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A Preliminary Instrument for Measuring Design Mindset

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# THE DESIGN MINDSET INVENTORY (D-MINDSET0): A PRELIMINARY INSTRUMENT FOR MEASURING DESIGN MINDSET

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## ABSTRACT

Mindset has been identified as an essential aspect of design and innovation, impacting both behaviours and performance. However, the concept of design mindset is elusive. Often design mindset is used indistinguishably from design behaviour, diminishing the complexity of the mechanisms and cognitive processes underlying design behaviour. As the initial step in researching these mechanisms, we operationalise the concept of design mindset and present the design mindset inventory (D-Mindset0) to measure it. The initial inventory centered around 16 agreement-to-value statements related to design practice. To analyse the inventory, we conducted an exploratory factor analysis based on 473 master students from different engineering disciplines participating in a course on innovation in engineering. The analysis revealed a four-factor structure with 11 final items. The four factors align with the concepts of 'conversation with the situation,' 'iteration,' 'co-evolution of problem-solution,' and 'imagination.'

**Keywords**: Design mindset, Design theory, Psychometrics, Research methodologies and methods, Design cognition

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## 1 INTRODUCTION

Mindset is one of the central pillars of innovation (Kahn, 2018), and since designing is a process of bringing about innovation (Weisberg, 2009), mindset is equally important to design. Furthermore, Andreasen (2003) and Daalhuizen et al. (2014) have established that mindset impacts design activities. Despite general agreement across the design field on what designers do to produce innovative solutions, the underlying mechanisms guiding them are not well understood (Cash, 2018). Theoretical constructs like solution-focus (Cross, 1990), human-centeredness (Dosi et al., 2018; Hassi and Laakso, 2011; Kahn, 2018; Schweitzer et al., 2016), abductive reasoning (Cross, 1990; Dorst, 2011; Dosi et al., 2018; Hassi and Laakso, 2011) and self-efficacy (Crismond and Adams, 2012; Dosi et al., 2018; Jobst et al., 2012; Kelley and Kelley, 2013), to name a few, are all said to be part of the mindset guiding design behaviour.

This paper presents the process of operationalising the design mindset phenomenon and developing the Design mindset inventory (D-Mindset0), an instrument for measuring it. Operationalisation of the phenomenon is the first step toward expanding our understanding of how these complex constructs are interconnected, their relation to other personal traits, and how they ultimately impact design behaviour and performance.

In the following, we first define design mindset and position the concept in the design literature. Second, we operationalise it based on attitudes toward design behaviours, building on the informed design teaching and learning matrix (Crismond and Adams, 2012) and constructing an inventory to measure design mindset. Third, we analyse and evaluate the design mindset inventory using a large sample of engineering students ($n$=473). And finally, we discuss the implications of our findings for our understanding of design mindset and future research.

## 2 DESIGN MINDSET

Mindset is the sum of the cognitive activities conducive to successful task performance (Gollwitzer, 2012). In general, mindset constitutes the beliefs and attitudes that determine how situations are interpreted and understood and influence actions. As such, mindset and behaviour are interconnected.

In a design context, mindsets influence, e.g., interpretation and understanding of the task, the context, and the design methodology used to guide the activity (Andreasen et al., 2015). A strong alignment of mindset and methods has been theorised to correlate with productive method use and design practice (Daalhuizen, 2014) and the effective implementation of design methodology (Andreasen, 2003; Andreasen et al., 2015). Based on this, we define design mindset as the beliefs and attitudes determining the interpretation and understanding of design situations and the choice of appropriate design strategies, e.i. the mindset that aligns with effective design practices. As the definition reveals, design mindsets are context- and method-dependent and, therefore, can vary across design professions and specialisations. Even different stages in a process can call for different mindsets (Gollwitzer, 2012). A specific method or approach might be appropriate in one context yet not in another, explaining the heterogeneity of beliefs, attitudes, and differences in how they are valued across the design field (e.g., the importance of human-centeredness). Even so, designers share some core behavioural patterns.

