Faculty of Design Sciences
Department of Product Development

Product-service system design

a synthesis approach

Product-dienst systeem ontwerp

een synthesebenadering

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List of abbreviations

AI	artificial intelligence
CSE	creative support environment(s)
CSI	creativity support index
CST	creativity support tool(s)
DIR	design inclusive research
FEI	front-end of innovation
GD	goods-dominant
GPRC	guaranteed peer reviewed content
HCD	human centered design
IoT	internet of things
IPO	integral product development
NPD	new products development
NSD	new service development
PAR	participatory action research
PC	pairwise comparison | priority count
PhD	doctor of philosophy
PSS	product-service system(s)
RC	research cycle
RIDC	research in design context
RWE	results worth effort
SA	statement agreement
SD	service-dominant
SDT	service design tool(s)
SME	small and medium-sized enterprise(s)
UI	user interface
UX	user experience
WoS	Web of Science

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CHAPTER 1

Design Research | Research Design

1.1 Introduction and positioning

On a daily basis, public and private organizations worldwide are challenged by technological changes such as the Internet of Things, AI, robotics, big data, Industry 4.0, etc., leading to the notion of an interconnected world and smart production systems (Lu, 2017; Metallo et al., 2018). In addition, an awareness on social issues, environmental consequences and wellbeing in general push user expectancy levels toward new standards. As such, organizations need to systematically rethink their businesses (Kiel, Arnold, & Voigt, 2017).

Still, innovations often result from a technology push, i.e., new technologies applied in market propositions. Correspondingly marketing has also gained importance and many company portfolios are frequently driven by market demands and branding considerations (Paslauski, Ayala, Tortorella, & Frank, 2016; Verganti, 2009). Unfortunately, this is the main reason why, to date, the designer has been assimilating a rather goods-dominant view (formulated by marketing and technology departments) on the design of single products or services (Figure 1.1). Yet, the wicked problems that companies face in their daily challenges (e.g., internet of things, industry 4.0, big data, social and ecological awareness, wellbeing in general and higher user expectancy levels), require a much broader view and seem to be forcing them to *explore* new paths to innovation that are more design-driven (Van Erp, 2011; Verganti, 2009). **Product-service systems** (PSS) provide that opportunity, creating innovative interactions between consumers, the products and services they use and the providers offering the system (Costa, Patrício, Morelli, & Magee, 2018).

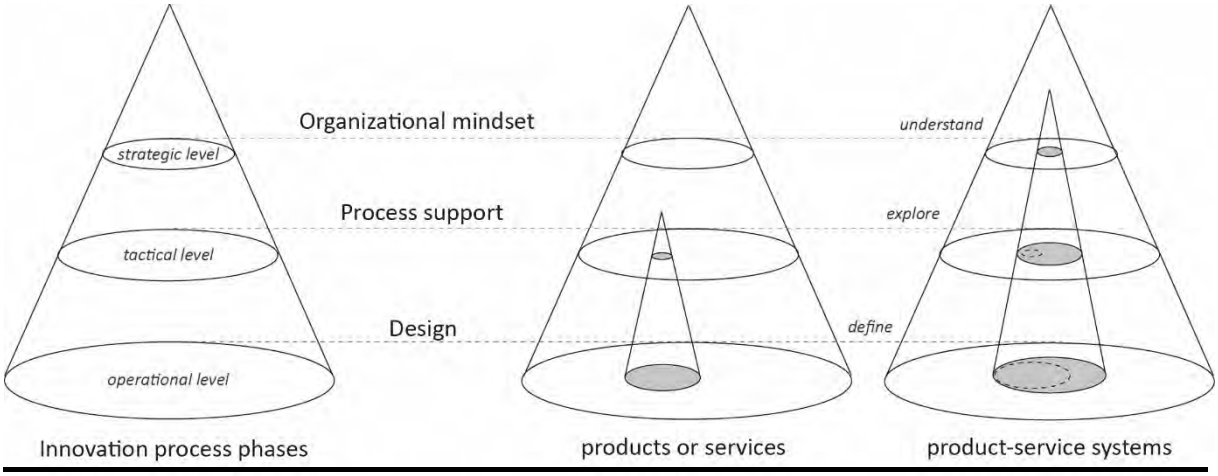


Figure 1.1 | Shifting playing field for product-service systems: interpretation from Van Erp (2011)

Despite the fact that an increasing number of companies are actually delivering bundles of product and service elements (Costa et al., 2018), there is no coherent picture of how these elements should be combined (Bertoni, Bertoni, Panarotto, Johansson, & Larsson, 2016). Central for research on PSS is to examine how companies need to combine product and service elements to create effective PSS, and how design may contribute to developing effective PSS. There is thus a need for research that acts on different levels simultaneously, providing support to design, unifying design processes related to the product, service and system, and finally creating the 'integrated' organizational mindset (Buschmeyer, Schuh, & Wentzel, 2016; Ryan, 2013; Teso & Walters, 2016). Integrating the product and service components of the PSS should support a coherent offering and address a more holistic nature of innovation, implying a range of consequences and decisions that have to be taken at the strategic level, and therefore a synthesis approach is essential.

The Web of Science (WoS) core collection shows 2254 publications with the search term "product-service system" as topic. Spread over the last three decades this still relatively young phenomenon grows substantially with a significant rise since 2008, and permanently breaching the 100 publications each year since 2011. The majority of publications stem from researchers affiliated with faculties and departments rooted in engineering (industrial, manufacturing, mechanical, product, design, science and technology), computer science, environmental studies (sciences, engineering and green sustainable technology), management, business, economics and operations research. One thing is clear; the phenomenon is of interest to diverse range of research areas and subject to cross-fertilization (Brambila-Macias, Sakao, & Kowalkowski, 2018). Considering the title of this dissertation 'product-service system design', we searched whether there is any association with design, by refining our search with "design", and 1226 remain. When setting the filter on the usage of the search term "product-service system" in the title, WoS shows 683 results. Refining our search within the results with the topic "design", it results in 440 publications. Going even more precise, using the search terms "product-service system" AND "design" within the title, still 179 remain, representing over 25 percent of the publications that use "product-service system" AND "design" in the title.

There is no such thing as applying it in the 'field of design', which as category or research area does not even exist in WoS. However, considering the context of the research and its multifaceted reach within disciplines, 'design' - usually a part of every innovation process - has a unifying factor among the more established 'sciences'. Design as a noun and a verb can cause misinterpretation quite easily. People thinking about design and designers, habitually have two perspectives. The first - the traditional - one is styling: they ask designers to make things look beautiful. The second - more recent - one is user-centered design. Designers have an amazing capacity to get close to users, understand their needs, and then creatively generate countless ideas. A third angle of design involved in innovation - but often overseen - is the radical research and in-depth exploration of new scenarios of how people give meaning to things, and taking a broader perspective on the context in which that person lives. Design is a creative activity whose aim is to envision and establish the multi-faceted qualities of objects, processes, services and their systems in whole life cycles. This third perspective of design will be coined as **exploration** throughout the rest of this dissertation. Thus making 'design' relevant in the early, turbulent phases of an industry (Verganti, 2009) and specifically relevant in the field of product-service systems.

In the context of innovation, exploration and exploitation are considered as an important trait, and when executed in balance, called ambidexterity (Geerts, Blindenbach-Driessen, & Gemmel, 2010; Stoimenova & De Lille, 2017). *Exploration* is characterized by search, experimentation, play, flexibility and investigation, and can result in new knowledge (Tabeau, Gemser, Hultink, & Wijnberg, 2017), essential for developing radically new and relevant solutions (Atuahene-Gima, 2005). However, its results are often distant in time, uncertain and ambiguously connected to the current context (Stoimenova & De Lille, 2017). *Exploitation*, on the other hand, provides greater certainty of short-term success, and focusses on refinement, choice, production, efficiency, selection, implementation and execution (Tabeau et al., 2017), relatively certain and closely related to the organization's current actions (March, 1991). Balancing both is far from easy, as they often draw from the same resources, yet ask for a very different strategic mindset and management style, and furthermore, practice shows that exploration and the service side of innovation remains largely under-addressed.

