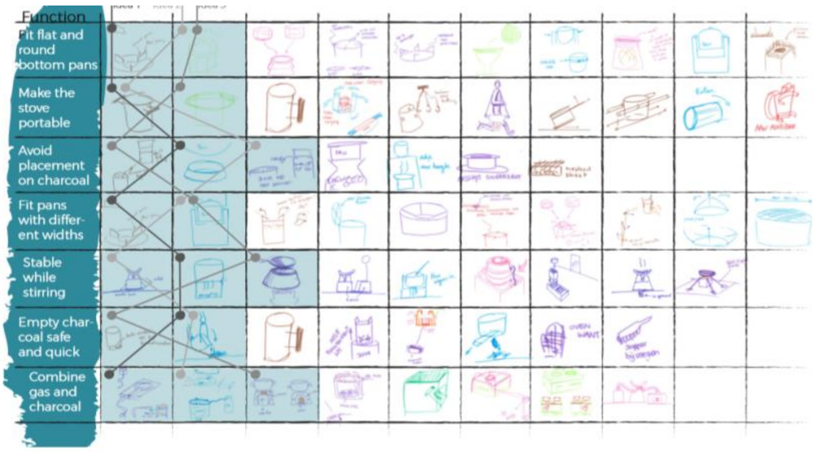

Figure 5. Morphological chart used within the CVD approach (Van Sprang, 2017)

What might this approach add to designers (and others)?

After having considered both the theoretical and empirical sides of the suggested CVD approach, we can now address the first aspect that we mentioned in the Purposes section of the Introduction. What might CVD-driven thinking add to a designer's arsenal, if anything?

We argue, supported by ample evaluations and discussion with junior as well as senior designers, that it adds the following. We know that open system models represent reality more accurately than closed models but that they also pose more challenges for humans due to the previously mentioned bounded rationality (Simon, 1969). We also know that closed system models align better with limited human capabilities to keep overview and, therefore, control. The core point of CVD, being the suggested early contextual variation when clarifying the design task, is an attempt to address this dilemma by creating, as we call it, a *multiple interconnected closed system*, where the different contextual perspectives are the main multiplicity source.

To show how creating insights in a multiple, interconnected closed system can be more intricate than simply comparing requirements stated by different user groups, we share another example from our cases.

Example: Cookstoves for three different contexts

In the first context that was investigated, a main requirement for a cookstove was that it should be in line with the households' aspiration levels. That is, it should look nice and 'shiny'. In the other two contexts, a main stated requirement turned out to be portability, e.g., being able to quickly move the stove between inside and outside the house (kitchen). In these contexts, looks did not matter much.

These are seemingly unconnected requirements. By considering them together, and probing the reasons behind their importance with the actual users, the demands' boundaries and reasoning were explored in a non-linear way. This yielded the idea that the cookstove could look aspirational by being mounted on a sturdy block, made from 'shiny' material. By making this block detachable, the users in the 2nd and 3rd contexts would also be served and their demand for portability respected. Making the stove able to attach to and detach from the sturdy block was still possible in this stage of the design process, and the idea could be discussed with and shown to users. With this 'adaptive design architecture' the stove could be brought to three different markets and very different requirements were satisficed with one design decision.

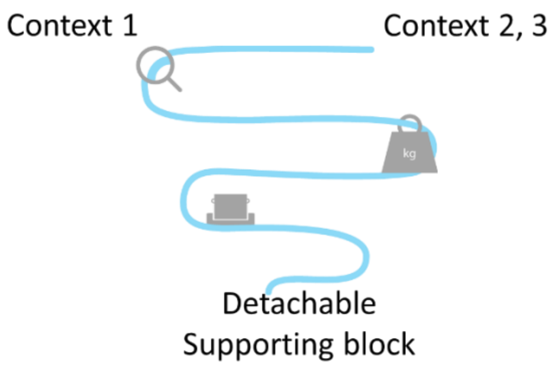

Figure 6. The non-linear process of combining perspectives

Acknowledging multiplicity prevents the lead designer's contextual hat from unduly limiting the design space. At the same time, the risk of infinite divergence is also limited. This combination seems to encourage the attitude required to tackle many contemporary design challenges. An important thing to realise is that multiple design tasks, and considering requirements from different contexts, does not automatically mean that implementation must occur in all these contexts simultaneously. In some cases, that may be beneficial or even necessary, but what scenario will be chosen depends on broader business strategies. However, in *all* cases, the design of the product versions for any context will have benefitted from the collective intelligence created by bringing together essential insights from multiple contexts early on.

