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Rachael

Karlskrona, Autumn 2018

ABSTRACT

Starting to include sustainability considerations in a design project is a transition requiring a change in how things are done, that is, a change in behaviour. Furthermore, this transition takes place in the midst of the usual pressures of product design. Prior research on sustainable design has mostly explored the so-called technical side – identifying what tasks should be performed, such as specifics of including sustainability criteria when analysing product concepts. However, this has not been enough. These tasks are not being performed to the extent that they could, or that is needed. Recent studies have advocated the consideration of the human nature of the people who are to execute these 'technical' tasks. In other words, there is a need to work with the socio-psychological factors in order to help sustainable design beginners to adopt new mindsets and practice (their usual way of doing design).

My aim was therefore to *investigate how to support individual product design team members with the human aspects of transitioning to executing sustainable design*. In particular, I focused on supporting good individual decision-making and individual behaviour change. This aim was addressed through multiple research projects with four partner companies working with the early phases of product design. Given a focus to change practice, I followed an action research approach with a particular emphasis on theory building. This action research approach comprised two phases: understanding the challenge and context, and then iteratively developing solutions through a theorise–design-act-observe-reflect cycle.

Through the research projects, my colleagues and I found that there are challenges related to behaviour change and decision-making that are hindering execution of sustainable design. In order to help organisations to overcome or avoid these challenges, we found that it may be beneficial for those developing sustainable design tools

and methods to (i) use techniques to mitigate for cognitive illusions, (ii) provide individuals with the opportunity to implement sustainable design while helping those individuals to increase their motivation and capability to execute sustainable design, and (iii) communicate with these individuals in such a way as to avoid triggering psychological barriers (self-defence mechanisms). I combined these points into two models.

Together with the partner organisations, we applied the two models to design some actions that we then tested. The actions included integrating behaviour change and decision-making considerations into sustainable design tools as well as stand-alone interventions in the culture.

Given the findings of these studies, I urge developers of sustainable design tools to see implementation of their tool as a learning journey. The beginning of the journey should comprise small steps supported by handrails, which then increase in size and decrease in support as the journey continues. Especially in the beginning, tool developers will also need to help travellers to avoid the decision-making errors that occur due to being in unfamiliar territory.

Keywords

Human side of ecodesign; soft side of ecodesign; sustainable design; decision-making; behaviour change; sustainable product development.

DISPOSITION OF THE THESIS

This is an article-based thesis and comprises an overview and the following six appended papers.

PAPER A: ***A method for comparing concepts with respect to sustainability and other values.***
Gould, RK, Thompson, A.
In: Horvath I, Rusak Z, editors. Tools and methods of competitive engineering (TMCE); Budapest, Hungary: Delft University; 2014. p. 661-72.

PAPER B: ***Using social sustainability principles to analyse activities of the extraction lifecycle phase: Learnings from designing support for concept selection.***
Gould RK, Missimer M, Lagun Mesquita P.
Journal of Cleaner Production. 2017; 140: 267-76.

PAPER C: ***Sustainable product development and tricks on the mind: Formulating conceptual models of cognitive illusions and mitigating actions.***
Gould, RK, Svensson, M.
Submitted to journal.

PAPER D: ***Shrinking and scaffolding the steps: Supporting behaviour change towards implementing sustainable design.***
Gould, RK, Bratt, C, Svensson, M, Broman, GI.
Submitted to journal.

PAPER E: ***Integrating sustainable development and design-thinking-based product design.***
Gould, RK, Bratt, C, Lagun Mesquita, P, Broman, GI. The 10th International Symposium on Environmentally Conscious Design and Inverse Manufacturing (EcoDesign2017), Tainan, Taiwan: Springer; 2017.

PAPER F: ***Why choose one sustainable design strategy over another: A decision-support prototype.***
Gould, RK, Lagun Mesquita, P, Bratt, C, Broman, GI. The 21st International Conference on Engineering Design (ICED17); 21-21 Aug 2017; Vancouver, Canada. p. 111-120.

The papers have been reformatted to fit the format of this thesis. The content is unchanged from the published/submitted versions.

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Chapter 1

INTRODUCTION

> *Nothing is so painful to the human mind as a great and sudden change.*
>
> - *Mary Wollstonecroft Shelley*

Although you may not consider the above literary quote to always be true, perhaps you can relate to the sentiment. Perhaps you have tried to make changes in your life, such as eat healthier or exercise more. You might have found plenty of advice on how many times a week you should aim to exercise, but it was seemingly impossible to change your habits (behaviour). And when you were stressed, you ended up eating cake! In this thesis, I address how to help reduce the 'pain' of the change involved in starting to work with sustainable design. Through this I hope to contribute to an increase in the extent to which sustainable design is implemented. The thesis considers how to help sustainable design beginners with changing their behaviour (habits). The thesis also addresses how to help product developers to avoid 'eating cake', that is making poorer decisions due to the changing conditions that occur when starting to work with sustainable design.

For the purpose of this thesis, sustainable design[1] is product design that aids transition to a sustainable society. Implementing (starting to use) sustainable design is inherently a transition but so is executing sustainable design since it is ever-evolving, changing as society changes in its transition to a sustainable future. This transformation involved in sustainable production and consumption in particular is also recognised as fundamentally complex (1). Integrating sustainability and new product development[2] "complicates an already complex process" (2, p. 106) and is perceived by product developers as complex (3).

Complex in its nature, sustainability relates to social and ecological systems, and includes considering not only current global issues, but also potential future issues (4). Sustainability has therefore been named a 'wicked problem' requiring a change of the whole societal system (5). Society needs change not only in technology and economy, but also in human aspects related to culture and organisations (6). For example, there is a psychological dimension; individuals can experience unsustainability as distant, in time and in space (7).

Some authors argue that the slow progress in implementing sustainable design may be due to support developers' scarce consideration of socio-psychological aspects. Examples of these authors are Pigosso, Rozenfeld and McAloone (8), Brones, de Carvalho and Zancul (9), and Verhulst and Boks (10). One barrier to the uptake of sustainable design is that users experience many of the tools as complicated and time-consuming (11), and according to European ecodesign practitioners, overly complex (12). From a survey in Japan and South Korea in 2003, Boks (13) found that the main challenges were socio-psychological – the gap between proponents and executors, organisational complexities and unwillingness. Slow progress might also be due to inadequately

[1] Sustainable design is also known as ecodesign and sustainable product development.
[2] 'New product development' is the development of new products, in contrast to the improvement of existing products.

considering change processes and management (14). All of these challenges relate to the *human side* – the socio-psychological side – of sustainable design.

Early on, Post and Altman (15) pointed out that sociological, psychological, emotional factors are essential for successful implementation of sustainable design. And Cohen-Rosenthal (16) found that an effective implementation strategy must therefore include human commitment, skills and social organisation.

The identification of the importance of socio-psychological factors and the simultaneous relative lack of consideration of these factors have led to more research on the human side of sustainable design, sometimes called the 'soft side of ecodesign' (for example, 13). In 2006, Boks (13) concluded that previous publications did not provide enough insights into the role of socio-psychological factors in the context of ecodesign. In fact, even by 2015, half of the sustainability integration models studied by Brones and de Carvalho (14) did not include any consideration of how to help the designers through the change.

Given that socio-psychological challenges are hindering uptake and execution of sustainable design and yet there is little literature informing us how to address these challenges, I decide to focus my research on this so-called 'human side' of sustainable design. In the next chapter, I will give a background on research on this human side and introduce my specific focus and research aim.

Chapter 2

BACKGROUND ON THE HUMAN SIDE OF SUSTAINABLE DESIGN

2.1 PREVIOUS RESEARCH ON THE HUMAN SIDE OF SUSTAINABLE DESIGN

Research on the human side of sustainable design has started to converge on the following general principles: the transformative nature of the process, the need for a systemic and multi-level approach and the need to incorporate both organisational and individual dimensions (17). Ritzén and Beskow (18) studied the adoption of ecodesign practices. They found that there were issues related to individual behaviour, work procedure and competence development. Lofthouse (19) also found that a more holistic approach should be taken to developing ecodesign tools, an approach that considers requirements related to guidance and education. Schäpke et al. (5, 20) looked at sustainability transitions (not specifically sustainable design) from the perspectives of empowerment, second order learning and social capital. Through a review of the literature, they found that these three perspectives are interrelated and mutually supportive.

Verhulst et al. (3, 21) give four human factors in successful implementation of sustainable design: *behaviour change /transformation* (resistance to change towards sustainability), *communication* about changes, *empowerment* and involvement and

organisational *culture*. These were identified through change management literature and then by checking which factors were significant in a case study with Belgian sustainability-frontrunners. They found that communication channels were present, but it was difficult to understand the issues related to successful communication. They also found that empowerment was needed from the very beginning, but only for a subset of people. Based on the work of others, they define empowerment according to three dimensions: *authority* (power, decision-making and responsibility), *resources and specialisation* (information, knowledge and skills) and *self-determination* (initiative, creativity and autonomy) (22). They discovered that autonomy and a clear assignment of responsibility was necessary in the firms studied.