The *exploration* of new possibilities (March, 1991) is crucial for long term firm survival and development (Oehmichen, Heyden, Georgakakis, & Volberda, 2017). Furthermore, **the *exploration* perspective of design is highly suitable for the design of PSS, considering its context of uncertainty and wicked problems** (Tabeau et al., 2017), **hence the focus of this dissertation**.

1.2 Defining the research question

1.2.1 Problem statement

Organizations are constantly challenged to introduce new offerings to the market, and more frequently the outcome results in product-service combinations or systems that require the organization to systematically rethink the design process. Integrating tangible and intangible components into one coherent offering, relies on managing a variety of underlying - product, service, interaction, (user) experience, and systemic - design processes in order to explore the opportunities provided by emerging PSS concepts (Buschmeyer et al., 2016). In the case of product-service systems, it is important that products and services are designed as a combined value carrier (Teso & Walters, 2016), rather than merely adding services as by-product or using products only as a means to provide services (Haase, Pigosso, & McAloone, 2017). In order to support a valuable inclusion or transition, this research project targets current academic researchers and design practitioners in the field of PSS in need of a logic that sets focus on the synthesis of both product and service.

1.2.2 Framing the problem

Based on the below threefold focus, we will define the main research question. We aim to support a strategic, tactical and foremost operational integration (the three levels on Figure 1.1) of both the product and the service side in the product-service system (PSS) design process. This manuscript thus describes a logic and a process theory that explains how organizations, design practitioners and teams arrive at PSS.

1.2.2.1 Front-end of Innovation

As a *first* motivation for this research, we justify the ***Front-end of Innovation*** (FEI) as our scope for an integrated approach to address both product and service parts and their integrated characteristics when designing for and thinking about PSS as innovation strategy (Carlborg, Kindström, & Kowalkowski, 2014; Drejer, 2004; Morrar, 2014; Sayem, 2012). In industry, innovation projects generally move along three major activity domains (Koen et al., 2001); (1) pre-development activities where future products or services are defined and decided, (2) development activities where these products and services are actually developed and (3) launching or commercialization activities where these newly developed products and services are brought to the market.

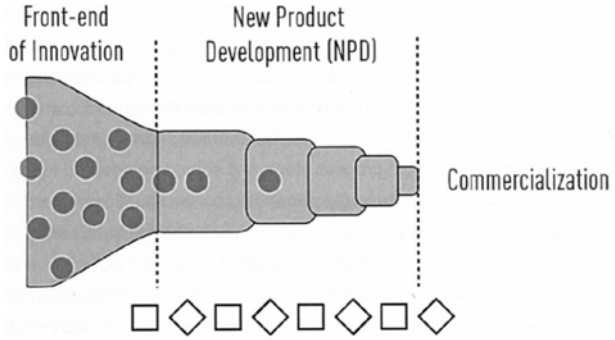


Figure 1.2 | The innovation process, adopted from (Koen et al., 2001)

The innovation processes of products and services depend to a large extent on the input to the process, the reason why we focus on the first activity domain, the front-end of innovation (Jacoby, 2012). Pointed out by prior research (Langerak, Hultink, & Henrys, 2004; Reid & De Brentani, 2004), FEI decisions impact both product and service parts in the supposed offer, whereas decisions taken in the development phase can only have an impact on partial aspects of the product or service (Karlsson, Larsson, & Öhrwall Rönnbäck, 2017). Product-service systems come with increased complexity and put additional pressure on an approach not only holding the design of separate elements but also the

integration of product and service and how they work together. Every process downstream from the FEI is shaped and determined by its outcome (Barquet, 2015; Baureis, Wagner, & Warschat, 2011; Merholz, Wilkens, Schauer, & Verba, 2008), if not coordinated and connected enough, it leads to sub-optimal results (Karlsson et al., 2017; Tischner & Vezzoli, 2009). *"As designers we establish initial conditions for the next succeeding stage of action (Simon, 1997), their conceptualizations and representations of the problem and solution during the earliest stages (FEI) of the design process are therefore critical to (comprehend) the procedures that will follow (Cross, 2006)".*

1.2.2.2 User experience

Secondly, for reasons other than environmental and economic benefit (Brezet, Bijma, Ehrenfeld, & Silvester, 2001; Ceschin, 2012; Mont, 2004), and because these approaches tend to overlook the customer experience (Valencia, Mugge, Schoormans, & Schifferstein, 2015), this research will put an effort in bridging the gap related to a stronger customer-centricity and experience related value (Stacey & Tether, 2015). An obvious and ever more demanding audience forces companies toward creating experiences that imply more interaction and emotion that go far beyond commoditized products, unburdening services, user friendliness or even usability (Carlborg et al., 2014; Coombs & Miles, 2000; Gallouj & Windrum, 2009; Pine II & Gilmore, 2011; Young, 2008). Customers are looking for products and services with a *story* that stimulates the imagination (Boswijk, Peelen, & Olthof, 2011), amazes their senses and touches their hearts (Lenderman, 2006). The integration into those experiences makes products and services more relevant to the user, and, as a consequence the willingness-to-pay increases (Pawar, Beltagui, & Riedel, 2009; Sundbo & Darmer, 2008). Therefore we place the customer perspective, need fulfillment, and value creation at the absolute center throughout the PSS design process (Tim Baines et al., 2007; Edvardsson, Gustafsson, & Roos, 2005; Lindahl, Sakao, Sundin, & Shimomura, 2009; Raijmakers, Thompson, & Van De Garde-Perik, 2012; Tischner & Vezzoli, 2009; Tukker, 2004). To outline the importance of integrated design, ***user experience*** has an intermediate role that affects all PSS lifecycle stages, being the result of a prolonged interaction with the system's components and its providers (Costa et al., 2018). *"As designers, we can offer as many alternatives as possible, a better body of knowledge, and especially a greater capacity for experience (Simon, 1997)".*

1.2.2.3 Synthesis approach

Unfortunately, the majority of academic research related to PSS does not explicit the 'integration' approach they are following. Similarly, industry usually jumps into the fray when it comes to alternative and more recent approaches. Thus, thirdly, and a final focus in this research, we explicitly adhere to an integrated reasoning on the process of PSS design and development, and thereby aim to close this maturity gap in shared product-service terminology. As a research concept and phenomenon, PSS requires a ***synthesis approach*** to a design process that has wider boundaries, a different context and other output expectations than its predecessors (Chapman, 2012; Nicolas Maussang, Zwolinski, & Brissaud, 2008; Van Erp, 2011). The diverse PSS streams in service innovation literature - assimilation, demarcation and synthesis - uncover a great deal of efforts that span over the past decades.

Following an *assimilation approach*, manufacturers gain ground and extend their businesses by adding or creating new services (de Brentani, 1991; Nijssen, Hillebrand, Vermeulen, & Kemp, 2006; Scheuing & Johnson, 1989). Designed in accordance with New Products Development (NPD) methodologies and principles, the full potential of the user and typical service characteristics remain under-addressed in such an approach.

As a clear answer to this, the *demarcation approach* increasingly addresses the customer's needs and experience, focusing on how interactions or touch points are made meaningful throughout the entire lifecycle of the offering. Well-established methods and processes put a user perspective

central to the design and development of services, with its unique set of characteristics (Lovelock & Gummesson, 2004; Nijssen et al., 2006; Trott, 2011; Vargo & Lusch, 2004b). *"A fixation on goods is understandable considering design's historical role, the half-hearted integration of services increasingly out of touch with times"* (Secomandi & Snelders, 2011). However promising each of the above approaches, in their transition toward creating successful product-service combinations, persist to under-address the integrated character (Ryan, 2013; Van Erp, 2011). Dealing with evermore-complex issues, organizations are required to methodically rethink their design processes in order to integrate both product and service components into a system. Understandably, because products and services are less sold and consumed independently, but rather increasingly as solutions, systems or experience (Djellal, Gallouj, & Miles, 2013). Service and manufacturing activities are becoming increasingly intertwined, creating the need for an integrative innovation model, synthesizing (Drejer, 2004; Vargo & Lusch, 2004b, 2004a) instead of maintaining the dichotomy between the two (Lovelock & Gummesson, 2004).