If for practical reasons collective intelligence is not brought together by actual people from the multiple contexts, then at least the designers can make sure the insights from these multi-contextual sources are included on equal footing. In a non-linear discursive design process, such collective intelligence might be created at some point, but the explicit notion of early contextual variation removes all doubts that this will occur before major design decisions have been made. In academic terms—i.e., referring to the seminal work of Beitz & Pahl (1996) and Pahl et al. (2007)—we define this moment as 'when clarifying the design task', as illustrated in the top part of Figure 2.

It can be expected that early contextual variation reduces the risk of decisions concerning the scale-up of a successful pilot being based on a concept or prototype tested in only one context, as happened in the Introduction's example case. The longer-term effects of using this approach are expected to be a shorter *time-to-markets* and lower end-to-end cost for that multiple-market implementation. There currently is no empirical data to support that expectation yet, nor to reject it for that matter. The early experiences did, however, provide initial empirical data demonstrating that this approach can yield positive results in terms of creativity, richness (Kersten et al., 2016; Kersten, Diehl & Crul, 2017) and the actual performance of a resulting prototype (Kersten et al., 2017).

Summarised in a somewhat prosaic way, by early contextual variation, we put the horse *in front of the wagon*, where it can, with more intent, pull the design process in a reasonable, un-arbitrary direction, instead of, with a very limited outlook, push it forward relatively blindly. Many who have experienced designing for problems relevant in multiple contexts, and who are introduced to this line of thinking understand, 'putting the horse in front of the wagon'. They also recognise how the examples from our cases demonstrate this metaphor.

Experienced designers would possibly consider CVD thinking to reflect common sense, but, as many people have acknowledged to us, that does not mean it is common practice yet. Our cases, a few of which are mentioned in this paper, demonstrate that the notion of multi-contextual connections and patterns being revealed because they have been intentionally sought is likely to lead to a more complete, rich and generative picture of the real-life situation. By the thorough reflection through the lens of academic literature that we share in this paper, we can now also state with more confidence that this is not just a coincidence.

When we create design spaces where generative richness plays a pivotal role, the intended outcome is to encourage an adaptive architecture, possibly including an integrated, multi-context business model. Such an architecture is suitable for a range of foreseeable, and less foreseeable, requirements. However, we like to emphasise that creating an adaptive architecture does not imply being able to play into all possible (future) requirements. Instead, we put forward that such architectures are more likely to be able to play into future requirements because they are based on requirements from different, real-life contexts and the associated, diverse intelligence, rather than assumptions of what those differences may be. This is where our approach moves away from the 'muddling-through' school of thought, which holds that, in complex, uncertain situations, we can only take small, incremental, opportunistic steps because we know nothing about how the future will unfold. We return to this discussion in the next section.

We share one last example from our cases from practice that demonstrates the effects of early contextual variation and how a purposeful, adaptive architecture can be the result.

Example: Maternal health care device

The partner company had taken steps to develop a health care device, initially intended to be used in emerging economies. The company quickly realised it could also play into an emerging trend in developed economies. The starting situation was a working, basic prototype for the device, integrated interaction with simple software and a user interface. The company did not, as in other examples, optimise it for the initial context. They opened toward a second context, using the CVD approach coordinated by a junior designer.