Pigosso et al.'s (8) ecodesign maturity model comprises sixty-two 'Ecodesign management practices'[3] categorized into twelve 'knowledge areas' (23). Two of the knowledge areas (categories of management practices) relate to the human side of implementing sustainable design, specifically (i) development of support processes and *ecodesign training*, and (ii) ecodesign *incentives*, *awareness* and *communication*. The practices were identified by a literature review and then checked by experts to see if they agreed. From the articles, it is unfortunately difficult to understand how often the practices came up in the literature, what they are based on (for example, empirical testing or derivation from robust theory) and therefore what their credibility is. Their inclusion at least gives some indication of what is considered (by at least some) to be important factors, as well as that the human side is important to consider when managing sustainable design.

[3] Pigosso et al. (8) define 'ecodesign practice' as "ecodesign activities aimed at integrating environmental issues in product development and related processes, whose application can be supported by techniques and tools" (p. 162-163). They refer also to the Project Management Institute's definition of a practice being an activity that employs tools or techniques to contribute to the execution of a process.

Brones and de Carvalho (14) built an ecodesign integration model based on fifty-two existing tools and models. This model highlighted the need to consider 'transversal integration'[4] of the soft side of sustainable design. They then, together with de Snezi Zancul (17), applied a transition management approach to sustainability integration, giving rise to their five P-pathways: Planet, Public, Programme, Pilot and People. These pathways involved planning and improving processes, as well as engaging people. When writing about engaging people, they did not specify details, although they did mention the tests that they did with their case company; they had held training courses, nudging workshops (see also (24)) and motivational training for gate-keepers, which gave limited results. In the article on their nudging experiment, Brones et al. (24) identify motivators through workshops with product developers self-selecting what motivates them.

In conclusion, the literature says that the human side is important, but little has been said on how to work with it. Although a young field with little empirical evidence, the following areas have been identified as relevant for investigation by the authors listed in this subsection: communication, empowerment and involvement, behaviour change, training, motivation, organisational culture, individual expectations, intuition and judgement, decision-making process, biases and power conflicts. This list contains overlapping and interconnected themes. In my research, I will start from the themes that are closer to ends-objectives than means-objectives. For example, empowerment is perhaps a means to achieve changes in behaviour and so I will begin from the theory on behaviour and behaviour change rather than on empowerment. Focusing on ends-objectives is about focusing on what really matters in the end while being open to how to achieve it (25), which is a critical component of creating a useful set of objectives (26). My foci are therefore:

[4] Transversal integration is integration in all levels of the business – strategic/macro, tactical/meso and operational/micro.

- decision-making (including bias, intuition and judgement)
- behaviour change (including consideration of motivation, communication and training)

2.2 DECISION-MAKING FOR SUSTAINABILITY

At the beginning of the transition to executing sustainable design, individuals lack experience. For inexperienced individuals, starting to include sustainability in product design makes the decision-making environment tricky. This challenging environment might trigger *cognitive illusions* (tricks on the mind) and thus decision-making errors that go undetected. Cognitive illusions lead to a perception, judgement or memory that *deviates* from 'reality'; this deviation is systematic (reliable and in a predictable direction), appears involuntarily and is hard to avoid (27). Many cognitive illusions can be seen as "the flipside of otherwise adaptive and prudent algorithms" (28, p. 111). These algorithms are referred to by some as *heuristics*, which are rules of thumb that may *bias* decision-making (29).

It is important to be knowledgeable about potential cognitive illusions when product developers integrate sustainability into their work since product lifecycle impacts are a major contributor to many of society's environmental and social challenges (30-32). The early phases of product development are a leverage point for integrating sustainability considerations since the early-phase decision-making influences the sustainability impacts of manufacturing and other lifecycle phases (33). Decisions in the early phases of the process also significantly impact development costs (34) and determine, to a large extent, the success of a product development project (35).

When making early-phase decisions, product developers know little about the design problem (36). The earliest decision-making is sometimes even referred to as the fuzzy front end (37). Knowing only a little can cause product developers to judge inaccurately and

evaluate incompletely (38). Furthermore, the novelty and complexity of sustainability results in tough decision-making (39), which can trigger inaction even when there is clear benefit from acting, such as failing to act on climate change (40-42).

To face the challenging decision-making environment described above, product developers need support because (i) it is very challenging for product developers themselves to be aware of cognitive illusions and (ii) forewarned does not equate to forearmed. One way in which our brain works, known as system 1, is automatic and we are unaware of its operations, and it can therefore send us off-track (43, 44). Often the picture that system 1 builds for us is true, but cognitive illusions is a well-examined exception. Due to the nature of this system, we rarely catch ourselves in the act of making errors, but rather simply accept the intuitive and effortless thinking. Providing support is also in line with behavioural strategy, which argues for behavioural informed decision processes rather than purely listing which cognitive illusions that decision-makers might be facing (45). (Behavioural strategy is a field that merges psychology with strategic management with the aim to bring realistic assumptions about human cognition, emotions, and behaviour to the management of organisations (46).)

I therefore consider it imperative to understand what decision-making challenges – cognitive illusions – individual product developers confront when bringing sustainability into early-phase (concept development) decision-making and how to support them in mitigating the illusions. I have not found literature specifically on cognitive illusions and mitigating actions related to sustainable design decision-making. However, Arvai et al. (39) have done a systematic review of the literature on decision-making as relevant for sustainability (generally, not specific to sustainable design). They found several approaches for supporting good (less biased /unbiased) decision-making for sustainability, which I have used to develop support relevant for sustainable design beginners.

The approaches identified by Arvai et al. (39) fell into two categories – active and passive decision support. Active decision-support breaks down a complicated decision into manageable parts and uses particular techniques to mitigate for cognitive illusions. This type of support explicitly addresses consequences and trade-offs (39). It also provides a structured process for including subjective values and objectives that are not easily defined or quantified (39). Emphasizing values and value-trade-offs helps decision-makers to navigate the complexity of the decision-making context and focus on the sustainability considerations that matter for the given project (26, 47), with empirical evidence from risk communication (47). Passive decision-support takes advantage of known biases in decision-making to make the 'right' decision easier (39). Examples include setting goals, 'nudging' (see (24, 48)), giving feedback and designing defaults (24, 39). My colleagues and I called on both types of approach when developing support.

2.3 BEHAVIOUR CHANGE TO SUSTAINABLE DESIGN

Implementing sustainable design demands product design project teams to change their habits and shift to regularly applying new tools, methods and approaches (49-51) and a change of mindset (52). In other words, the team members need to change their design behaviour. Although the sustainable design research described in Section 2.1 argues for the importance of considering behaviour change in designers, there is very little research on how to do it.

Work on 'Design for sustainable behaviour' has addressed a related topic. That body of work addresses how the design of a product can influence users' behaviour to be 'more sustainable', often in the sense of reducing frequency or impact of unsustainable behaviours (53). Design for sustainable *user* behaviour approaches are often mapped along a spectrum from user-in-control to product-in-control and, depending on the user's attitude, these can result in positive or negative behaviour change (54). There are many sub-strategies for influencing user behaviour (55). Much of that work has focused on electricity consumption and the domestic context

(53). My research was not concerned with how individuals interact with inanimate objects such as fridges and showers; my research focused on how designers can be supported to adjust their design practices[5]. The 'users' in my research are users of design processes and practices, not regular users of physical artefacts. The work on designing for sustainable user behaviour is also based on a wide range of theoretical grounds. Much of it rarely considers the individual in a social context and often considers attitudes, beliefs and needs as fixed (56). There is, in general, a limited consideration of the extensive bodies of knowledge on psychology and sociology (54), perhaps because it is regarded by some as a "comprehensive and rather unmanageable range of literature" (57, p. 108). I therefore propose to not start from the literature on design for sustainable behaviour, but rather to start from the literature on behaviour change and associated areas of sociology and psychology, while seeking inspiration from the theoretical grounds for design for sustainable behaviour where that ground is stated and is relevant to my research.

2.4 RESEARCH AIM

In the introduction, I introduced that socio-psychological challenges are hindering uptake and execution of sustainable design and that there is little literature informing us how to address these challenges. Early in the background section (Section 2.1), I shared literature that emphasised that considering the human side is important but found little literature on how to work with it. My research aim was therefore:

> *to investigate how to support individual product design team members with the human aspects of transitioning to executing sustainable design*

[5] Definition of a practice: "something that is usually or regularly done, often as a habit, tradition, or custom" (Cambridge English Dictionary).

Based on the areas for investigation suggested by literature on the human side of sustainable design (Section 2.1), I chose to focus on (i) decision-making and (ii) behaviour change. And I therefore scoped my research to supporting:

- good[6] individual decision-making
- individual behaviour change

This aim was addressed through multiple research projects that are described in this thesis, with each project having its own specific research question(s). The overall research design used in these projects is described in the following chapter.

[6] By 'good decision-making', I mean less biased decision-making.

Chapter 3

RESEARCH DESIGN: ACTION RESEARCH WITH THEORY BUILDING

There are several essential choice moments in qualitative research. I will address each of the following essential choice moments stated by Savin-Baden and Howell Major (58): Philosophical stance, Who or what of study, Research approach, Data collection, handling and interpretation, and Quality.