Central in this design research, the ***synthesis approach*** merges this diversity of disciplines and their underlying processes (Djellal et al., 2013; Drejer, 2004; Gallouj & Weinstein, 1997; Vargo & Lusch, 2004a, 2004b; Witell, Snyder, Gustafsson, Fombelle, & Kristensson, 2016) and might bring previous neglected characteristics of innovation to the forefront. *"Synthesis emphasizes the context, mutual relationships and the whole, a more integrated approach to problems, and a total view instead of the fragmentary. When the components are merged into a larger functional whole, new characteristics emerge that did not exist at the underlying level, or were not recognized (Toffler, 1980)".*

1.2.3 Research question

This leads us to the formulation of the main research question and two sub-questions of this research:

Main research question: How can a synthesis approach be strengthened or advanced?

Sub question 1: what preconditions must an integrated PSS design process meet?

Sub question 2: which methodology can we develop to support the integrated PSS design process?

We hypothesize that, following a synthesis approach previous neglected characteristics of innovation will surface, relevant for both manufacturing and service provider context.

1.2.4 Assumptions | Working hypotheses

To improve the synthesis approach, we aim to go beyond the mere addition of product design and service design. We set the objective on creating an integrated mindset, process support and an actionable design tool to have an impact on strategic, tactical and operational level in the organization.

Assumptions | working hypotheses:

1 ***In support of the synthesis approach, a focus on the Front-End of Innovation and User Experience will (a) add to a better understanding of PSS as a phenomenon, and (b) complement the current product-service transition by a set of process preconditions for PSS.***

2 ***A synergistic interaction between products, services and people requires a new PSS toolkit that reinterprets existing design approaches that (a) positively influences the design process, (b) the designer and (c) ultimately the design itself.***

1.3 Methodology

1.3.1 Design research (philosophy)

In general, design disciplines incorporate the act of designing and the theory of design (Cross, 2006), both co-exist and are interrelated through knowledge. With the intention to encompass varying viewpoints, we touch four domains of design in which design knowledge resides (Horvath, 2004), and in which we relate to in this PhD: design science, design research, design education, and design practice. *Design science* (i) is the philosophy and theory of design, refers to an explicitly organized, rational and wholly systematic approach to design; not just the utilization of scientific knowledge of artefacts, but design in some sense a scientific activity itself. The aim of design science is to recognize laws of design and its activities, and develop rules, the procedures of designing organized in a systematic way. *Design research* (ii) embraces the values and aims of both science and design. In this PhD, design research is conceptualized as a research strategy, aimed to develop, articulate and communicate knowledge that can be used in an instrumental way to design and implement actions, processes or systems (i.e., the research methods and the practice) to achieve desired outcomes (Simon, 1997). This design research looks into the three sources of design knowledge: people, processes and products. Firstly, design knowledge resides in people. This relates to design epistemology, the study of 'designerly ways of knowing' (Cross, 2006). Design research investigates how people design, how people learn to design, and how that might best be nurtured in *design education* (iii). A second major source, design knowledge resides in processes, design praxeology, being the study of the practices and processes of design. This is about the study of the processes of design, and the development and application of processes, tools and techniques that aid the designer, *design practice* (iv). Thirdly, design knowledge resides in products, design phenomenology, i.e., the study of the form and configuration of design. Interesting, because a design contains knowledge of what things should be, embodying design attributes.

Nowadays it is still unclear how organizations should tackle an integrated PSS design process. We therefore study the preconditions relevant for an integrated PSS design **process**. Succeeding, we develop a **PSS design toolkit** (process and tools), validate that knowledge in the **context of design education**, and explore the knowledge related to the **design practice and its outcome**.

In our search to frame our design research (Beck & Stolterman, 2016; Cross, 2006; van Aken, Chandrasekaran, & Halman, 2016), we recognize a plea for methodical structure, very similar to the approach for doing design research coined by Horvath. In order to contribute to the design discipline in close connection to what he describes as framing methodologies, design (research) necessitates conducting systematic investigations through observation and reasoning, and building a general, orderly and testable body of knowledge. A framing methodology is a strategy of reasoning, it indicates a possible research design (a methodological approach, structure, process flow and set-up of research actions), and the way research actions are to be done.

In his research, Horváth (2008) introduces three framing methodologies, of which we use two, *'research in design context'* (RIDC) and *'design inclusive research'* (DIR). Besides the clear difference between both framing methodologies, they share a similar systematic six-stage procedural approach (Figure 1.3). Design inclusive research incorporates a creative phase between the explorative and confirmative phase.

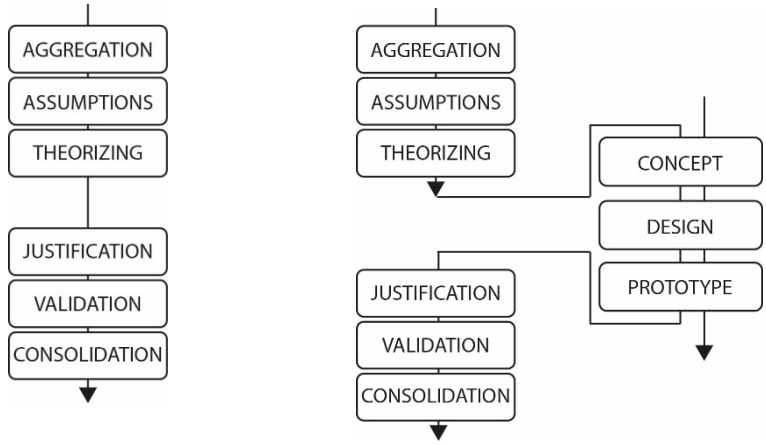


Figure 1.3 | RIDC cycle (left) <> DIR cycle (right)

This (design) research is about ***aggregating*** knowledge about the phenomenon 'product-service systems', how it affects the design process, with a tendency to understand and support practitioners in the given context (Beck & Stolterman, 2016). In anticipation of better products, services, organizational behavior, and ultimately meaningful innovation, we reveal ***assumptions*** about the phenomenon's mindset, design process and its related preconditions. Opposed to only building a theory of designing, this design research describes how the ***theory*** might affect design practitioners in everyday design situations. Iteratively involving design (the **PSS design toolkit**) in the research immediately brings contextualized insights to the surface, ***justified*** by its effectiveness, and satisfying given specifications in a given context. Apart from the design itself, the participation of experts and system users (design students) yield important additional insight and supports ***validity*** by proving that it works and saturated evidence of experienced professionals that are able to use it with the desired performance (practical relevance). This evidence comes from triangulating with a mix of methods, subjective explanations of people engaged in the context (thick descriptions), and a number of instantiations of the design, making the collected data of greater value for our study. Ultimately, we intend to ***consolidate*** our design research on PSS with its existing body of knowledge, and to transfer the insights to contexts other than the ones in which it has been made and tested without losing its basic effectiveness (van Aken et al., 2016).

1.3.2 Research design (methodology)

In order to get a clear view on our methodological approach, we present the structure of the entire design research of this PhD with the below visual representation of five research cycles, and their sequence (enlarged Figure 1.4 included in **Appendix I**). Research Cycle 1 in our research represents the framing methodology 'Research in Design Context (RIDC). In Research Cycles 2-5 we make use of 'Design Inclusive Research' as framing methodology.