The parallel, contextual research revealed, amongst other things, that, apart from some small changes to improve user-friendliness, the device's basic features could remain largely unchanged for both contexts. One 'shared insight' was that the working environment in the emerging economy was primarily paper-based, but was digital in the developed economy. This fuelled the idea to create a (digital) diary-function for the latter. Most importantly, it was realised that the differences between the contexts were mostly related to storage and methods of showing data to the end-users. It seemed conceivable to hard-code a few profiles into the hardware to facilitate universal devices. However, it was realised that such profiles could also be captured in the software with the added advantage that future, yet unknown, profiles could then be easily added to the software.

Thanks to considering, in parallel, the different sets of requirements for the contexts, one main design decision was, therefore, to move more functionality to the software. Putting more intelligence in the software meant that the hardware could be turned relatively 'dumb'. Because software is much easier to change and develop versions of, this architecture made the overall design very adaptive to support future changes, including yet unknown ones. Because the hardware contained less functionality, the changes also positively affected the price, which was a welcome benefit for the level of market adoption and, therefore, the business case.

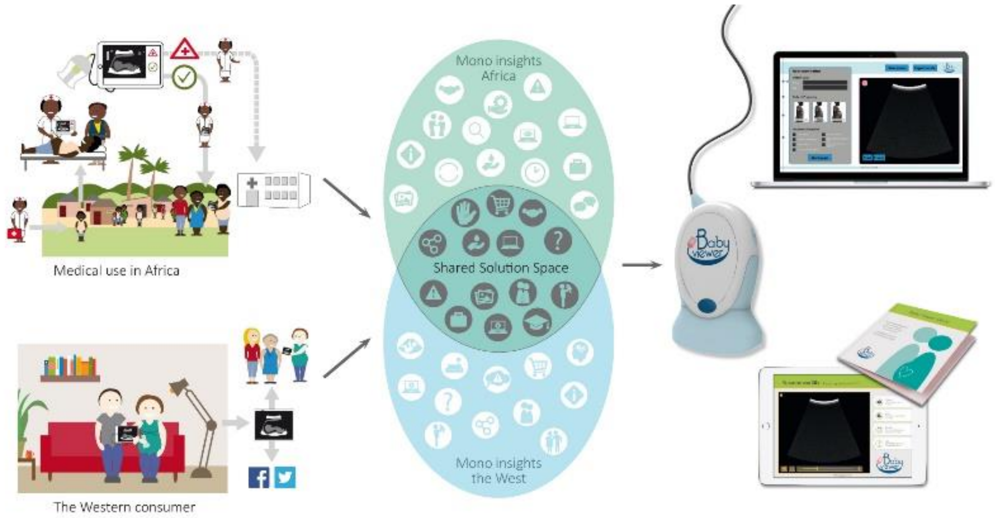

Figure 7. Visual of applied design engineering process (Van Gils, 2016).

In summary and towards next steps

In this section we first discuss the presented findings in light of the paper's three main purposes as they were stated in the Introduction. These are then used to suggest guidance for next steps at the paper's end.

In summary: Findings in relation to the paper's purposes

1. Possible added value of early contextual variation

The paper's core exploration refers to the (possible) value for industrial designer engineers of applying early contextual variation when 'clarifying the design task'. Below, we translate the findings into conclusions regarding the practical and the academic values.

Practical value

We have argued and demonstrated that this type of variation creates benefits, not only for the longer-term (catering for diversity that comes with scale), but, in many cases, also for the short-term. The convened collective intelligence that results in shared insights represents a rich appreciation of the multiformity of many complex, contemporary problems. In practice, this turns out to be a good basis for a high quality—conceptual and actual—adaptive design architecture that also yields benefits for the initial market the company decides to enter. For example, in the previous section's example case of the maternal health care device, one short-term benefit was, for example, reduced price because more intelligence was built into the software instead of the physical hardware (where it was located before a multi-contextual perspective was used). If that change had not been made, producing versions to serve needs in different circumstances would have become more expensive.