3.1 KNOWING HOW TO CHANGE PRACTICE – A PHILOSOPHICAL STANCE

As justified in the introduction and background sections, the research aim is grounded in a desire to improve how things are usually done, that is to enhance practice. And enhancing practice is in line with the purpose of sustainability science to be solutions-orientated (59, 60). To develop tangible solutions, we need to focus on knowing *how to* do sustainable development, to focus on learning *how to practically* make change happen (61).

Enhancements to how things are done cannot be achieved by academic researchers alone. It is the research participants (for example, product developers) whose practices are being investigated and so their reality (mental construction) is part of the

reality that the research must engage with. Seeking to understand individuals, and reality as an individual's mental construction, is representative of research that takes a constructivist stance (58). Taking a constructivist stance, to understand how to enhance individuals' practice (that is, change their reality), we need to engage with these individuals through *collaborative* research.

3.2 STUDYING INDIVIDUAL BEHAVIOUR CHANGE & DECISION-MAKING – THE WHO AND WHAT

The studied phenomena were individual behaviour change and the conditions that trigger, or mitigate for, cognitive illusions when implementing sustainable design. The individuals of interest were members of product design project teams for whom it is new to execute sustainable design (sustainable design beginners). The project teams of study were those working with needfinding and/or concept development (early phases of product development).

3.3 ACTION RESEARCH WITH THEORY BUILDING – RESEARCH APPROACH

3.3.1 Justification for choosing action research

The nature of my research aim is one of investigating *how to practically* make change happen, which matches well to an action research approach since action research aims to improve a situation through cycles of inquiry through action. Action-orientated, reflexive, interdisciplinary research is critical when doing research in support of transformation towards a sustainable society (62).

Although there is no one agreed definition of action research (58, ch. 16), Reason and Bradbury's (63) position of working collaboratively to bring together action and reflection, theory and practice, to solve relevant practical problems seems appropriate for sustainable design research and is compatible with my philosophical stance. Given that the unit of analysis (the who and what) of the study concerns product developers' practices,

Kemmis's (64) focus on acting in order to transform people's practices is also relevant.

Diving into specific contexts, as done in action research, is particularly useful for problem-solving due to the flexible and responsive nature of working with cases (58). Real cases also enable in-depth and thorough evaluation and understanding of a situation (58, 65). The depth of understanding can also be enhanced through increased level of collaboration with case study participants.

Where possible, my colleagues and I tried to shift the research projects towards the type of action research that is *participative* knowledge construction, in order to achieve the benefits of collaborative research. This combines action research with collaborative methods for constructing knowledge together with those immediately affected (participatory research). In the action research literature, this combination is known as participatory action research (66), pragmatic action research (67) or pragmatic orientated action research (68). The people who are immediately affected are knowing subjects, participants, rather than objects of the research (66-68) and the participants and academic researchers have a 'reciprocal collaboration' (insider-outsider teams) with equitable power relations (69).

3.3.2 Action research cycle

The particular action research cycle that I have used is shown in Figure 1. The later research projects, particularly with the fourth company, were designed using this cycle. When my colleagues and I designed the earlier projects, we did not have this particular cycle in mind. And the work in these projects was less collaborative than the work with the fourth company. However, all the projects were solutions-orientated and involved using theory to design actions relevant to the context. The early projects can therefore also be approximately mapped to the cycle shown in the figure.

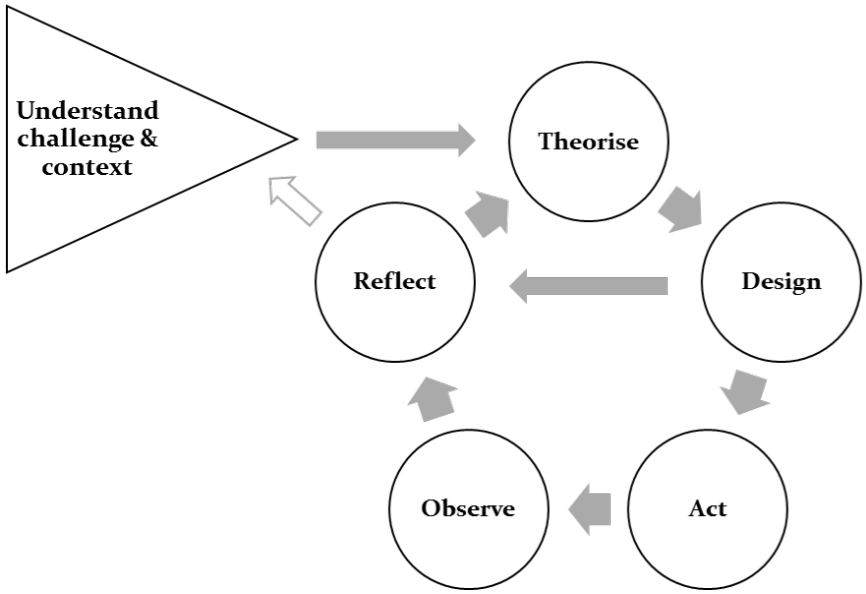

Figure 1 – My research can be framed as action research cycle comprising two phases, where the second phase involves iterating between 5 steps.

There were two overlapping phases of research that the research projects can be mapped to. The initial phase is illustrated by the triangle in the top-left of the figure. In the second phase, my colleagues and I iteratively planned and (to a limited extent) tested actions that the various organisations can take to tackle the identified challenges. Despite the lack of common definition, there is a common theme for action research - that of inquiring through "thinking, acting, data gathering and reflection" (58, p. 245). Together with my colleagues, I chose a cycle is based on Kemmis et al.'s (70) plan-act-observe-reflect spiral. I have divided up the plan step into 'theorise' and 'design', thus giving a 5-step cycle shown in the figure.

In the following subsections, I outline each of the steps of the two phases and then, in Section 3.3.4, I add how data was collected from and with the partner company participants.

Phase 1 – understanding the challenge & context

The aim of the initial phase was to increase collective understanding of relevant academic fields and of the practices in the context of the partner organisations. This included seeking to understand what is hindering individuals from changing their behaviour to execute sustainable design, what they need to change in behaviour and what is hindering them from making good decisions when implementing sustainable design. An important aspect of this phase was also building relationships between academic researchers and participants.

See Chapter 4 and Section 5.1 for the results from this phase.

Phase 2 – designing & testing

Theorise: My colleagues and I found a lack of existing theories that we could apply directly in the context of sustainable design implementation. We therefore employed existing literature (from related fields) to theorise – to formulate and express a conceptual system. According to Jaccard and Jacoby (71), a conceptual system is concepts placed in relationship with each other to facilitate understanding. With each iteration, we increased our understanding of the challenge and the potential solution space and so we modified or added to our conceptual system (our model).

Since we needed to formulate much of the conceptual system ourselves, our research design therefore became action research with more theory building than is probably usual for action research. The implications of this are that further empirical testing is needed, but that our proposals are rooted more in theory than they may otherwise have been, potentially increasing usefulness across contexts.

See Section 5.2 and Papers C-D for a description of the models resulting from the latest iteration of this step.

Design: In the design step, we applied the conceptual system to design actions that could be taken in each of the particular action research projects. This step involved generating ideas and then selecting some ideas, a design process. See Section 5.2 and Papers D-E (and to a lesser extent Papers A-B) for examples of the ideas that were generated and selected.

Act and observe: We then undertook some selected actions that organisations could potentially employ to support individuals with behaviour change and decision-making and gathered data on how it went.

Reflect: Using the evidence that we collected that is related to undertaking the actions, in conjunction with our experience from designing the actions, we reflected on and updated our understanding of the challenge and the potential solution space. Reflection was performed individually, and through discussions between academic researchers and between academic and practitioner researchers.

Balancing between theorising & prototyping

When seeking the learning from completing an entire loop, I had to strike a balance between how comprehensively I completed each step and how many iterations I could complete. In other words, I had to balance between the time spent in a single iteration of each step in Figure 1 versus the number of iterations. There were a number of factors influencing this, including the companies' and wider projects' needs. It is indeed common that the extent to which a research team completes each of the steps of their (design) research depends on the purpose of the research and the time constraints (72, p. 18-19).

Due to the complexity of sustainable development, research in this area should be iterative attempts to achieve the change (61), otherwise known as a prototyping. In line with a prototyping approach (73), we attempted to iterate several times between designing and testing in order to learn quickly and early, and then

to incorporate these learnings in the next design task. However, we also tried to achieve a balance with the theorising step. As already mentioned, we could not find readily applicable theory that addressed the research aim and it was therefore necessary to make the 'theorise step' more explicit than is sometimes required for action research.

3.4 RESEARCH METHODS & PARTNER COMPANIES

3.4.1 Four partner companies working with the early phases of product design

The individuals and their decision-making and working contexts were studied in four partner companies. The companies (or divisions of the company) design products and sell business-to-business. Our research projects worked with the parts of the companies that deal with early phases of product design, namely needfinding and/or concept development. The companies were also all just beginning, or wishing to begin, to work with sustainable design. Combined with their willingness to participate in the research projects, the above arguments justify that these four companies were relevant choices in the pursuit of the research aim.

Table 1 shows how the partner companies differ.