## 3 OPERATIONALISING DESIGN MINDSET

At the core of operationalisation is the inference of unobservable phenomena from observations and theory (Abell et al., 2009). As the directly observable aspect of design mindset, the best starting point for operationalising the phenomenon is design behaviour.

### 3.1 Mindset, not behaviour

The core assumption is that the mindset supporting effective design behaviours can be measured by gauging attitudes toward the behaviours of informed designers and their underlying design strategies. Several existing instruments for measuring design (thinking) mindset (e.g. Chesson, 2017; Dosi et al., 2018) focus on behaviours rather than the underlying beliefs and attitudes towards them. The ability to act a certain way does not necessarily relate to one's mindset. As Bandura (1997, p. 227) points out: "There is a major difference [...] between possessing knowledge and being capable of proficient action". In other words, one might have a highly developed design mindset without having embodied



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the knowledge and made it part of one's practice. In some cases, behaviours might even align with efficient design practice without being aligned with beliefs or attitudes, e.g., working iteratively but believing a linear process is superior. To avoid conflating behaviour and mindset, we opted for a format of agreement-to-value statements rather than behavioural self-assessments in formulating the items for the design mindset inventory.

## 3.2 Developing the inventory

To operationalise design mindset at a general level, we built on *The Informed Design Teaching & Learning Matrix* developed by Crismond and Adams (2012). In their work, they define nine design strategies representing core behavioural patterns displayed by so-called 'informed designers' in contrast to naïve designers. These contrasts provide the foundation for operationalising design mindset into attitudes towards specific design behaviours making up the inventory (see Table 1).
We recognise that the matrix does not include all aspects of design mindset. Crismond and Adams (2012) acknowledge that their matrix does not cover, e.g., the role of social interactions in designing. Also, we have excluded *Troubleshoot* due to an overlap with other strategies and little mention as a separate design capability in the design literature. However, the intention never was to make a comprehensive instrument but a lean one, covering core aspects of design mindset.

*Table 1. The design mindset inventory*

| **Design strategy** | **Items** |
|---|---|
| Understand the challenge | 1. It is important to challenge the problem statement before trying to solve the problem. |
| | 2. Problems should be well-defined and fully understood before attempting to develop a solution. (reversed) |
| Build knowledge | 3. To improve the future, you should not try to solve today's problems but imagine a new future. |
| | 4. You should spend more time building the solution than understanding the question. (reversed) |
| Generate Ideas | 5. It is more important to spend time generating many ideas than it is to refine a few. |
| | 6. As soon as you have a good idea, you should move from idea generation to idea refinement. (reversed) |
| Represent Ideas | 7. Representing ideas in non-verbal ways, e.g., using diagrams, sketches, prototypes, and dramatisation, is essential in understanding a problem. |
| | 8. Sharing ideas with others throughout the process makes them better. |
| Weigh options and make decisions | 9. It is important to look at a solution from different stakeholder perspectives. |
| | 10. Once you have a good idea, you should not waste time figuring out how it might fail. (reversed) |
| Conduct experiments | 11. A failed experiment can be as important as a successful one. |
| | 12. Spending time testing continuously is more important than testing the end result. |
| Revise or iterate | 13. Even late in the process, you should pivot and rethink a solution if learning something important. |
| | 14. If done right, you should not have to revisit past stages of the innovation process. (reversed) |
| Reflect on process | 15. Following a process is more important than adapting to the circumstances. (reversed) |
| | 16. Methods are more a guideline than rules you must follow. |

For each strategy in The Informed Design Teaching & Learning Matrix, we generated multiple items in the form of statements of belief. From this initial pool of items, we selected two for each strategy, intending to keep the inventory short. This choice means we might have missed nuances of the core


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construct, adding to the risk of construct underrepresentation (see Abell et al., 2009). In selecting items, the authors evaluated the items based on relevance, fit to the design strategies and the broader design theory, reformulating the items for readability and clarity of concept. To improve the instrument's sensitivity and reliability (Abell et al., 2009) and align it with the other Instruments used in our research, we designed our items to fit a universal 7-point Likert scale, ranging from *strongly disagree* (=1) to *strongly agree* (=7). The selected items were evaluated by academic design experts and representatives of the sample population (teaching assistants for the course) for disambiguation and to improve clarity. Table 1 contains the resulting items. The subsections below cover the reasoning behind each item in relation to the strategies identified by Crismond and Adams (2012).