Based on our findings, we conclude that the high quality of creating adaptive design architectures in multiple-use cases is not coincidental. 'High quality' should be interpreted as fitness for use (Juran & Gryna, 1980). It is true that, without this approach, the benefits captured in adaptive architectures might have materialised. However, there is no logical reason for assuming this, particularly if there initially would only be attention for one context and time-to-market. All experiments we conducted to this effect also support this latter statement. To a very large extent, whether decisions would have been made that could cover future requirements depends on how large 'the system' under the designer's consideration would have been. There are not many realistic reasons to assume that the system under consideration, and, therefore, the associated conceptual design space, would have been similarly rich without the notion of early contextual variation.

Academic value

Earlier in this paper, we presented academic writings in which the concept of 'variation' in the design process has been mentioned, sometimes implicitly. Most of these were listed in the section *Which current alternatives do exist?* In this paper, we have explicitly emphasised, and shown examples of, our version of variation in relation to the regular design engineering process—i.e., allowing a multi-contextual scope to shape the step of clarifying the design task. We now briefly discuss how this contribution further strengthens the ingredients developed by the authors we acknowledged. Thereby, we contribute to the continuous process of academic discovery.

By bringing together intelligence from multiple contexts—without a preconceived notion of which one is more important—the design challenge's multiformity is acknowledged. This can be interpreted as allowing 'not-knowing' (D'Souza & Renner, 2014; Montuori, 2012) to drive the design process instead of hampering it. The multi-contextual input allows diverse contents to feed into a multi-media design space (Sevaldson, 2008). By combining both dimensions of diversity (sources and media), the outcomes are more uncertain, but are also in line with the statements that the mere process of constructing rich pictures has demonstrable, positive effects on designers' creative power (Lewis, 1992). Embracing a path that leads to less certain outcomes is in line with Morin (2008), who considers connecting, contextualising, being relational and acknowledging reality to be more important than striving for full certainty. Methodologies like systemic design (Jones, 2014, 2015a) and systems-oriented design (Sevaldson, 2017), or specific tools related to these, can and should be used. The multi-contextual angle can then help designers imagine the relevant system not to be smaller than it is (i.e., limited to one context), but also not to be arbitrarily large. The examples demonstrate how this can work in practice.

Providing a purpose and high-level principles, not jumping to prescriptive procedures and encouraging individual interpretations and visualisations to support the design process respects the wish of scholars—for example Lindgaard & Wesselius (2017), Sevaldson (2013) and Verganti (2017)—that designers should be encouraged to use the skills that make them designers. Our examples—i.e., the objectively good results of using CVD-driven thinking—demonstrate that this, too, can be realised in practice. Based on our experiences, we suggest not providing detailed instructions to designers, but, rather, encouraging them to purposefully look broad early on and allowing them the freedom to execute the design process accordingly. This is consistent with the paradigm of 'freedom within a framework' (Gulati, 2018), which refers to a combination of purpose and principles—i.e., high-level guidance on *why* but not on *how* or *what*.

Broadening, or, in fact, multiplying, the contextual scope when defining the design task can support the practice of reframing (Dorst, 2015) and gives direction for where to source without prescribing that process in detail. This addresses the problem identified by Gonçalves (2016). Being confronted with different manifestations of the same problem helps produce variations of the design task, thereby creating a holistic, overarching design task.

Early contextual variation, as advocated, in this paper clearly reduces the risk of path dependencies (Meyerson, 2015) that are based on premature simplifications (Jones, 2015b). Socialising, and increased use of approaches with similar aims to CVD, may also provide new impetus to accelerate the field of multi-sited design (Lindtner et al., 2011; Williams et al., 2014) and possibly ethnography (Falzon, 2016). Finally, using early contextual variation supports a process of open-ended design (Ostuzzi et al., 2017) by providing explicit insights into parts of the design architecture that can be fixed, open or adaptive. Intentional sourcing of relevant insights from multiple contexts prevents having to work from assumptions.