The partner companies provided empirical input for the *understanding* phase and context for *designing* and *acting*, as described in more detail in the following subsection.

Table 1 - The four partner companies varied in terms of design process, industry and size.

Partner company	Type of design process	Industry	Number of employees	Participants
I	Engineering design with some add-on-service design	Road construction	~300	1 main person responsible for add-on services. 3 additional people from product development & process development.
II	Systems engineering	Aerospace engine systems	~2000 (in the division)	6 people in Research & Technology Development
III	Stage-gate 'idea-to-launch'	Lighting solutions	~300	8 key contacts (over the course of the project) from product development and project management. And approximately 8 additional product developers.
IV	Design-thinking-based design process	Design consultancy	~250	55-120 people. Majority work with product design. Some sales & business development and other support functions involved.

3.4.2 Data collection methods

The multiple iterations that we completed with the various partner companies are illustrated in Figure 2. The description here is a simplification to aid communication of what was an iterative and alive process, complicated with the messiness of reality.

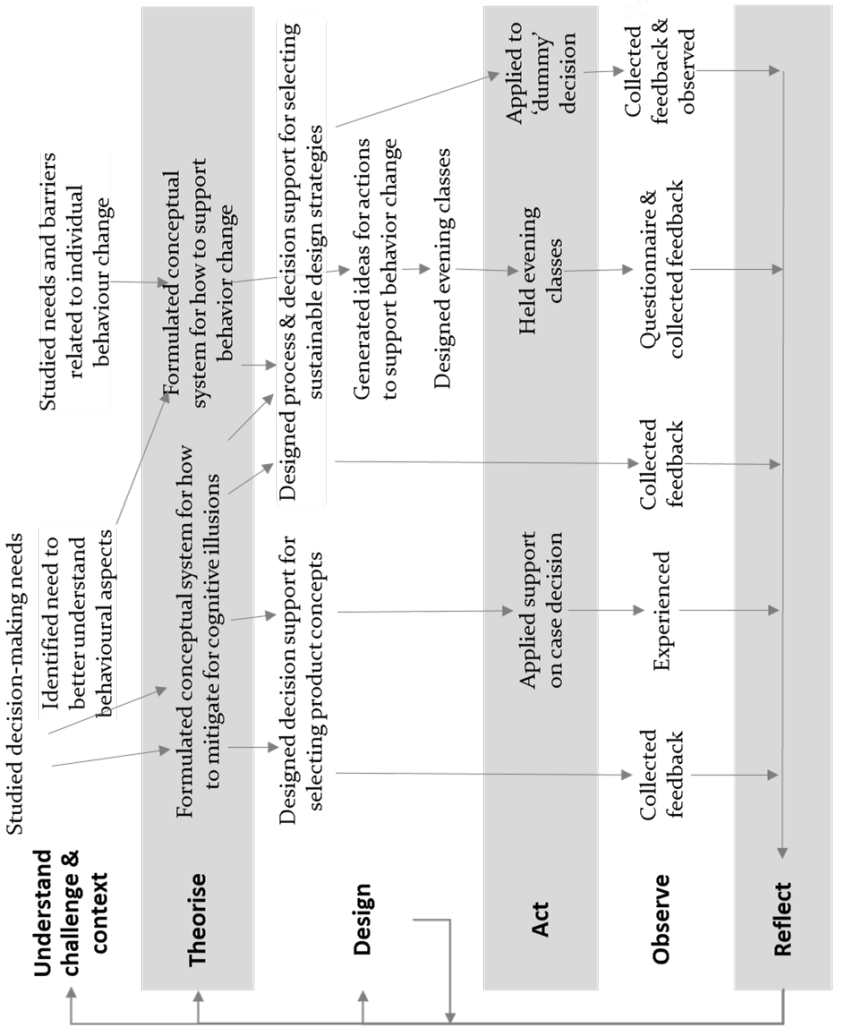

Figure 2 - I have performed multiple iterations of the action research cycle across various partner companies, with most emphasis on the understand phase and the theorise and design steps.

In companies I and II, my colleagues and I studied the decision-making needs (*understand*) of product developers when integrating sustainability considerations into concept selection. In company II, this research was co-designed with some company participants. This work led to the identification of the need to address the research aim of this thesis. In particular, my Paper B co-authors and I identified the need to better understand the behavioural aspects, namely how to take a learningful approach, of starting out on the journey that is sustainable design execution.

After formulating (*theorising*) the first versions of our conceptual system for how to mitigate for cognitive illusions, we used these first versions to *design* actions for companies I to III.

With companies I and III, there was limited collaboration around designing actions, but we did receive feedback on the designed actions. The main company I participant used the developed 'action' (decision support) to facilitate dialogue in a meeting with their customers and other stakeholders. In company II, we tried out the developed decision support (*acted*), with us researchers playing the role of product design team members and obtained feedback form company participants. All of these provided inputs into the *observe* step.

For company IV, we sought to *understand* needs and barriers related to individual behaviour change towards executing sustainable design. This was achieved through a number of activities, some of which were collaborative, such as a joint workshop on understanding the context and challenges and co-design of a survey. We then *theorised* (formulated a conceptual system for how to support behaviour change) and subsequently *designed* related actions for this case. This design step was highly collaborative with all actions being designed in joint meetings and in a joint design workshop. We also used our previously formulated conceptual system to *design* actions related to achieving good decision-making (in a design strategy selection decision). To a limited extent, we also *observed* how it went to *act* with one of the designed actions.

See the appended papers for more details of the participants, data collection, handling and analysis methods.

3.5 RESPECT, BENEFICENCE & JUSTICE - ETHICAL CONSIDERATIONS

Action research is based on three shared values (74):

- participation in democratic processes
- improvement of human life
- engagement in morally committed action

I incorporate these three values with the following three ethical principles for research with human participants from the Belmont Report (75):

- respect for persons via, for example, informed consent
- beneficence via assessment of risks and benefits
- justice via, for example, fair selection of candidates

3.5.1 Respect for persons and democracy

Key principles of action research are that democracy is a pre-requisite and that a safe space where participants can be open and show dissent needs to be developed (66, 67). This is also a means of respecting the people involved. Each company has agreed to take part in the research and has, in fact, been involved in goal-setting and the design of the research. Although building trust can take time, I believe that we have been fairly successful in creating this space and a power-equality between academic and practice-based knowledge, especially in the later projects. For example, participants shared many ideas, gave open feedback of both a positive and a negative nature and even disclosed emotions. Company representatives also spoke up when they felt that the academic researcher's needs were diverging from their own.

3.5.2 Beneficence and improvement of human life

Beneficence refers to not doing harm and to maximising possible benefits while minimising possible harms (75). This is done by

assessing the potential benefits and risks, both for the benefactors of the research and for the research participants. In our action research, the benefactors are the companies that participate (as well as hopefully other companies) and the participants are employees of the same companies. Our overall aim is to improve practice such that the company benefits in the long run. Of course, we then needed to consider what risks the individual human participants might face in the course of the research. The research involved asking them to participate in tasks that are in line with the types of task that they normally perform – no extreme activities.

Many of the participants said that they benefited from participation, mostly through learning more about sustainable design. For example, all 31 respondents to a post-evening-class questionnaire answered 'yes' to the question: 'After this evening's class, do you now understand more about sustainable design and how you can work with it?' Furthermore, many cited the key messages from the class when asked what was the most valuable thing that they had learnt.

3.5.3 Justice and morally committed action

Justice relates to the fair inclusion and exclusion of participants and the protection of people who may not have the capacity to give informed consent. In our research, answering of questionnaires, interviews, requests for feedback and surveys was done voluntarily. Participation in workshops was voluntary as far as we could see – although it is hard to know for sure if participants had been encouraged or pressured by their bosses to participate. In addition, we gathered data from adults who were, to the best of our understanding, non-vulnerable.

Data was handled and stored anonymously as much as possible.

It is also important to consider the balance of power in terms of ownership and control of the results. We have shared the results of our research with participants in easily accessible formats, including a written guide for how to work with sustainable design in the

product development projects and presentations. All of that material is free for the participating companies to use as they wish. This will hopefully also increase utility/benefits of the research for the companies and individual employees.

The notion of justice also takes on a wider meaning in action research where researchers are seeking social justice and promoting action (74), such as in pursuit of and for sustainable development.

3.6 ITERATIVE AND MULTI-SOURCED – QUALITY OF THE RESEARCH DESIGN

The research captured in this thesis was not designed as a coherent whole from the beginning. Rather, the research has evolved with time, determined by what was found in the early projects and by the needs of specific projects in which I was involved.

Greenwood and Levin (67) define *credibility* as "the arguments and processes necessary for having someone trust research results" (p. 67). *Internal credibility* is when the group generating the knowledge trusts it and *external credibility* is when it is trusted by outsiders (67). Greenwood and Levin emphasise that internal credibility is especially important in action research and external credibility is difficult to measure since this type of research involves generating data and knowledge in specific contexts. They suggest ways to 'test' for credibility: workability, making sense and trans-contextual credibility. The design of my research addresses the first to a larger extent, the second to some extent and the third to a lesser extent. We constructed conceptual systems through argumentation based on literature, and our testing sought to investigate the adequacy of our suggestion according to how well it works in the local context (known as workability (67)). By working with multiple companies, I can start to consider potential transcontextual credibility.