#### 3.2.1 Understand the challenge

The strategy *Understand the challen*ge is rooted in the dichotomy of problem-solving and problem-framing (Crismond and Adams, 2012). When encountering a problem, a novice designer tends to approach it as if it were a well-defined problem, jumping straight to a solution (Crismond and Adams, 2012). More experienced designers start by exploring the framing of the problem, approaching even well-defined problems as if they were wicked (Cross, 2001). The intention of item 1 was to reveal tendencies toward approaching problems as if they were wicked by reframing the problem statement, while item 2 focuses on letting the problem and solution co-evolve.

#### *3.2.2 Build knowledge*

Where *Understand the challenge* focuses on experimental knowledge, *Build knowledge's* strategy is more about formal research. This strategy builds on the dichotomy of skipping vs doing research (Crismond and Adams, 2012). Skipping research, like the problem-solving approach described above, is related to approaching problems as well-defined and going straight for a solution. In solving a wicked problem or a problem as if it were wicked, more experienced designers rely on research to limit the inherent uncertainty associated with wicked problems. Research in the design process supports the developing understanding of the problem and opportunity space, acts as inspiration, and forms the basis for evaluating proposed solutions. Item 3 builds on the fact that design is about imagining and implementing future states (Findeli, 2001; Lawson, 2005) or what Evans et al. (2005) term hypothetical thinking. Item 4 aims to reveal preference towards doing research as part of the process.

#### *3.2.3 Generate ideas*

*Generate ideas* are centred on the dichotomy between idea scarcity and idea fluency. It is well-established that generating more ideas leads to better solutions. Like the strategies mentioned above, where novice designers jump straight to a solution, in this strategy, they attach to an early idea, neglecting to explore other opportunities or even adding to the chosen idea (Crismond and Adams, 2012). Fixation with an idea is not limited to novice designers. However, high idea fluency, in combination with research and the iterative co-evolution of problem and solution, reduces the risk of fixation. The underlying concept of this strategy is divergent thinking—going wide before going deep.
Item 5 goes right to the core of the idea scarcity and idea fluency dichotomy and the value of generating many ideas over refining a few. Item 6 explores the importance put on idea generation vs idea refinement and, indirectly, the willingness to suspend judgment until all ideas have been explored.

#### *3.2.4 Represent ideas*

In the strategy of *Represent ideas*, we move from the focus on breadth to depth; it is all about exploring and communicating details. Representing ideas in terms of visual and verbal media helps make thinking explicit, experiment with different ideas and solutions, explore new directions, and facilitations the precise communication of ideas. Besides, getting ideas out of the head helps reduce the cognitive strain of designing, allowing for a more complex understanding to develop. Items 7 and 8 are designed to uncover preferences for externalising ideas and letting others engage with them, respectively.

#### *3.2.5 Weigh options and make decisions*

Decisions are made throughout the design process. The strategy *Weigh options and make decisions* focuses on the underlying process of making these decisions. With neither domain-specific knowledge nor situation-relevant strategies, novice designers must rely on research to make appropriate decisions; research they tend to skip (see above). Crismond and Adams (2012) have identified a dichotomy



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between ignoring vs balancing benefits and trade-offs. Novice designers neglect to evaluate ideas and solutions against criteria and constraints and balance benefits and trade-offs. Item 9, focusing on stakeholder perspectives, aims to bring forth preferences toward evaluation ideas and solutions from multiple perspectives. Item 10 aims at preferences for dealing with both the positive and negative aspects of a proposed idea or solution.

#### 3.2.6 Conduct experiments

Conducting experiments is another way designers build knowledge. The effectiveness of the experiments distinguishes novice and informed designers (Crismond and Adams, 2012). Like *Weigh options and make decisions*, novice designers tend to ignore trade-offs, focusing on benefits when doing experiments (Crismond and Adams, 2012). They change several variables for each experiment, confounding the results and limiting the learning to whether a solution is better or worse than another. While Crismond and Adams (2012) focus on establishing a more rigorous testing practice, our questions aim to reveal attitudes towards experimenting. Item 11 probes the value of learning from failure, while item 12 focuses on the role of experiments in the design process.