2. Required general attitude

In practice, a design approach must go hand-in-hand with a more general underlying attitude. In this case, the attitude should be conducive to designers, and the managers with whom they interact, approaching uncertainty, but not becoming apathic or reactive because of that uncertainty. An appropriate mix of ‘dealing with uncertainty’ and not going for full control seems to be struck by using strategic intent as guidance. In that way, one is adaptive enough to change course, or select from a number of anticipated potential courses, based on changing circumstances, while working with some form of purpose in mind. When this strategic, rather than operational, intent is more explicitly present at the start of the design process, it empowers designers to, for example, develop scenarios to give themselves guidance. This is not in line with just relying on ‘muddling through’ and ‘opportunistically taking whatever action is possible at the moment’ (Norman & Stappers, 2015) in the face of uncertainty.

Whereas ‘muddling through’ might be considered an adequate formulation to describe evolution (Dennett, 2017), we might more critically wonder whether the same is true for a product (architecture) development process. Contrary to the continuous, infinite and, in essence, design-less, trial-and-error-driven process of evolution (Dennett, 2017), it seems reasonable to state that, in cases of the human-driven product creation process, more specific purpose and conscious anticipation on possible outcomes might be in order. This is especially true if we are dealing with large-scale societal issues for which evolution-type patience—with the occasional ‘hit’ and the many misses—is not an acceptable attitude.

The size and complexity of larger systems and problems, and, thereby, the increased uncertainty of what may happen in the future, should not be an excuse for not thinking or informing oneself about it. Not knowing what exactly will be important is not the same as the absence of all knowledge (D’Souza & Renner, 2014). Rather, it might mean knowledge that can help to create a better understanding resides elsewhere—for example, in other contexts, or points in different directions than initially expected (Sunstein & Hastie, 2015). Importantly, incorporating insights from different sources early on does, by all means, empower people, including designers, not to be merely the victims of circumstances, even in highly uncertain situations, or, to quote Dwight Eisenhower (first part paraphrased), ‘…[when facing complex situations] a plan is useless, planning is indispensable’ (Eisenhower, n.d.).

To demonstrate how acting on that quote might work, we now present the ‘what-if’ version of the first case in this paper—a fictitious alternative scenario imagining what would have happened if a more adaptive approach had been used.

Example case 1, revisited

How might reality have unfolded if the company had used an approach that revolved around early context variation and adaptiveness?

- *Considering variations for different markets*. By considering variations early in the process, crucial decisions, on both the product and business model levels, would have been intentionally informed by insights from these different markets.
- *Preventing path dependency*. The short-term efficiency (lean, time-to-market) would not have been the main driver of the process, thereby leaving room for taking onboard longer-term considerations (time-to-markets).
- *Not over-relying on initially validated assumptions*. Using a broader perspective from the start, would have minimised the risk that the entire version 1.0 (product and business model) would be built on only one specific set of validated assumptions.

- *Dealing with complexity*. By considering multiple contexts from the start, the complexity of the challenge—in both design and business—would have been acknowledged. This still does not imply certainty or control, but the broader multiform, perspective would have enabled a design and business strategy that could more easily adapt to different sets of circumstances.

In fact, the case company when presented with this analysis, agreed that it would make sense to work in this way, but lamented that the funding agreement did not allow for any changes.

3. Level and type of guidance for (new) design approaches

As referred to early in the paper, we encourage designers to have an attitude of exploration and discovery and not one of immediately jumping to detailed, prescriptive methods and tools, particularly when faced with complexity. One might counter that any newly introduced approach, on any level of abstraction, requires clear instructions, especially for junior designers. It is easy to foresee how discussions about this assumed preference can continue forever. For the moment, we consider our vision on this matter to be consistent with scholars like Gulati (2018) on 'freedom within a framework'. This means, firstly, that the purpose must be clear—in this case, acknowledging diversity of (future) requirements. Secondly, further guidance should come from high-level principles that still leave enough room to manoeuvre without feeling stifled. A consequence to this could be that designers will interpret the principles differently than foreseen. We do not consider this to necessarily be a problem if it helps them to take and feel ownership of the design process.