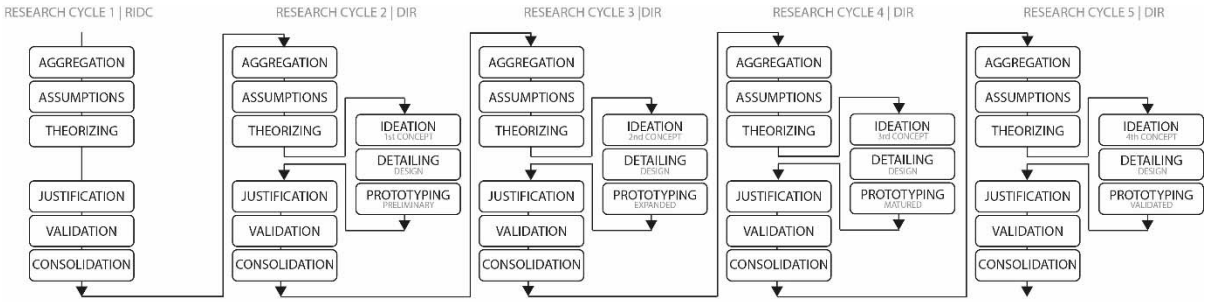


Figure 1.4 | Research Design

Apart from DIR introducing an additional creative phase to the standard six-stage procedural approach of RIDC, the process flow of all five research cycles remains the same to a large extent. Below we discuss the epistemological and methodological aspects of the two framing methodologies, i.e., RIDC and DIR used in this research.

1.3.2.1 Research in Design Context as a framing methodology (RC 1)

First, we describe *'research in design context'* as framing methodology, going in detail about its epistemological aspects. Research in design context (RIDC) supports analytical disciplinary research aiming at insights, understanding and predictions and concentrates on building and proving theories that add to the disciplinary knowledge of design, which in our case is related to the phenomenon PSS. The context of inquiry comes from the consideration of the various concerns of design, such as people (individuals, teams and communities of designers and customers), who are involved in design and who are influenced by design, respectively, in whatever way. These people have experience with concepts, designs, services, etc., which are respectively forming the input and output of design processes, furthermore they have the knowledge of the context in which humans and products/services manifest, exist and interact. In practice, the contextualization of this type of design research influences (i) the definition and purpose of PSS, (ii) the creation of conditions in which PSS can be investigated in the context, (iii) identifying the relationships, and (iv) interpretation of data in the given context (Horváth, 2007).

Concerning the methodological aspects, the learning process involved in research in design context follows the pattern that is typical in fundamental research. This can be described in an abstract and simplified form by a six-stage process flow model shown in Figure 1. The process of research in design context holds two parts: a first phase of explorative research actions, and a second phase of evaluative or confirming research actions. The arrangement of these phases gives a specific pattern to Research in Design Context, the first and second phase, respectively the explorative pre-study and a confirmative post-study (Horváth, 2008).

In Research Cycle 1, our research has a more explanatory component, the chosen problem type, its causes and contexts are analyzed and addressed by a literature study and practice-based interviews, to derive a PSS organizational mindset and a set of process conditions.

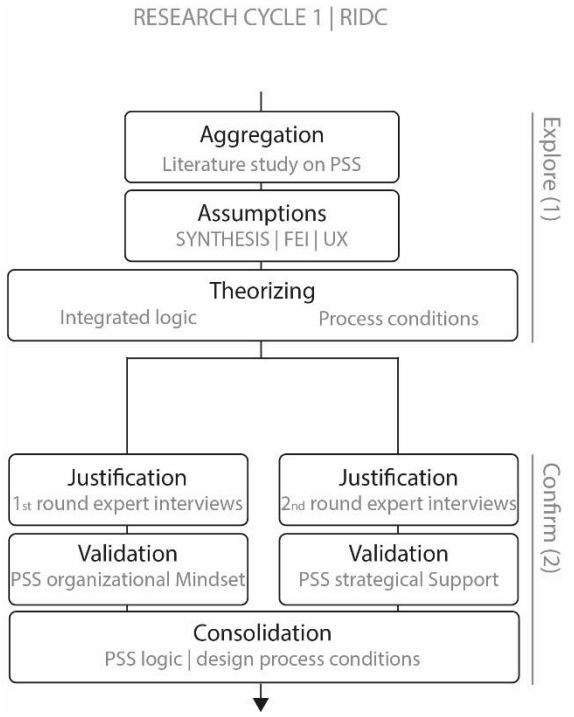


Figure 1.5 | Research Cycle 1 | RIDC

1.3.2.2 Design inclusive research as a framing methodology (RC 2-5)

One clear epistemological aspect of design inclusive research is that it embeds 'design' as a research means, it may be an artefact, process (PSS design toolkit in our case), entity, phenomenon and knowledge. The goal of inclusion is to create new opportunities for generating new knowledge, which cannot be derived otherwise. From an epistemological point of view, the evolving design and/or the recurrent design process contributes to theory building in context. This allows combining scientific study and 'designerly' inquiry in a scrupulous way. In our case, the goal of the embedded design process is to achieve a better understanding, inventing new methodologies, and providing a better solution through creating pilot versions and various instantiations of a PSS design toolkit. The recurrent research and design actions can enable theory building and refinement in context. It should be also noted that this toolkit allows designers to complete the designing exercises by themselves and simultaneously involving them as subjects for the research. For the reason that the research means are dynamically evolving and that they provide immediate feedback for the researchers, they may influence the research actions in design inclusive research.

On the methodological aspects, the general process of Design Inclusive Research (DIR) naturally decomposes to three parts: a first phase of explorative research actions, a second phase of creative design actions, and the third phase of evaluative or confirming research actions. The first and the last phases listed above can be called pre-study and post-study, respectively and are similar to the two consecutive phases of *research in design context* (as discussed in the previous section). The goal of the pre-study can be aggregation of existing and new knowledge about a specific phenomenon, formulation of a critique of the current understanding and existing approaches or the synthesis of research questions as well as the goal to optimize the theoretical framework that in turn will produces a better toolkit. The post-study actions are orientated to the verification and validation of the hypotheses, the constructed theory and the outcome of the design processes. And finally the consolidation of the results by matching them against the existing body of knowledge, and by generalizing them toward other applications (Horváth, 2007, 2008).

Design Inclusive Research (DIR) goes through a similar six stages procedural approach as RIDC, however it integrates a second creative phase between the first phase 'explore' and the third phase 'confirm'. In Research Cycles 2-5 a generic research design for addressing the problem is developed in design-testing-redesign cycles, ultimately resulting in the design component: the **PSS design toolkit**.

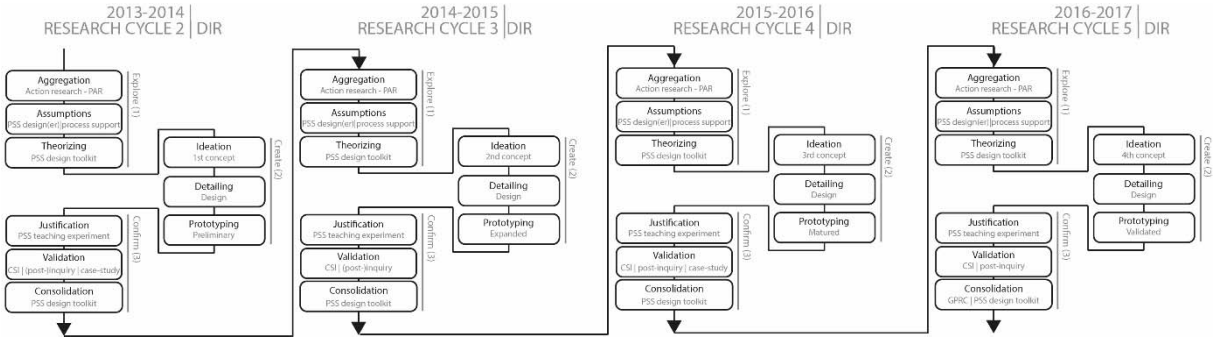


Figure 1.6 | Research Cycles 2-5 | DIR

Methodologically, research cycles 2-5 are identical. Having these research cycles as a constant, gave us the opportunity to refine our assumptions and evolving theory. For this reason we shortened Figure 1.6 (enlarged Figure 1.6 included in **Appendix I**) and depict one procedural approach, in which we make use of a circular arrow that represents the four consecutive research cycles in Figure 1.7.