#### 3.2.7 Revise and iterate

The strategy of *Revise and iterate* moves us to the process level of designing. The central claim of this strategy is that the design process is not linear but iterative. This relates to the difference between solving well-defined and wicked problems. Wicked problems present no obvious or definitive solutions. There are many ways to frame wicked problems, each providing myriads of opportunities and potentially appropriate solutions, forcing designers to adapt as their understanding of the problem and solution evolve. Item 13 aims at revealing a willingness to pivot and revise a solution even after investing many resources. Question 14 is aimed more at the strategy of working iteratively and revealing attitudes against working iteratively.

#### 3.2.8 Reflect on process

To be effective in an iterative process, designers continuously reflect on their processes and methods, adapting them to their circumstances. All of the design strategies are affected by this metacognitive process, informing good design behaviour. Since reflective practice is foundational for good design behaviour, we, in exploring this strategy, focused more directly on process management than reflective practice. Item 15 is about diverting from a process as circumstances change. Item 16 is similar but in terms of how rigorous you need to follow the instructions of a method. As designers become more experienced and reflect on their practice, they tend to be more willing to disregard the prescribed approach in response to the context.

## 4 EVALUATING THE INSTRUMENT

The inventory was implemented in a questionnaire administered as part of a master-level course on innovation at the Technical University of Denmark (DTU), using SoSci Survey (see Leiner, 2019). Participation in the study was voluntary. Out of the 586 students in the course, 473 completed the questionnaire (response rate: 81%). The collected data is the foundation for evaluating the design mindset inventory in this section.

### 4.1 Construct validity

With the foundation in design theory, represented by Crismond and Adams' (2012) matrix, and the positive feedback on the initial items when finetuning the items, we are confident that the items are relevant to and capture core tenants of design mindset. Supporting this assumption, the students with more design education scored higher overall in design mindset than students with less design experience. Comparing the average score across items for design and innovation students ($M$=5.56) and the rest of the sample ($M$=5.14; $t(471)$= 3.16, $p$=.0008), Cohen's $d$ (=0.830) qualifies as a large effect ($d$>0.8) according to Cohen (2013). The result indicates that our inventory measures design-specific properties as intended. However, without any data related to performance in a design process, we cannot definitively conclude that the measure correlates with effective design practice, i.e., design mindset.



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## 4.2 Factor analysis

We employed explorative factor analysis with an oblique rotation, using the Promax criterion, which allows factors to be correlated to reveal the factorial structure underlying the design mindset inventory (see Table 2). This analysis identified four underlying components of design mindset, recombining and clustering items from the different design strategies identified by Crismond and Adams (2012).

*Table 2. Exploratory factor analysis with items assigned to different factors and ordered with decreasing factor loads*

| Item | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Uniqueness |
|---|---|---|---|---|---|
| 8 | 0.9249 | | | | 0.3843 |
| 9 | 0.5482 | | | | 0.5496 |
| 7 | 0.4583 | | | | 0.7152 |
| 15 | | 0.6668 | | | 0.5466 |
| 6 | | 0.5848 | | | 0.7067 |
| 10 | | 0.5273 | | | 0.6821 |
| 14 | | 0.5112 | | | 0.7166 |
| 2 | | | -0.6420 | | 0.6643 |
| 1 | | | 0.4976 | | 0.7013 |
| 5 | | | | 0.5560 | 0.7041 |
| 3 | | | | 0.4589 | 0.8118 |
| 4 | | | | | 0.8174 |
| 11 | | | | | 0.8122 |
| 12 | | | | | 0.8668 |
| 13 | | | | | 0.6967 |
| 16 | | | | | 0.8910 |

Note. Oblique rotation was used with the Promax criterion.