Expanding on the 'making sense' dimension, and in line with Jaccard and Jacoby (71), we consider the primary evaluative criteria of a good model or theory to be its *utility*. In our case, it is utility for

organisations and researchers who are seeking to support individual decision-making and behaviour change towards implementing sustainable design. Additional quality criteria for a theory are that it is *consistent* internally and in agreement with existing knowledge (76). When formulating our conceptual systems, we strove to achieve exactly this by using existing knowledge and combining it in a coherent manner.

Many of the methods that I have used in the various projects are not especially participatory, for example, interviews and surveys. Indeed, the extent to which the research has been collaborative has varied. With company I my work was in between consultation and cooperation, with companies II and III my work was cooperation and with company IV my work was colearning as mapped onto Cornwall's (77 cited in 69) modes of participation:

- Consultation: Local opinion asked, outsiders analyse and decide agenda.
- Cooperation: Local people and outsiders work together to determine priorities. Outsiders drive process.
- Colearning: Local people and outsiders share knowledge to create new understanding and work together to form action plans, with outsider facilitation.

However, the interviews and surveys were research techniques that were familiar to the participants and therefore served both as a knowledge building step (for all involved) and for constructing the safe space and trust necessary for the later use of more participatory methods, such as co-design workshops. In fact, action research is not a matter of standardizing methods, but rather choosing methods appropriate to the participants (66).

Chapter 4

FINDINGS FROM APPENDED PAPERS

In this chapter, I summarise the findings that are included in the appended papers, paper by paper. Papers A and B cover the early parts of my work with the individual human side of sustainable design. In fact, the projects in these papers did not have the same aim as this thesis, but rather helped me to understand the need for the research described in the rest of this thesis. Papers C and D provide the core theoretical part of my thesis. They cover the building of the theoretical grounding of the work, as well as some empirical testing and initial recommendations. Papers E and F cover some of the early thoughts of the theoretical grounding, more empirical testing and some initial recommendations.

Figure 3 illustrates how the papers map onto the research design described in Sections 3.3-3.4. The papers are not presented wholly sequential. Much of the work was developed over time and some of it was reported in parallel. I have ordered the papers by a combination of theme and date to aid the reader's understanding.

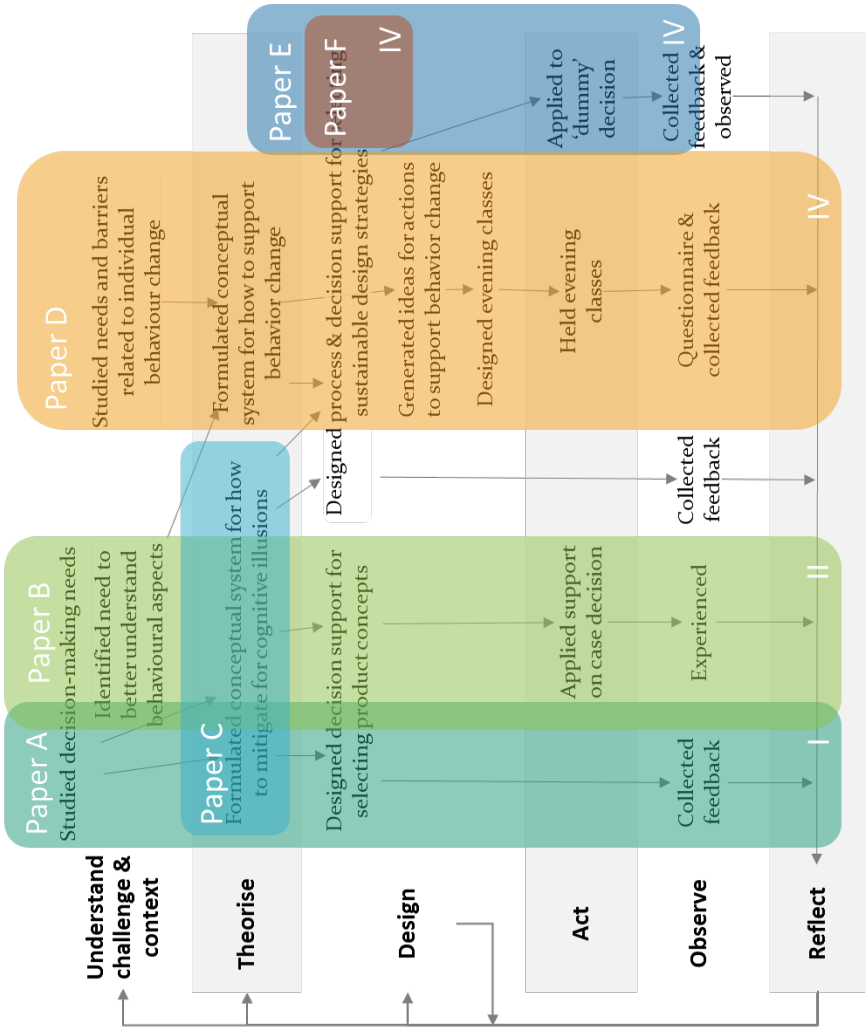

Figure 3 – The dissertation comprises six papers that cover various steps of the research design and involve three of the four partner companies (I, II & IV).

4.1 PAPER A

Gould RK, Thompson A. A method for comparing concepts with respect to sustainability and other values. In: Horvath I, Rusak Z, editors. Tools and methods of competitive engineering (TMCE); Budapest, Hungary: Delft University; 2014. p. 661-72. (78)

Paper A describes a method that my colleague and I developed to compare road construction concepts with respect to sustainability and other values. The method provides this support by asking decision-makers to:

- compare alternative concepts
- develop indicators that are both
    - based on what actors value, and
    - relate the differences between the alternatives to what the actors value

  (that is, indicators of relative value of the concepts)

The method was used in the case to support a decision between alternative road construction concepts. The resulting decision support took the form of an MS Excel file.

The relationship of Paper A to the thesis is mostly that we identified the need to consider how to support good decision-making, specifically how to avoid negatively effecting decision-making quality when supporting product design teams to integrate sustainability considerations in product design. Paper A also covers how we applied an early version of the model for mitigating cognitive illusions to develop decision support.

My contribution to Paper A was as principal investigator, of course with general support from my colleagues. Anthony Thompson helped to prepare the manuscript for publication.

4.2 PAPER B

Gould RK, Missimer M, Lagun Mesquita P. Using social sustainability principles to analyse activities of the extraction lifecycle phase: Learnings from designing support for concept selection. Journal of Cleaner Production. 2017; 140: 267-76. (79)

Paper B describes what we learnt from attempting to create a method and tool for analysing product lifecycles with respect to social sustainability, using existing indicators. We found that that the approach may make it possible for product developers to analyse extraction activities, but the level of accuracy of analysis that is possible is not good enough for comparing the concepts in the case study decision. We proposed further research to investigate (i) how the approach could be made useful for supporting other decision-making, including providing cross-functional support; and (ii) how the approach could be developed or re-designed to be learningful for the product developers by raising awareness of potential contributions to unsustainability.

The relationship of Paper B to the thesis is mostly in the identification that it is important to consider the learning that is needed and that can potentially be supported by purposefully designing learningful support. The research also tested using a value-focused and comparative approach.

The research covered by Paper B was an equal team effort throughout all phases. I led the preparation of the manuscript, but it was a team effort to develop it into the final version.

4.3 PAPER C

Gould, R. K., & Svensson, M. Sustainable product development and tricks on the mind: Formulating conceptual models of cognitive illusions and mitigating actions. Submitted to journal. (80)

Paper C describes a model of cognitive illusions that can hinder product developers when they are starting out working with sustainable design. This model is based on the decision-making tasks that product developers undertake when they are developing concepts and the conditions that they experience when integrating sustainability considerations into this decision-making. From decision-making literature, we identified the following cognitive illusions as occurring when undertaking those tasks under those conditions: *availability*, *anchoring* and *confirmation bias* when generating ideas; *illusory correlation* and *validity effect* when selecting between ideas; *evaluability bias* and *status quo bias* when gate reviewing. Based on the model, we synthesised literature on how to mitigate for the identified illusions and organised this synthesis into a model according to when (during which task type) a product developer should perform the mitigating actions. These mitigating actions vary according to task type and focus on the *quality of the decision-making process* (that is, how decisions are made, including exploiting analysis and reaching a decision, in contrast to focusing on the quantity and detail of analysis).

Paper C covers the development of models generated in the understanding phase and in the theorising step. It also details the results (the models) that are summarised in Sections 5.1.1 and 5.2.1.

I led the documentation and the drafting of the Paper C manuscript. The further development of the manuscript was a team effort.

4.4 PAPER D

Gould RK, Bratt C, Svensson M, Broman GI. Shrinking and scaffolding: Supporting individual behaviour change towards implementing sustainable product design. Submitted to journal. (81)

Paper D describes the construction of the second model presented in this thesis – a model of how to support individual behaviour change towards executing sustainable design. Firstly, we identified some barriers to behaviour change; these barriers were related to motivation, capability and opportunity to apply sustainable design. Secondly, to investigate how to address the barriers and support individual behaviour change, we integrated concepts on behaviour change, motivation, learning for sustainability and climate communication to form a model. In this paper, we also describe the action research where we used the model to generate ideas for action and then started to test some of the actions.