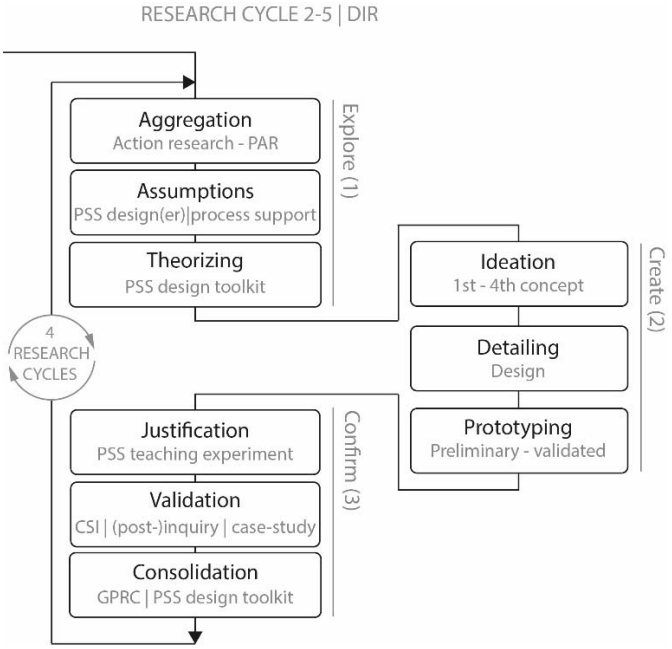


Figure 1.7 | Research Cycles 2-5 (condensed view)

1.3.2.3 Design research (including methodological approach)

Depicted in Figure 1.8 below, our methodological approach represents five research cycles, and their comparable sequence: Research in Design Context (RIDC) in Research Cycle 1 and Design Inclusive Research (DIR) in Research Cycles 2-5. These abbreviated versions of the research design, including an explanation of the procedural approach, will be used more often as to guide the reader through the following chapters.

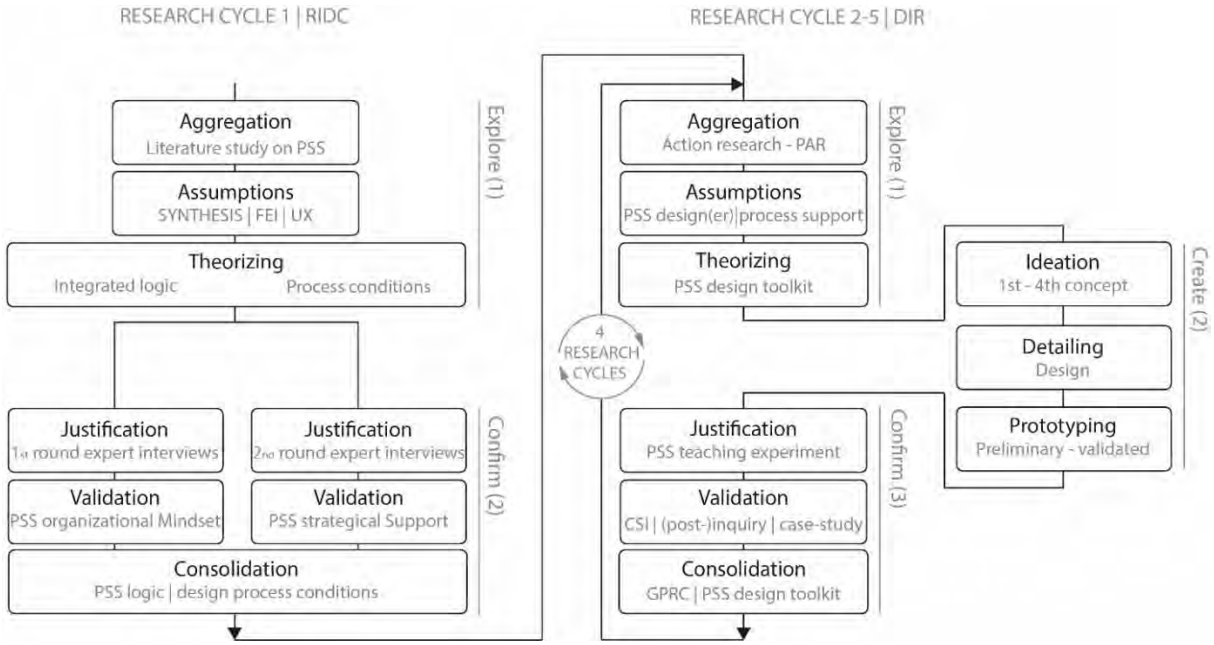


Figure 1.8 | Research Cycles 1-5 (condensed view)

Rather important to mention is that the exploratory and design components are not separate phases in the project timeline, requiring one to be completed before the other begins. On the contrary, it is important to begin soon after project launch with sketching rough outlines of possible alternative designs. Doing so yields insight on the descriptive and explanatory knowledge to be produced by the explanatory component of the project to enable sound designs and design choices by the design component. Thus implying an overlap of cycles and their respective phases. However structural the research cycles and their procedural approach are depicted, it's important to acknowledge that the different steps are not always performed in that same order, some are done simultaneously.

Still, we will provide a detailed set-up of research actions for each framing methodology in each chapter.

1.4 Exposition of chapters | structure of the thesis

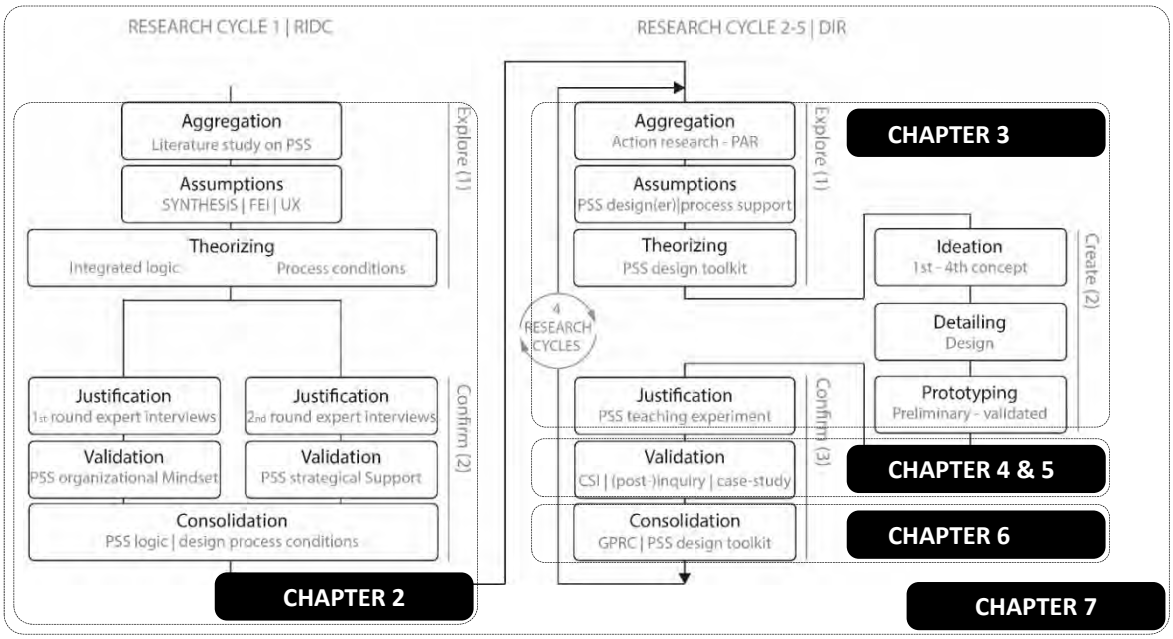


Figure 1.9 | Research design - chapters

This first chapter describes the philosophical reasoning behind this PhD from a design research point of view. Figure 1.9 shows how the different chapters can be mapped onto the research design.

Chapter 2 provides the results of systematically combining literature and expert-interviews, applied in RC 1. This leads to combined insights on the organizational mindset and strategical support as foundation for the PSS design toolkit.

Chapter 3 to 6 give a stepwise understanding of our approach in RC 2-5, also shown in Figure 1.10.