Out of all the strategies, only *Understand the challenge* translated directly into an underlying factor (factor 3). Furthermore, except for the strategy *Represent ideas*, all paired items split into different underlying constructs (see Figure 1). The factor analysis also shows that items 4, 11, 12, 13 and 16 can be excluded from the inventory, leaving us with a final inventory of 11 items (see Figure 1).
In section 7, we follow up on the factor analysis by framing each factor in terms of theory, discussing the implications for our understanding of design mindset.

## 4.3 Reliability

To estimate the internal consistency of the inventory, we calculated Mcdonald's Omega. We calculated Mcdonald's Omega for the entire inventory and each factor. For the complete inventory of design mindset, McDonald's Omega ($\omega$) = 0.6884 [CI95% 0.64..0.73], which is at the lower end of the threshold for acceptable scales (>0.70) but typically qualifies as sufficient for initial research stages as it is the case here (Nunnally, 1978).

*Table 3. McDonald's Omega ($\omega$)*

| Factor | McDonald's Omega ($\omega$) |
|---|---|
| 1 | 0.6541 [CI95% 0.59..0.71] |
| 2 | 0.6464 [CI95% 0.57..0.70] |
| 3 | 0.4661 [CI95% 0.33..0.57] |
| 4 | 0.3895 [CI95% 0.27..0.50] |

Analysing the factors separately, we see similar results for Factors 1 and 2, while factors 3 and 4 show a lower internal consistency (see Table 3). Part of the explanation for the lower performance can be that item 2 does not perform as intended. It was designed to reveal tendencies toward learning by experimenting with solutions rather than only analysing the problem space. However, as the factor



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analysis shows, it negatively correlates with factor 3. We believe this is due to a poor formulation of the item, resulting in subjects agreeing that, *ideally*, the problem should be fully understood before trying to solve it; rather than the intended: the only way to understand a problem is by experimenting with solutions. This, however, should not diminish the relevance of the factor.
The results indicate that ecological validity can be improved by adding items that address each of the four underlying constructs more completely. However, it is worth noting that "…reliability is a characteristic of the test scores, not of the test itself" (Streiner, 2003, p. 101) and depends on the sample as well as the quality of the items. Further item analysis is required to determine whether the low consistency results from poor design of the inventory or the complexity of the underlying phenomenon of design mindset.

## 5 DISCUSSION

The factor analysis revealed an underlying structure of four factors and combined inventory items significantly different from the original theoretical basis in Crismond and Adams' (2012) matrix. That is, analysis of the items of each factor revealed an alignment with design behaviours on a higher level of abstraction than Crismond and Adams' (2012) strategies, pointing towards a complex interplay between design behaviours. This section recontextualises the items in terms of these new clusters and interprets them in terms of design theory.