We learnt that it is important to not just define what 'technical' tasks project teams should ideally perform, but to also scaffold the journey as a series of simpler steps. Shrinking the 'technical' tasks into meaningful steps that are within reach helps individuals to feel confident and competent, which in turn leads to increased intrinsic motivation and behaviour change. Progressively achieving small steps aligned with their values reduces the risk of dissonance and denial, and therefore increases the potential for action.

My contribution to Paper D was to lead the theory construction and the drafting of the manuscript. I was active also in the empirical research, together with the second author.

4.5 PAPER E

Gould RK, Bratt C, Lagun Mesquita P, Broman GI. Integrating sustainable development and design-thinking-based product design. 10th International Symposium on Environmentally Conscious Design and Inverse Manufacturing (EcoDesign2017); Tainan, Taiwan: Springer; 2017. (82)

Paper E describes research to integrate sustainable development thinking and design-thinking-based product design in an action research project. It describes the application of (earlier versions of) the models presented in Chapter 5 of this thesis in the development of an integrated sustainable design process. We learnt that it is better to integrate sustainability considerations with the process used for generating and choosing between ideas, rather than merely adding 'sustainability' as an additional need. We also found that sustainability considerations should be integrated into the process such that teams are facilitated to work with sustainable design in a way that is relevant to their particular project (industry, market, customer needs). This can also support stronger competence development in the project team.

My contribution to Paper E was as one of the main people involved in the research activities. I also prepared the first version of the manuscript.

This paper was one of four papers awarded a best paper award, out of 129 papers presented at the conference.

4.6 PAPER F

Gould RK, Lagun Mesquita P, Bratt C, Broman GI. Why choose one sustainable design strategy over another: A decision-support prototype. The 21st International Conference on Engineering Design (ICED17); 21-21 Aug 2017; Vancouver, Canada 2017. p. 111-20. (83)

Paper F is closely related to Paper E. It describes a decision-support prototype that we developed for product design teams to use to compare between sustainable design strategies, which is a step that they could do according to Paper E. Sustainable design strategies provide tangible ways for integrating sustainability considerations into early phase product design work. Examples include design for remanufacturing and design for the base of the pyramid. There are many such strategies and it is difficult to choose between them. Sustainable product design activities also need to be tailored to business priorities. We therefore designed a decision-support prototype to aid project teams to choose strategies based on relevance to the project in terms of both near-term business value and sustainability value. The prototype described in Paper F enabled us to test ways to integrate the selection of sustainable design strategies into the early phases of product design, as described in Paper E.

Paper F includes the application of part of the models presented in this thesis, particularly those related to supporting good decision-making.

My contribution to Paper F was as one of three researchers who performed the study. I also prepared the first draft of the manuscript.

Chapter 5

DISCUSSION OF THE MAIN FINDINGS

In this chapter, I will summarise and discuss the main findings. I will also provide a further discussion of the quality aspects of the research and ideas for future work.

The findings summarised here were derived from cognitive illusions research (84-87), the COM-B model of the individual behaviour system (see, for example, 88), research on how to mitigate for cognitive illusions and achieve less-biased decision-making (89-91), self-determination theory (for example, 92), theories on second-order and social learning (for example, 93), the individual dimension of organisational learning (for example, 94) and strategies for communicating sustainable development (based on 7, 95).

I summarise the results step-by-step, as per the steps shown in Figure 1, namely:

- understanding of the challenge
- models for supporting individuals
- actions designed using the models
- observations and reflections

5.1 UNDERSTANDING OF THE CHALLENGE

In this section, I summarise individuals' challenges in transitioning to executing sustainable design.

5.1.1 Cognitive illusions

Through the study described in Paper C, we found that product developers might be hindered by the cognitive illusions shown in Figure 4 when they are starting to integrate sustainability considerations in the concept development decision-making. The illusions shown in the central column occur under the conditions shown in the left column and for the types of decision-making shown at the far left. Example implications are given on the right.

An example argument for inclusion of a cognitive illusion is as follows: V*alidity effect* occurs when decision-makers are more familiar with some information than other information being used to inform a decision; product developers who are just starting to work with sustainable design are relatively unfamiliar with sustainability aspects compared to other aspects and so validity effect was included in our model.

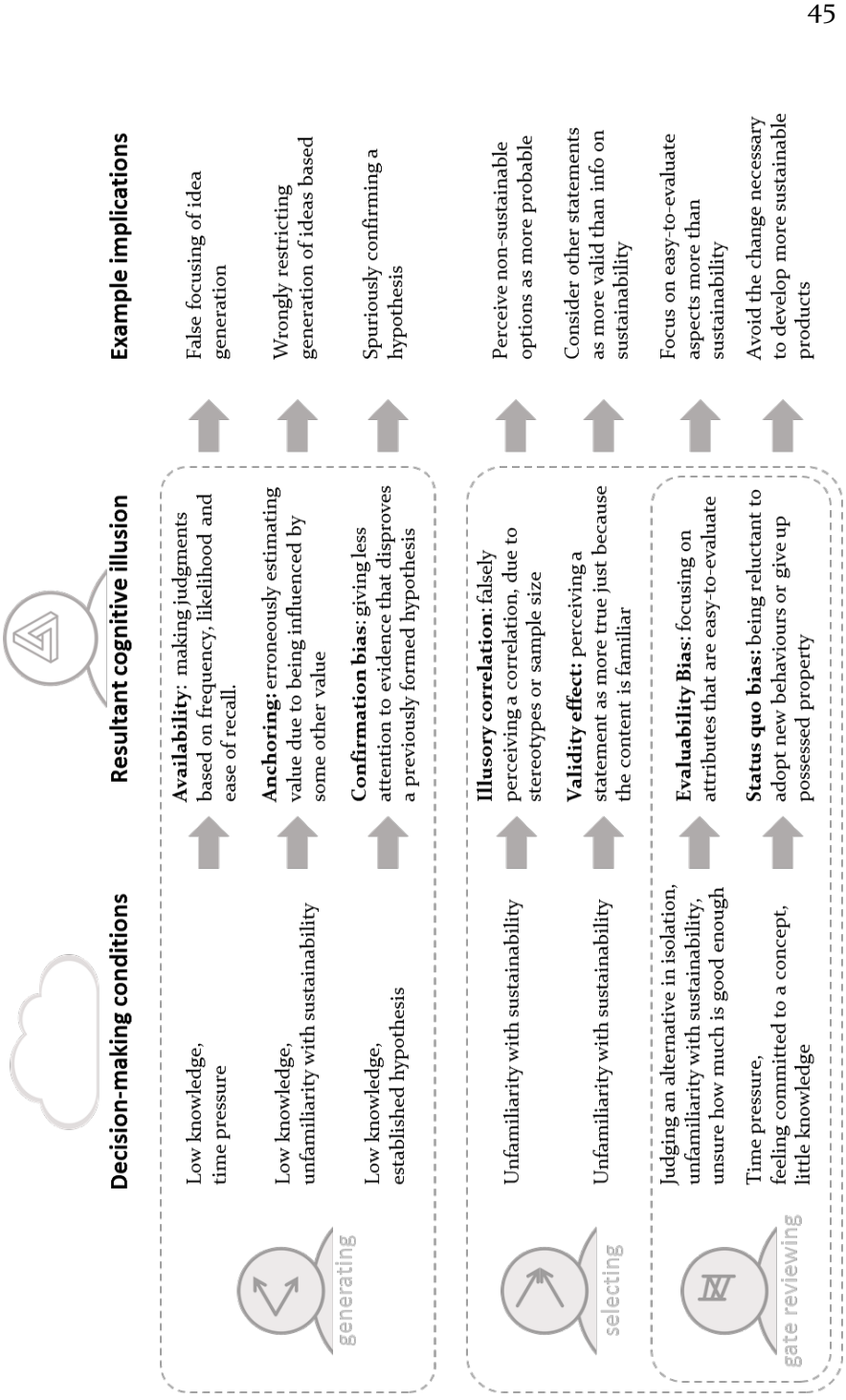

Figure 4 - Cognitive illusions for the three types of concept development decision-making with the conditions that lead to them and example implications.

5.1.2 Barriers to behavioural change

From the literature, we found that there are several barriers to individual behaviour change towards executing sustainable design. And our empirical work showed that at least some of them were present in our partner organisations. An example of such a barrier is lack of awareness of the benefits of sustainable design. When organisations are seeking to support individual behaviour change towards implementing sustainable design, the challenge is to seek to avoid or counteract the barriers by (Paper D):

- helping individuals to increase their motivation to implement sustainable design
- helping individuals to develop the capability to implement sustainable design, including by increasing capability in such a way as to increase motivation
- providing individuals with the opportunity to implement sustainable design, including by providing opportunity to increase motivation
- avoiding triggering psychological barriers while communicating with the individuals

5.2 MODELS FOR SUPPORTING INDIVIDUALS

In this section, I introduce the models that were constructed during the *theorise* step of our research. These models were constructed to help support designers to address the above challenges and needs.