Chapter 3 formulates a critique on the current situation and sets a basis for actionable PSS design tools and methodologies. Consecutively, we describe all the different actions needed for this integrated PSS design toolkit alongside Research Cycles 2 to 5 on the basis of immediate feedback from the students taking part in the teaching experiment and constant discussions with the expert panel. Every change that we made, has been explained for each of the PSS design toolkit versions. Participatory action research was used to generate necessary knowledge and data as input for the next Research Cycle(s), ultimately justifying the PSS design toolkit by testing its iterations in design educational context.

In Chapter 4 we validate the PSS design toolkit by evaluating how it supports creativity on six different factors (collaboration, exploration, results worth effort, expressiveness, immersion, and enjoyment) by means of a psychometric tool *Creativity Support Index* (CSI). Moreover, we present the results of a post-inquiry that we conducted with the same students as a way to check their perception one year after they used the PSS design toolkit.

Chapter 5 illustrates two cases that reflect on the PSS design toolkit, the process and its representation.

In Chapter 6 we make an effort to consolidate our knowledge by submitting our PSS design toolkit for a guaranteed peer reviewed content (GPRC) procedure, a double-blind peer review in the field of PSS.

We present the academic feedback that ultimately brings together the knowledge from Chapters 2 to 5, and gives the reader the summarized version of the last iteration on the PSS design toolkit which has gone viral in the last quarter of 2018, with GPRC label.

Chapter 7 connects Research Cycle 1 (Research in Design Context | RIDC) with Research Cycle 2-5 (Design Inclusive Research | DIR). Here we merge the integrated mindset, the process conditions and the actionable approach (PSS design toolkit) into one whole, the Integrated PSS Design Framework.

Finally, Chapter 8 results in a synthesis of Chapters 2-7 (RC 1-5), it discusses and concludes this design research on how the research results contribute to design knowledge and design science (Chapter 1) in general, and finally we briefly tap into the future research connected to our outcome.

A planning of this design research can be found in **Appendix II**, and **Appendix III** show the details of the full bibliography of the author specifically related to the PhD research**.**

CHAPTER 2

PSS - phenomenon and preconditions

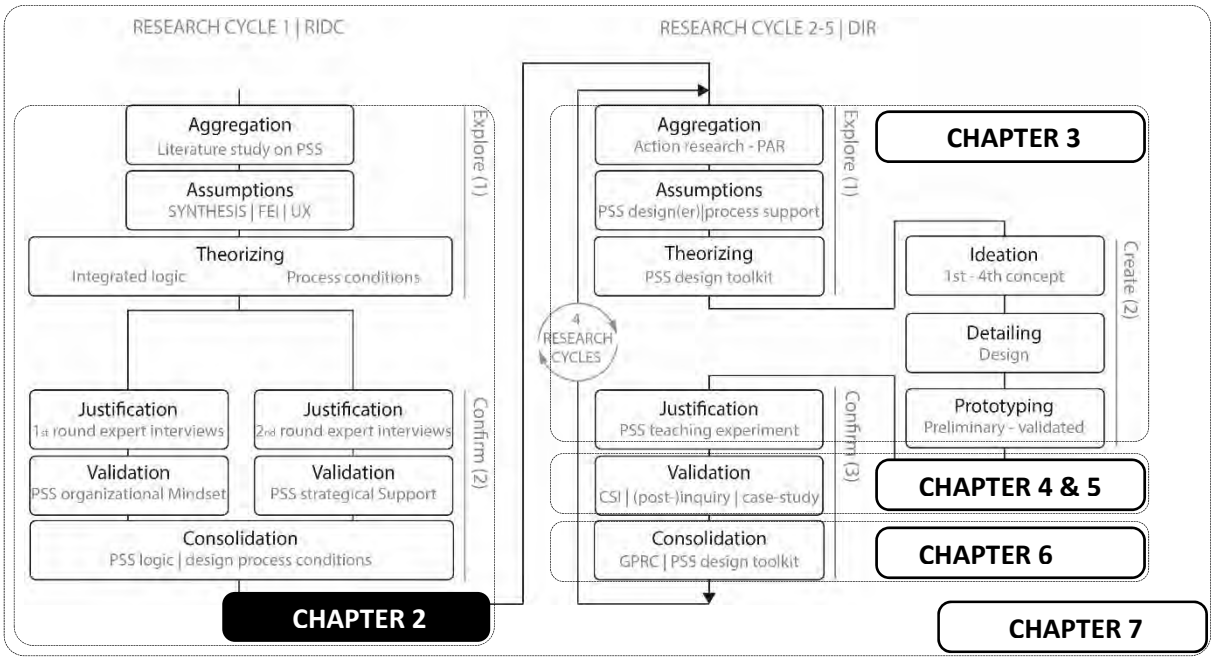


Figure 2.1 | Research design - chapters

2.1 Research framing methodology | RIDC

This chapter uses *'research in design context'* (RIDC) as framing methodology. This type of design research is about developing an understanding and building theory that adds to the disciplinary knowledge of design, in our case related to the phenomenon PSS. Furthermore, this type of design research, and specifically in the context of PSS, considers people who are involved in design and who are influenced by design, respectively, in whatever way.

In Research Cycle 1, our research has a more exploratory component. The chosen problem type, its causes and contexts are analyzed by a literature study and infused with practice-based interviews, to derive a **PSS definition, integrated mindset** and **process preconditions** that strengthen the integrated PSS design process in the Front-End of Innovation. RIDC follows the six-stage process flow model shown in Figure 2.2 below and is described more extensively in the subsequent paragraphs. The process holds two parts: a first phase of explorative research actions, and a second phase of confirming research actions (Horváth, 2008).

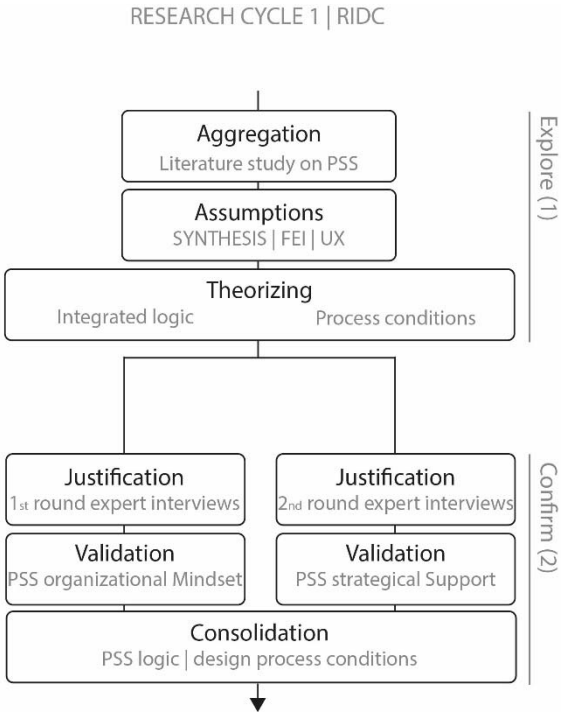


Figure 2.2 | Research cycle 1 | RIDC

1st phase – Explore (1)

The first stage of the research cycle concentrates on gathering relevant knowledge, that results from the literature study as a basis for ***aggregation*** and indicating the actions needed. In addition to compiling knowledge, the goals of the explorative activities also serve to formulate a critique of the current understanding and existing approaches, identifying opportunities for progression. This stage is about the identification and definition of a problem to be solved. Terminological analysis, chaining, and conceptual mapping are applied as reasoning techniques to arrive at sufficiently generic assumptions. These research assumptions provide a clearer view on the phenomena to be studied and the specific research objective(s) linked to that in the context of the knowledge problem. The specific findings of the review revealed a duplex research ***assumption*** that becomes the foundation for the second stage working hypotheses: *In support of the synthesis approach, a focus on the Front-End of Innovation and User Experience will add to a better understanding of PSS, and complement the current product-service transition.* The third stage of the research cycle proposes a motion to develop a

preliminary ***theory***, which is able to fill in the knowledge gap of the studied phenomenon in design context, PSS design, considering alternative courses of action to solve the problem. The objective is to arrive at an abstract scientific theory about 'integrated logic and process conditions' that should be confirmed through practice. As a basis of theory development, it is presumed that all the generalizing assumptions made in stage two are defendable and the claims of the working hypotheses are true.