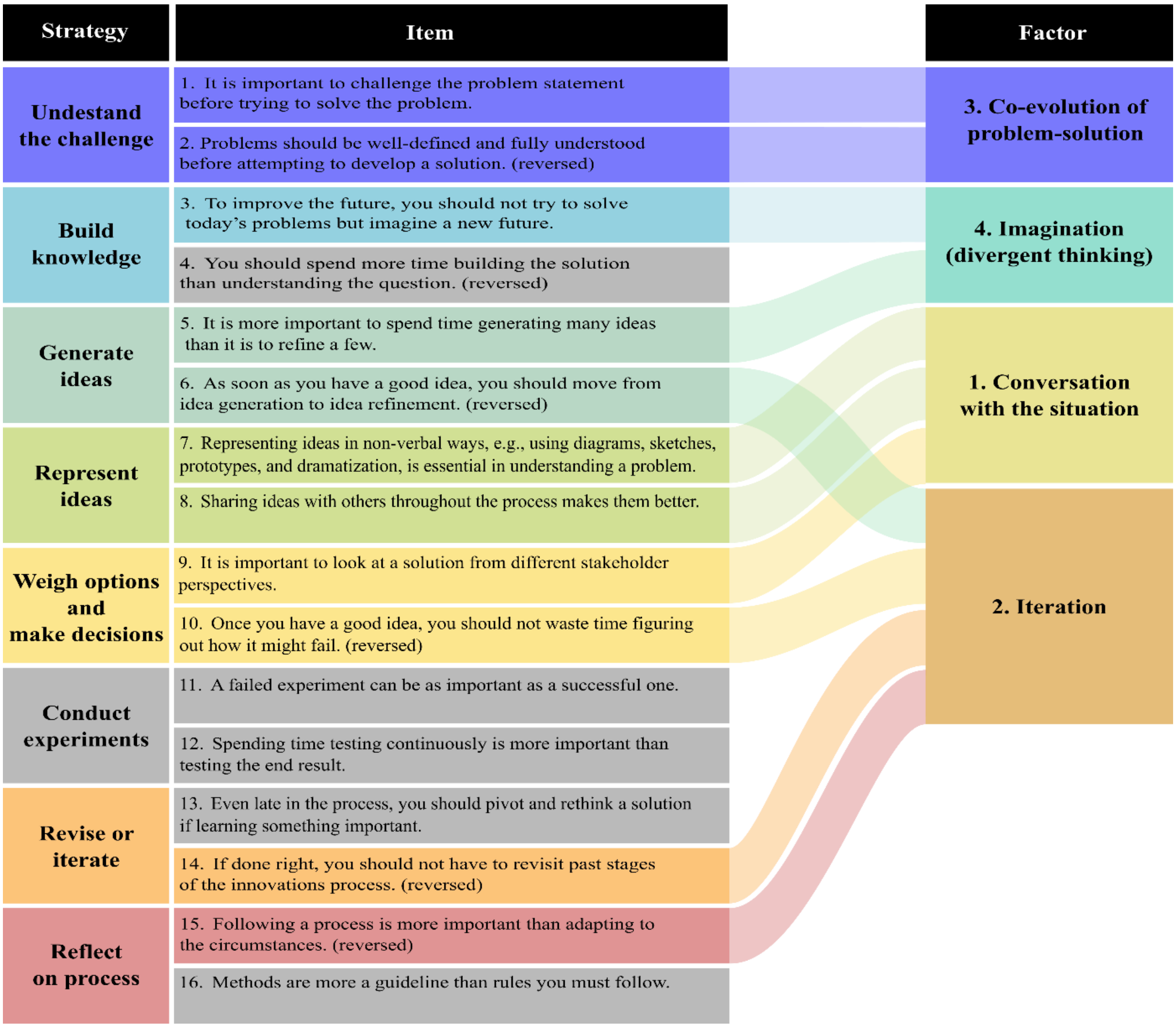

*Figure 1. Evolution of the design mindset inventory*

### 5.1 Factor 1: Conversation with the situation

Factor 1 consists of two items from the strategy *Represent ideas* and one from *Weigh options and make decisions* (see Figure 1). These items have a common denominator in being about representing



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and sharing ideas with the purpose of viewing them from different perspectives. We interpret this new combination of items as being about externalising ideas to see them in a new perspective, fostering a 'conversation with the situation' (Schön, 1983). This is in line with the view of design as a situated phenomenon (Daalhuizen, Jaap, 2014; Schön, 1983; Simon, 1996) in which the externalisation of ideas plays a central role (Cross, 2001; Dove et al., 2018; Schön, 1983). Moving ideas into the physical world means that others can interact with them; it makes assumptions explicit and facilitates communication. In interacting with the world, these manifestations reveal their intended and unintended consequences from a multitude of (stakeholder) perspectives, thus providing the designer feedback for evaluating their actions and understanding of the context (Schön, 1983). Together the three recombined items (see figure 1) indicate a willingness to engage with the situation, using representations to engage both team members and other stakeholders in a dialogue.

### 5.2 Factor 2: Iteration

Factor 2 combines strategies from *Generate ideas*, *Weigh options and make decisions*, *Revise or iterate* and *Reflect on process* (see Figure 1). Implicit in all four items is an element of attitude toward the process; should you follow the procedure, move on, keep iterating, or revisit earlier stages? These items have a common denominator in being about the importance of iteration throughout the design process to address wicked problems. To be effective, designers continuously reflect on their processes and methods, adapting to their circumstances. As shown in sections 5.1 and 5.3, there are learning opportunities throughout the design process. Working iteratively, revisiting earlier stages, and revising earlier decisions, is how designers implement learning. Overall, we interpret this cluster of items as allowing feedback loops at both the idea and process levels serving the co-evolutionary nature of designing (see Dorst and Cross, 2001).