5.2.1 Countering cognitive illusions

Behavioural strategy can be used to understand how design of decision-making processes and conditions can be used to mitigate for cognitive illusions. The goal is not zero risk or maximum sustainability performance, but rather conscious choices about risk, innovation, agility and other desired outcomes (45).

In line with Lovallo and Sibony (90), in the work described in Paper C, we selected practices and tools that are appropriate for mitigating for the identified illusions (Figure 4). Even if we cannot

say that every product developer will be thwarted by each of the illusions, we urge taking a precautionary approach in order to help product developers to achieve good decision-making when they are setting out on their journey to work with sustainable design. Even if we know which cognitive illusions we are facing, knowing which illusions you might face is not enough (45). Forewarned is not forearmed and decision-makers therefore need support for mitigating the cognitive illusions (91). For sustainability related decisions, using decision support techniques to mitigate for illusions can lead to changes in preferences and even the stabilising of preferences (which is a mark of good decision-making) (96).

The following subsections highlight what support developers can do to help product developers to counter the identified cognitive illusions. It will vary how the following mitigating actions are integrated into sustainable design processes and practice (as indeed these processes and practices vary). Support developers should therefore integrate these mitigating actions into the support.

Support needs to vary with activity (Dia)

The model in Section 5.1.1 shows that product developers may face different cognitive illusions for different types of concept development activities. They therefore may need different types of support for integrating sustainability considerations in the different types of decision-making activity. For supporting decision-making for sustainability (in general), Arvai et al. (39) mapped decision support techniques (from the literature) into two distinct groups depending on the type of decision being supported. We therefore rejected one-size-fits-all solutions and highlighted the need for the support to vary according to decision-making activity being undertaken.

Mitigation measures might take place in a previous step (Dib)

In addition to needing different support to mitigate for different cognitive illusions, support may need to encourage a mitigating action in the activity that precedes the one where the illusion

occurs. For example, to mitigate the effects of confirmation bias (that might occur during selecting), product developers need meaningful alternatives to select between. In other words, the support should encourage mitigating action (generating meaningful alternatives) during the preceding idea generating step. Similarly, how information is selected influences the extent of anchoring and availability while generating ideas. In Figure 5, I therefore present the mitigating measures according to the activity during which they need to be taken.

Mitigating measures for countering cognitive illusions

Figure 5 lists mitigating measures that can be used to support individual members of product development teams to reduce/avoid the bias in their decisions. See Paper D for more details.

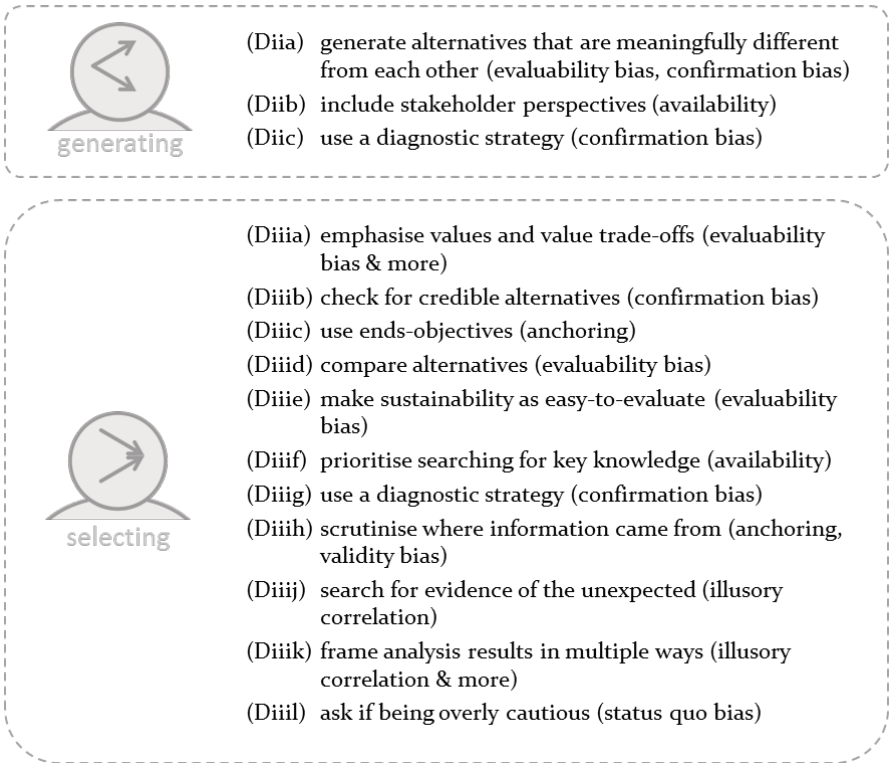

Figure 5 - Mitigating for cognitive illusions when integrating sustainability considerations into concept development.

5.2.2 Beating behavioural barriers

To meet the needs listed in Section 5.1.2, organisations can support individual behaviour change towards implementing sustainable design by (Paper D):

(O) providing individuals with the opportunity to implement sustainable design;

(M) helping individuals to increase their motivation to implement sustainable design by supporting individuals to:

- (Mi) feel competent and confident in implementing sustainable design;
- (Mii) experience self-determination in relation to implementing sustainable design, through:
  - (Miia) helping the individuals to feel free to experiment and initiate their own sustainable design behaviours and not feel pressured and coerced to behave as directed; or
  - (Miib) providing the opportunity for individuals to understand alignment between their work/behaviours with that which is important to them in life; or
  - (Miic) providing the opportunity for individuals to personally identify the importance of their work /behaviours; and
- (Miii) feel respect and belonging with both supervisors and peers in relation to sustainable design; and

(C) helping individuals to increase their capability to implement sustainable design by providing opportunities to for individuals to:

(Ciiia) increase embrained knowledge[7] through formal education and training of individuals;
(Ciiib) increase embodied knowledge[8] through practical experience and interactive problem-solving in a relevant context; and
(Ciiic) nurture the interaction of tacit and explicit knowledge through iterations between Ciiia and Ciiib.

This learning should then ideally occur:

(Cia) in participatory settings;
(Cib) with a trustful atmosphere;
(Cic) through intensive, open dialogue between participants as well as reflecting on your own position;
(Ciia) through surprises;
(Ciib) through being exposed to outside views; and
(Ciic) in safe spaces.

(S) Using generalisations of the following climate communication strategies will help engage the individuals in action rather than triggering psychological barriers:

(Si) Social: Use the power of social networks.
(Sii) Supportive: Find deep framings that are positive and support action.
(Siii) Simple: Make it easy and convenient to act in a climate-friendly manner.
(Siv) Story: Use the power of storytelling.
(Sv) Signals: Use indicators and metrics that monitor progress on green growth and jobs.

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[7] Embrained knowledge is formal, abstract or theoretical knowledge that depends on the individual's conceptual and cognitive abilities. It is explicit by nature. (94)
[8] Embodied knowledge is context-specific bodily knowledge developed through practical experience. It is tacit by nature. (94)

One synthesis of some of the above is that it is important to *shrink and scaffold the tasks* that we give to individuals (Paper D). To scaffold somebody's learning means to break it up into readily achievable chunks and provide temporary support to help the learner progress (97, 98).

5.3 ACTIONS DESIGNED USING THE MODELS

In this section, I summarise the actions that were designed using the above two models. The letter in brackets indicates the component of the above models being applied.

5.3.1 Integrating sustainable development and concept selection

In the work with company I, we developed a method for analysing ways of constructing roads (Paper A). When developing this method, we applied some measures for mitigating for cognitive illusions, but only a little since the work to develop the model in Figure 5 was in the early stages of development. The method supports decision-makers to (Paper A):

- *compare alternatives* (Diiid)
- develop *indicators* that are both based on what actors *value* and relate the differences between the alternatives to what the actors value (Diiia)
- incorporate global society as an actor who values *sustainable* development

We also applied the method to a case decision and developed decision-support in an MS Excel file. We created multiple views of the results within this file, with the intention of helping the uses to adopt a variety of frames (Diiik).

In the work with company II, we prototyped a method for analysing product concepts with respect to social sustainability (Paper B). Again, we used the knowledge on mitigating measures that was available in the early days of the work on cognitive illusions. In

particular, we were attempting to make social sustainability as easy to evaluate as other factors (Diiie) and we designed our analysis as a comparison and displayed relative performance (Diiia).

5.3.2 Integrating sustainable development and the strategy and ideas parts of new product development

In the work with companies III and IV, we developed and compared two approaches to integrate sustainability considerations - using an early (but later than the above) version of the described models. The selected approach involved supporting product development teams to choose sustainable design strategies to work with during their upcoming project (Papers D and E). A very high-level overview of the suggested sustainability enhancements is shown in Figure 6. This figure shows the integration with a design-thinking-based process, from company IV. At a high-level, the integration was principally the same for company III.

Figure 6 - Overview of sustainability enhancements (blue text) to a design-thinking-based product design process (Paper E).