2nd phase – Confirm (2)

The fourth stage is dedicated to the ***justification*** of the theory, providing an initial circumscription (integrated logic), and a more comprehensive overview (process conditions) on PSS. We have tested the integrated logic and the process conditions with two rounds of practice-based expert-interviews. We can confirm internal justification on the basis that consistency (conceptual integrity) is taken into consideration, a reflection on coherence of facts and relations has been verified during the analysis of the interview data. External justification is about how much our research is compatible with other theories. In the fifth stage, ***validation*** is about the evaluation of methods and findings, we want to define to which extent the research project can be regarded as accurate and reliable, and its findings relevant and useful in a given context or in general. In general, validity expresses the extent to which our first research cycle satisfies the objectives that it was intended to achieve. In our case, we can speak of (testing) internal validity through method validity, by differentiation and variation in methods i.e., literature and interviews. However, focusing on the conduct, the set-up, it tells us about research, and not its findings. External validity concerns the extent to which the (internally valid) results of a study can be held to be true for other cases, for example to different people, places or times. To capture the manifestation of external validity, we specifically focus on sampling validity. Whether our research participants (practice-based experts) are true representatives of the general population and how well the sample used can be extrapolated to a population as a whole along relevant dimensions. This is why we connect the interviews to the literature to augment internal and external validity. Finally, in the sixth stage, this study provides new knowledge with the intention of complementing the existing knowledge, integrating products and services. It informs about how strongly the conducted research is dedicated to the given research problem, and what may be expected to occur in other research contexts. Hence ***consolidation*** may involve both specialization and generalization of the validated knowledge. Specialization is concerned with adjustment of the attained knowledge in the same or refined contexts for the subsequent research cycles where, combined with other aggregated knowledge, it is used as input for the development of the PSS design toolkit in Research Cycles 2-5, DIR. Generalization is concerned with putting the attained knowledge into a broader theoretical context, and in correspondence with the real world we connected the theory to the practice-based interviews.

* This chapter is based on the following publications by the author: one H3 Book chapter (PLANC14), three published P1 Proceedings (TMCE14, IPSS16, DMA17), and one A1 Journal article (IJPR18). This chapter also presents insights, submitted to 'Designs' under the working title *"Toward an integrated PSS design framework".*

2.2 Research methods

This chapter combines diverse research methods for data collection with corresponding levels of analysis, suitable when research questions tackle innovation issues (Currall & Towler, 2003). More specific, within the framing methodology RIDC (Figure 2.2) we confront our aggregated literature on PSS, its assumptions and theory with five in-context interviews. The findings from the explorative phase are solidified by the confirmative phase, iteratively characterizing the theory with its applicability in practice.

Research in Design Context (RIDC) has quite a few similarities to the approach of systematic combining (Dubois & Gadde, 2002), a logic used in the field of industrial marketing that rests on interpretive methodologies and abductive reasoning. Its constant infusion of research methods (Figure 2.3) and combined knowledge offers more guidance for theory development and allows for managerial recommendations that are highly contextualized (Dubois & Gadde, 2014; Orton, 1997). Thus, resulting in more actionable and relevant prescriptions when dealing with complex issues and phenomena that are highly unstructured and still in their context of discovery (Hunt, 2002). We highlight the importance of exploring and confirming the research in design context and discuss the usefulness of a more qualitative approach to consolidate theory and practice. This approach, researched with the appropriate methods, links theory and practice in-context with enriched relevance (Matthyssens & Vandenbempt, 2003). Not to create new theory, but rather to integrate and extend existing theories on PSS, we examined the literature relevant to the dynamic phenomenon of product-service systems, and employ the empirical data to fill in the gaps, reveal its flaws, elaborate its meaning, and extend its coverage (Danneels, 2002; Matthyssens & Vandenbempt, 2003).

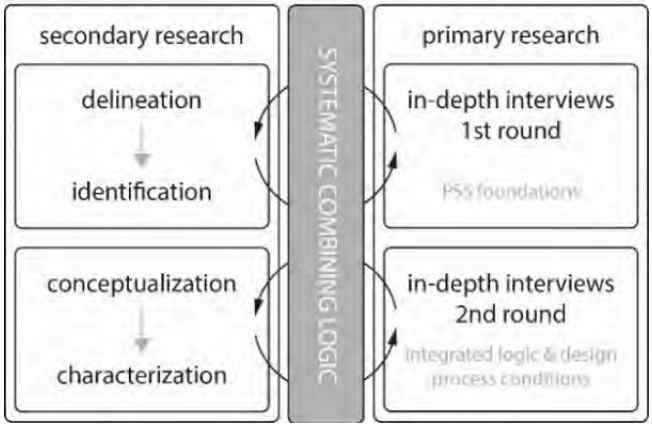


Figure 2.3 | Systematic combining logic

Without neglecting the benefits of other research designs and methodologies, we conclude that a qualitative, interpretative research methodology seems to offer guidance for in-depth exploration of PSS as the central phenomenon and theory development therefor. It offers context-rich descriptions and implementation aspects, suggesting valuable prescriptions to practitioners (Hunt, 2002; Cresswell, 2009).

2.2.1 Literature review

With its explorative purpose (Hart, 1998), this chapter presents a literature study as a qualitative and aggregative research method for theory generation. The literature review describes the transition to integrate products and services into systems and contributes to the understanding of the design research field considering PSS as an emerging area and as a phenomenon. Therefore terminological analysis, chaining and concept mapping were applied as search methods supporting the transition from author-centric to a more concept-centric approach (Webster & Watson, 2016).

In a stepwise approach to the literature review, we used three search methods within a concept-centric approach (Webster & Watson, 2016):

1. ***Terminological analysis*** served as a controlled finding of search terms to spot new emerging concepts and terminology. First, we used Web of Science to navigate the core collection of books, journal articles and conference proceedings on 'product-service system(s)'. Secondly, we performed a free text search and extending our search on the Web of Science (WoS) database with broader and narrower terminology associated or interchangeable with PSS. *PSS, NPD, NSD, product design, service design, assimilation, demarcation, synthesis, process, methods, characteristics, differences, similarities, servitization, etc.*

Table 2.1 | Terminological analysis

Concept-centric approach to literature reviews
Concept X … [author A, author B, …]
Concept Y … [author A, author C, …]

2. A ***chaining strategy*** was used to check the author's institute, website, publications and references as search technique. Advanced refining options on Web of Science enabled us to analyze the search results on distinct research areas, source and meeting titles, etc. This technique allowed us to find the initial projects their research was based on, its reports and briefings and related dissertations, that provide thick descriptions of the phenomenon in PSS design context.

3. ***Concept mapping*** enabled to specify the core terms by separating concepts, organizing synonyms of the core concepts and enabling a sequenced search on definitions, characteristics, keywords that leads to the foundation and our current understanding of the design research field PSS as emerging area and as a phenomenon. This concept-centric approach allowed us to do a review of PSS definitions (n=46) and its related terms, categorizing its building blocks.