During our research, we encountered a situation that allowed us to do a quick experiment to discover to what extent students view and appreciate clarity and instructions. The conclusions of this test are only to be interpreted as an indication, and the use of numbers is not intended to imply any statistical significance.

Reflecting on the desire for instructions to move forward

In a recent course for industrial design students (MSc level), a wide range of approaches, methods and tools was suggested for the students to consider for their complex assignment. Two of these were new to them: Gigamapping and CVD. These had been presented early in the course, focusing on main principles, and their use was further clarified further by discussing examples. Other than that, the students only received the online instructions (Sevaldson, 2017b) on Gigamapping and were mostly encouraged to 'Just start using and experiencing it' if they felt the suggested approaches or methods were relevant for them. Directly after the course, the students were asked to assess and reflect on their understanding of using Gigamapping as well as CVD, before and after they actually used them (if the latter was the case) and about their attitude towards instructions in general. The experiment resulted in 18 responses. Here, we only report the results for CVD, though the results for Gigamapping were similar.

- 12 students reported to have understood CVD better after having used it. Five said they understood it the same as they had before using it, and one understood it less after using it than before. All students who assessed their understanding as 'the same' had already graded their own understanding before using it with 8 or higher (on a 1-10 scale).
- The average number for how well the students' said they understood CVD before and after using it themselves was 6.3 and 7.5 respectively. The total number of 'increase-points' (grade after use -/- grade before use) was 23, and the total number of decrease points was 1.
- The average grade for the question 'Did you receive sufficient instructions on how to use CVD?' was 6.1—in other words, not very high.

- Over 2/3 (13 from 18) of the students awarded a 7 or higher for whether they enjoyed using CVD and whether they thought they would use it in the future.
- There were a few notable outliers in both directions regarding the grades given for quality of the instructions vs. future use. In four cases, the quality of the instructions was considered low (5 or lower), but the grade on likely use in the future was high. There was also one case in which this was the opposite; the quality of instructions was considered higher than 7, but likelihood of use in the future was lower than 6.

If we combine these results, we can identify an overarching pattern. While the students did not feel very well instructed (6.1 on a scale of 10), a majority felt they had a basic understanding (6.3) and 'just doing it' strongly increased their appreciation of CVD (20% increase of the grade to 7.5). Based on their own experiences, a clear 2/3 majority (13 out of 18) imagined themselves using CVD in the future (score of 7 or higher). This result was the same for Gigamapping.

Regarding their general attitudes towards needing instructions, most students mentioned that clarity of purpose and seeing examples are important. A small portion of the students did state that they also appreciate detailed instructions to, for example, '…prevent that we use the method or tool in the wrong way'. Others, however, mentioned that instructions would limit their own creative manoeuvring space. In short, and as expected, different attitudes exist, ranging from explicit appreciation of autonomy to explicit appreciation of detailed instructions. The students' general attitudes towards the need for instructions seemed to have some influence on how they graded the level of instructions in the first place. Formulated differently, while all students received exactly the same information, the ones who indicated they did not need very detailed instructions to get started graded that input-information higher than those who indicated they preferred receiving detailed instructions.

The main point that we derive from this small test is that the majority of junior designers (Masters Students in Industrial Design Engineering) in this sample did not consider the sub-optimal instructions as an excuse to not voluntarily try CVD, and they positively rated their experiences using CVD. Using CVD in practice, as compared to receiving detailed instructions from a lecturer on how it should be done, apparently helped them to understand its value and created a positive attitude toward using it in the future.

Towards next steps

How can we use the above reflection to guide future steps, for academics as well as practitioners? Based on identified patterns in the conclusions, we suggest the points below. The red thread in these points is the suggestion to combine a strategic intent (acknowledging instead of reducing complexity) with practice-based experiences.