The suggestion is value-focused (Diiia) but differs from the method used with company I since here product design teams are supported to compare potential value of various sustainable design strategies

for their project, rather than adding 'sustainability' as a function that is valued by society. As is evident from Figure 6, the suggestions do vary with type of decision-making activity (selection / ideation) (Dia). The suggested enhancements encourage the project teams themselves to learn tacit knowledge by taking practical step-by-step action (Ciiib). The suggestions also provide positive framing (Sii) by taking an opportunity-based perspective of sustainable design (Paper E).

5.3.3 Additional human-side actions

With company IV, we also explored how to focus on the human side in other ways, beyond integrating it in the description of the 'technical' process. We had an ideation session together with representatives from the company where we used the model for supporting behaviour change to generate ideas (Paper D). 108 ideas were captured in the workshop. Here are some illustrative examples:

- "'Design for sustainable behaviour' competition between offices. For example, to design fun waste sorting." (Mii, Miii, Cia, Ciic, Ciiib, Si, Siii)
- "The management talk about why sustainability is important to them on a personal level" (Miib, Miii, Sii)
- "[The company] must create 'champions' that other employees can learn from and be inspired by" (Cia, Si)
- "Instagram drive: #sustainability inspiration that I've seen" (C, Si)
- "Gallery: why sustainability is important for me" (Miib, Sii)
- "Path choice - individual chooses [for] themselves how to increase their competence" (C, Miia)

One idea for an action that had come up earlier than this ideation workshop was to hold evening classes on sustainable design for company employees. We designed the evening classes to address many of the points from Section 5.2.2 (beating behavioural barriers), for example, points related to increasing self-efficacy. See Paper D for details.

5.4 CREDIBILITY REFLECTIONS

In the following subsections, I consider Greenwood and Levin's (67) three dimensions of *credibility* of action research: workability, argumentation (making sense) and transcontextual credibility.

5.4.1 Workability of the actions

Workability is an evaluation criterium for action research where academics and research participants collectively judge how well the implementation works to solve the problem in the local context or whether revision of the model or redesign of the actions is needed (67). Since workability is considered relative to a local context, I consider the contexts one at a time.

In the work with companies I and II, we found that comparing alternatives (Diiid) and presenting relative performance based on a consideration of values and value trade-offs (Diiia) was appreciated by decision-makers even though, in one case, we had to persuade them to take that approach and not perform an absolute analysis on a concept in isolation. This gives an indication of workability in those contexts.

Responses to the post-evening-class questionnaire in company IV indicate that the actions may have increased feelings of competence and confidence to do sustainable design (Mi), understanding of alignment of own tasks with the overall goal (Miib) and increased competence (C), including some expression of being surprised by elements that they learnt (Ciia) (Paper D). The survey showed increased perceived importance of sustainable design and raised confidence to start executing sustainable design (Paper D). These results indicate potential workability of evening classes and the other actions applied in this context.

5.4.2 Utility of the models

Expanding on the Greenwood and Levin's argumentation dimension, and in line with Jaccard and Jacoby (71), we consider the primary evaluative criteria of a good model or theory to be its *utility*. In our case, it is utility for organisations and researchers who

are seeking to support individual decision-making and behaviour change towards implementing sustainable design.

Using the models worked well, particularly in the ideation workshop with company IV and in the development of the process presented in Paper E. Ideas have been generated against all of the model components (from Section 5.2), although we left the communication strategies (S) mainly to further work. Our reflection, and that of practitioner participants, was that the models helped us to think beyond what we would have otherwise considered and helped us to generate ideas for concrete actions.

The thinking around shrinking and scaffolding the tasks was readily accepted by participants of the ideation workshop (Paper D). They related to their own feelings of not being competent enough to get started. They left the workshop determined to put some small and meaningful first stepping stones in place.

5.4.3 Transcontextual credibility

Action research results need to be examined and understood in terms of determining factors in the given context; they cannot be generalised through abstraction (67). In this subsection, I therefore discuss the potential transcontextual credibility of the results in terms of trying to understand factors that may have led to success. Since this thesis describes ongoing work, only a few actions have been designed and even fewer tested.

The two models presented in Section 5.2 were generated using theory about human beings in the context of being beginners when it comes to working with sustainable design. The models were not developed specifically for the partner companies and should therefore be applicable to a range of companies where the project teams are composed of sustainable design beginners.

Company IV's embracement of the behaviour change model and the concept of 'shrinking and scaffolding' may have been accelerated by their own understanding of the human behaviour. When they are

performing design-thinking projects, they consider the needs of potential product users and try to uncover hidden needs – they are familiar with working around or with the 'irrational side' of humans. Perhaps it was therefore easier for them to consider ways of supporting individual behaviour change beyond pure informing, which might not be the case for product design project teams who work with other types of design and engineering.

We tested taking a value-focused and comparative approach in all companies, albeit with limited testing. The feedback was positive in all cases. In addition, in the work with company I, we learnt that it worked somewhat to sustainable development as a value in its own right. However, in that case, there was a public procurer involved who must consider sustainability. We learnt with companies III and IV that it is probably better to identify the ways of working with sustainability that deliver win-wins, that is, that deliver benefits that are valued both by society and the project team. Companies III and IV were both very positive about focusing on values and value trade-offs by supporting teams to select sustainable design strategies based on what is valued by the project team (so called customisable design) (see Paper E). Their positive responses may have been due to their internal cultures and proactive attitude to sustainable design and could also be related to their particular design processes. The customisable sustainable design approach needs to be tested in other contexts to determine the success factors.

5.4.4 Comparison with other studies

Decision-making

We did not find any studies that address the same research aim. There is, of course, the literature on decision-making for sustainability by Arvai et al. (39), which we used when building our model. However, we found no model for which cognitive illusions may hinder product developers when starting to include sustainability considerations in concept development, or how to mitigate for these illusions.

Liedtka (99) has published a perspective piece on design thinking and reducing cognitive bias. It is difficult to compare the studies since the perspective piece does not include a description of how the biases were selected. She identified nine cognitive illusions related to product development, two of which are the same as ours. It would be interesting to know if Liedtka (99) identified the biases by considering which ones would likely be mitigated through design-thinking. This would give insight into whether integrating sustainability considerations into design-thinking is an especially promising approach to sustainable design.

While we were executing our study, Sibony et al. (45) published a piece on which illusions may be present in investment decisions (such as gate decisions), resource allocation decisions and blue sky processes. It is unclear just how they selected the particular cognitive illusions that they list. Through identifying the outcome variable for each of the three types of decision and considering the behavioural tendency of decision-makers in relation to that variable, they then identified ways ('levers') to reduce that tendency. Parallels can be drawn between our suggestions and their suggestions, for example, between their 'participation' lever and our suggestion to include stakeholder perspectives. However, a thorough comparison is not possible since their suggestions are on a more general level than ours.

Behaviour change

Despite there being several papers arguing for the importance of working with behaviour change for sustainable design, there is little on how to do it that we can compare our models with. Pigosso et al. (8, 100) provide a comprehensive list of example practices but not a synthesising model. Similarly, Brones et al. (17, 24) also give example actions.

Our findings that autonomy/self-determination and competency are important components match that found by Verhulst et al. (3, 10, 22). They also found that appointing sustainable design champions was viewed as a successful way to spread responsibility

by participants in some of their cases. Partner company IV in our research also listed this as a potential practice during the ideation workshop.

5.5 CONTRIBUTION

My contribution includes an increased understanding of the challenge of supporting individual product design team members to transition to executing sustainable design. Specifically, I contribute with a model of which cognitive illusions these individuals might face when starting to work with sustainable design and an understanding of the barriers to behaviour change in this situation. My contribution also includes a model for how to counter or mitigate for the identified cognitive illusions and how to beat the behavioural barriers to support individual product design team members with the human aspects of transitioning to executing sustainable design. The models presented in this thesis contribute to the filling of a gap in including the human side when developing support for sustainable design.

Given the findings of the projects included in this thesis, I urge developers of sustainable design tools to see implementation of their tool as a learning journey. The beginning of the journey should comprise small steps supported by handrails, which then increase in size and decrease in support as the journey continues. Especially in the beginning, tool developers will also need to help travellers to avoid the decision-making errors that occur due to being in unfamiliar territory.

5.6 FUTURE WORK

Given the above reflections and lack of similar studies, it is important to continue with testing and developing the findings presented in this thesis. In particular, we have not yet worked much with the integration of communication aspects (S) in the presentation of the integrated sustainable design process. When choosing which actions to test, we could use Osbaldiston and

Schott's work (101) on which interventions are likely to be particularly effective.

One very important consequence of taking a behavioural approach is the need to measure the outcomes and be prepared to adjust (45). Future work should therefore include long-term measurement of those tendencies that we wish to generate or avoid, such as the tendency to have too narrow a focus for ideation and for that focus to not include sustainability considerations.

Another interesting question has arisen: Are the actions suggested in Chapter 5 more easily integrated into some firms than others, depending on, for example, their culture and their design processes? For example, might it be easier to generate alternatives that are meaningfully different from each other (Diia) and include stakeholder perspectives (Diib) in a dessign-thinking consultancy that is used to valuing these perspectives than in a business-to-business systems engineering company that develops sub-components? What are the consequences of this? What should be done about it?

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