### 5.3 Factor 3: Co-evolution of problem-solution

Factor 3 consists of items 1 and 2 of the inventory and matches the strategy: *Understand the challenges* (see Figure 1). The two items go beyond the mere understanding of a challenge and touch upon the co-evolution of problem-solution, which underlie the process of framing and reframing (Dorst and Cross, 2001). The co-evolution of the problem and solution space is central to design practice (Crilly, 2021; Dorst and Cross, 2001). Letting the understanding of the problem co-evolve with the solution enables the designer to suspend the decision on a solution (Crismond and Adams, 2012), learning through experimentation, reducing assumptions, and refining the understanding of the problem and what constitutes an appropriate solution (see Dorst, 2015; Dorst and Cross, 2001).

### 5.4 Factor 4: Imagination

Factor 4 combines item 3 from the strategies *Build knowledge* and item 5 from *Generate ideas* (see Figure 1). Of the four factors, this one leaves us with the weakest link to design theory. Besides, consisting of only two items, the precise nature of their relationship and role in the design mindset is unclear.

One possible framing, encapturing both hypothetical thinking (item 3) and generating ideas (item 5), is imagination. For example, *brainstorming* was originally framed as applied imagination (Osborn, 1963). Further, imagination highlights the creativity involved in hypothetical thinking. To go beyond the apparent or existing and into the realm of innovation, we need to be able to imagine new realities. Central to this is the transition from the concrete to the abstract, an ability related to the associative thinking so central for stimulating idea generation. Hypothetical thinking theory tells us, however, that the cognitive process of evaluating hypothetical possibilities is not optimised to find the best but rather a satisfactory path forward (Evans et al., 2005). Cash et al. (2019) relate this cognitive bias toward satisficing to fixation and getting stuck with one often local analogy, hindering imagination and divergent thinking. The combination of the two items could hint at designers ability to apply imagination productively. However, further research is needed to establish the viability of this interpretation.

These four underlying structures of design mindset provide us with a new perspective on the existing theory. The transition from Crismond and Adams' (2012) strategies into these factors (see Figure 1) highlights the interconnectedness of design behaviours. Furthermore, the instrument enables us to analyse these relationships quantitatively. Consequently, in line with guidelines for theory-building



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research (see Wacker, 1998), the alignment with existing theory strengthens the validity of the higher-level concepts of 'iteration,' 'conversation with the situation,' and 'co-evolution of problem-solution' as core design components. The connection identified between divergent (item 5) and hypothetical thinking (item 3) also shows how quantitative analysis, based on operationalised constructs, can reveal new relationships worth investigating.

## 6 FUTURE RESEARCH

The design mindset inventory (D-Mindset0) allows us to explore differences among designers, their preferences in approaches and methods, and the role of design mindset in developing design competencies. Going back to Cross (1990), concepts like ambiguity tolerance have been associated with design behaviours. However, our understanding of how such traits related to design influence attitudes and beliefs about appropriate design behaviours is limited. Going forward, we suggest exploring how concepts like ambiguity tolerance, willingness to take risks, and openness influence the core tenets of design mindset.

The design mindset inventory is only a first step towards understanding the complexity of design capabilities and how to measure them effectively. Further studies are necessary to establish the extent to which the instrument measures design mindset and to what degree this measure helps predict design behaviour and creative outputs in the longer term.

## 7 CONCLUSION

This paper reports on the operationalisation of a key construct in design: design mindset. It also reports on developing and testing the design mindset inventory (D-Mindset0). We have outlined the development process and argued for our initial assessment of its validity. The presented operationalisation of design mindset and the resulting instrument for measuring it provides a promising proof of concept for digging below the surface of design behaviours and investigating the underlying elements that inform them. *D-Mindset0* has the advantage of being short, and its format makes it easy to use in combination with other instruments measuring other aspects related to design mindset and behaviour.

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