(Academic) positioning and use

As stated throughout the paper, the existence of academic and practice-based ingredients that have inspired the CVD-approach shows that it is connected to many existing and ongoing practical and academic developments. This reflects our intention to be more interested in arguing whether it has value and demonstrating why, rather than proving, with mathematical precision, how much value it exactly adds. We feel it to be more relevant to demonstrate that we stand shoulder-to-shoulder with colleagues who aim to advance a continuous process of exploration, than proving that we have 'beaten' them. We have identified room for development, if the aim is to effectively face complexity as an industrial designer, tried out an approach that uses this room and assessed and reflected on the results. This room is most accurately described as 'Variation by bringing together multiple contextual perspectives when clarifying the design task' (i.e., the top part of Figure 2).

Appreciated use of any approach, method or tool in practice is based on people accepting an internal logic, trying out that logic in practice and observing whether it works. In the case of CVD, we suggest interpreting ‘it works’ as: ‘it helps (junior) designers to create design results (concepts, prototypes) that are inherently more suitable for addressing requirements from different contexts, which, altogether, is relevant in contemporary society’. If that interpretation is accepted, our suggestion, based on real-life examples and an academic perspective, is that the CVD approach, in conjunction with relevant methods of designers’ choice, is likely to empower designers when facing complexity.

Whereas the conclusion and associated suggestion is certainly justifiable for junior industrial designers, more experienced designers might also consider using the approach. There is, after all, no end to any learning process, and open-mindedness reduces the risk of over-relying on existing expertise (Antle, 2017; D’Souza & Renner, 2014; Kahneman, 2011; Tett, 2015). We warmly encourage designers to stay openminded, even if they have expert-status. Using CVD in practice will help to further refine or clarify it and therefore create more value for designers.

Assessing relevance for types of cases

Testing the suggested way of thinking and designing in practice must be continued so that more understanding can be gained for the *types* of challenges in which this multi-contextual approach makes most sense. For simple or complicated design challenges, the added value may not be substantial enough, because these types of challenges can be approached with straightforward, domain-knowledge-heavy methods. Drawing this knowledge from one context may then be sufficient. For now, the initial effort and required attitude of using approaches like CVD seems particularly applicable to complex challenges. These are not a priority for all designers. Based on discussions with designers about their experiences so far, the approach may, as mentioned earlier, be most relevant for large-scale societal issues, with (many) different international manifestations. Considering multiple user groups breathes the notion of inclusiveness, which is particularly interesting in cases of these issues, more so than for purely commercial endeavours.

Type of support and guidance

As discussed, any approach that is advocated to deal with complexity, in our view, benefits from encouraging an attitude characterised by discovery and inquisitiveness. If designers were to receive a structured process and easy-to-use support tools, this could dampen their eagerness to explore for themselves. All our cases demonstrated that (junior) designers, who embrace the value of exploration and discovery, proactively take steps to make the approach their own, while others seek the certainty that they think codified methods provide them.

In our cases, without exception, designers in the former group thrive when being offered the CVD-mindset, while designers in the latter group do not. This thriving, in some cases, included the designers’ developing creative ways to select relevant contexts in the first place or original ways to bring information from different contexts together. Continued reflection on actual use of the approach will provide experience-based insights concerning which type and level of (detailed) guidance—beyond providing purpose, principles and examples—strikes the right balance. That balance refers to desire for clarity, on the one hand, and space for autonomy, on the other. The result of more extensive use of the approach by different groups of designers might, in the future, lead to the conclusion that the type and level of guidance for different types of designers must be varied.

Wouter Kersten
Thematic Coordinator
Delft University of Technology, Faculty of Industrial Design Engineering
w.c.kersten@tudelft.nl

Jan Carel Diehl
Associate Professor Design for Sustainability
Delft University of Technology, Faculty of Industrial Design Engineering
j.c.diehl@tudelft.nl

Jo van Engelen
Chaired Professor Integrated Sustainable Solutions,
Delft University of Technology, Faculty of Industrial Design Engineering
Chaired Professor Business Development
University of Groningen, Faculty of Economics and Business Administration
j.m.l.vanengelen@tudelft.nl

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