Table 2.2 | Concept mapping

Articles	**Concepts**				
	A	B	C	D	…
1		x	x		x
2	x	x			
…			x	x	

2.2.2 In-depth expert interviews

For the in-depth exploration of the central phenomenon of this research, the use of semi-structured in-depth interviews - as qualitative and interrogative research method - was deemed most appropriate. The interviewees received ample time and scope to express their specific views, which in turn allowed us to react to and follow up on emerging ideas and unfolding events. The results could then be more easily compared and minimized the influence of the researchers' attitudes and previous findings (Coopey, Keegan, & Emler, 1998; Creswell, 2014; Nohl, 2010; Silverman, 2006). The research required opinions of people with specific responsibility, knowledge and experience with PSS design projects in order to generate theory from industrial in-context empirical descriptions, facts and experiences or perceptions complementing the previous literature review. Consequently, these specific selection criteria - for the unit of analysis - set out purposive-expert sampling as nonprobability method to ultimately build on the experts' experience. The purpose is not to generate a representative sample and then generalize the results to other contexts, but rather to learn from people who are 'information rich' that help to understand different perspectives on the central phenomenon (Creswell, 2014) and allowing a holistic analysis typical for PSS. It offers context-rich descriptions, implementation aspects and suggests valuable prescriptions to practitioners (Hunt, 2002; Cresswell, 2009). Ultimately, the results are likely to benefit from a reflected respect and to be more credible with an audience that accepts those institutions and its people as experts in the matter and true representatives of the general population along relevant dimensions. Without neglecting the benefits of other research designs and methodologies, we conclude that a qualitative, interpretative research methodology seems to offer apt guidance for in-depth exploration of PSS as the central phenomenon and theory development therefor.

Two rounds of in-depth interviews were conducted with five experts, the respondents represent institutions respectively in Belgium, the Netherlands and Germany, which are moving into the design and development of product-service systems.

- The first two experts, a program manager for knowledge transfer and a design management coach, represent the Expertise Center Business Design & Innovation at the Antwerp Management School (BE), which emerged from the former Flanders Inshape, a government vehicle for stimulating PSS design. In order to create capacity and competences in Flemish SME's, they develop knowledge and tools in the areas of product and service development, design and design management, with the user as source and inspiration for innovation.
- The third expert is partner at Namahn (BE), a full service design agency that recently refocused toward a better understanding of human behavior, organizational processes and whole systems, in order to design products, services and purposeful experiences in a complex, digital environment.
- The fourth interviewed expert has lead the Competitive Advantage through Strategic Design (CASD) project related to the Creative Industry Scientific Program (CRISP) at TU Delft (NL). The project was about achieving effective strategic design thinking that enhances the competitive position of PSS.
- The last expert is a project manager for service design and innovation at the Service Science Factory (SSF). Their innovation projects focus on design and development of a new/improved service concept, complex service systems, technology-intensive services and transformative services at Maastricht (NL) and Köln (DE).

These experts have experience with concepts, designs, services, etc., which are respectively forming the input and output of design processes, furthermore they have the knowledge of the context in which humans and products/services manifest, exist and interact. In practice, the contextualization of this type of design research influences (i) the definition and purpose of PSS, (ii) the creation of conditions in which PSS can be investigated in the context, (iii) identifying the relationships, and (iv) interpretation of data in the given context (Horváth, 2007).

A list of questions was compiled and used to guide the expert interviews in order to make sure that all respondents address the issues that are of interest for this study. However, this list was not used for standardizing the data collection procedure, it merely provided a frame for the discussions and was intended to trigger and guide the experts' narratives. We contacted the experts with a personalized email request for a recorded, face-to-face interview with a short description of the research purpose, central phenomenon, and questionnaire attached. The interviews consisted of two parts (Figure 2.3), the first solidifies the PSS content in-context and supplements our theoretical delineation of PSS, the second transforms theoretical characteristics into actionable practice in the PSS design process.

In order to gauge the respondent's background and knowledge on PSS, we directed the interview questions of the first part toward the strategic importance of PSS to the company, and the drivers and inhibitors related to the projects they facilitate. First, the experts reflected on physical or digital trails of specific PSS-related terminology in the design briefing, preparation, and verification of this type of projects. Secondly, we confronted the experts with pathways that describe how organizations initiate their transition toward an integral approach. As the advocate for PSS in their respective organization or institute, we then asked the interviewees about their underlying motivations and objectives in their pursuit of PSS. In addition we collected top-of-mind PSS definitions, descriptions and related terminology, enabling a clarification of the phenomenon. Absence of in-house experience and resources for a transition into PSS frequently necessitates different types of collaboration and related approaches. In order to obtain more detail, we assessed the respondents' knowledge about the scope and facilitation of product-service integration at different business levels. The second part of the interviews was set up to verify the set of preconditions that we derived from the literature review (Table 2.8). The aim was to do a preliminary check on the terminology, sequence and completeness of the theoretical characteristics, and to transform them into relevant prescriptions during the PSS design process.

The interviews took one to three hours, have been audiotaped and transcribed. Subsequently, we analyzed the qualitative data according to the procedure described in Table 2.3 (Creswell, 2014), constantly keeping the context-content-process nexus focus central to our interpretation lenses:

Table 2.3 | Interview analysis, procedure

procedure for analysis
transcribing Interviews
reading through the data
generation of relevant themes
interpreting the meaning of the themes
compare these findings with literature

2.3 Infusing theory with practice

In this section, we present the findings from our literature review. An analysis of key terminological concepts has lead us to six prototypical definitions and two major dimensions (Haase et al., 2017). The recurrent elements of these PSS definitions were visual mapped, and resulted in six building blocks that structure the preconditions in the support of an integrated design process. The experts, in order to discuss the concept of PSS and validate the results of this research cycle, constantly infused this process with context-rich information.

2.3.1 Background clarifying definitions

A ***product*** is a man-made (set of) component(s), having specific characteristics fulfilling one or more functions that satisfy a human need (Roozenburg & Eekels, 1995).

A ***service*** is intangible, cannot be touched, tried on for size, or displayed on a shelf. The dynamic, subjective, and ephemeral nature of intangible elements in services prevents them from being described as precisely as products (Shostack, 1977).

A ***product-service*** indicates a value proposition that derives its value for a significant part from both the product and service element (Tukker & Tischner, 2004).

The word '***system***' in product service system indicates that the offer consists of a mix of products and services (Goedkoop, Van Halen, Te Riele, & Rommens, 1999). The context can be extended when the system represents the (value) network, (technological) infrastructure and governance structure (or revenue model) that 'produces' a product-service and puts it on the market (Mont, 2004; Tukker & Tischner, 2004).

Product design, also called product development and/or industrial design, is a field, which has been practiced professionally for more than hundred years now. Tischner and Vezzoli (2009) describe product development as the entire design process or development process which aims to develop, produce and market (new) products. However, it has undergone changes during the past decades, the design of objects is no longer restricted to form, function, material and production. Design is focused on the interaction between people and technology, and products serve as platforms for experiences, functionality and service offerings (Lindahl et al., 2009).

In recent years, the activity of ***service design*** grew in importance. Companies turn to service design methods to better understand the customers' needs and experiences. The customer perspective is central to the development of the services. Service design has its source in classical service marketing, where Vargo and Lusch (2004, 2008) introduce Service-Dominant Logic, and its focus on how interactions between service provider and receiver make a service transaction meaningful. The field of service design has embraced this holistic approach by seeing services as "systems consisting of people, artefacts and their interactions" (Segelström, 2010).

2.3.2 The delineation of PSS

When trying to understand PSS, Tischner and Vezzoli (2009) stress that this field has strong connections to product design and its methodologies as well as service design and its methodologies. Nevertheless, ***product-service system (PSS) Design*** is more than just a combination of the former two fields. As such, we conclude that research and practice in the domains of product and service innovation are moving toward each other, applying each other's tools and methods due to the complex nature of today's offering, and implying an actual *product-service* integration. Without pushing one definition forward, we will delineate PSS and its characteristics.

2.3.2.1 PSS, a terminological jungle

In this part, we present our literature study as a qualitative and aggregative research method to unravel the 'terminological jungle' surrounding product-service systems. With an explorative purpose (Hart, 1998), we initiated our literature review on Web of Science with a navigation of the collection journals (Gokula Vijaykumar, Roy, & Corney, 2015; Gokula Vijaykumar, Roy, Lelah, & Brissaud, 2012; Manzini & Vezzoli, 2003; Morelli, 2002), books (Birkhofer, 2011; den Ouden, 2012; Hesselbach, 2011; Merholz et al., 2008; Sakao & Lindahl, 2009; Van Halen, Vezzoli, & Wimmer, 2005), and proceedings that have enabled us to describe the transition to integrate products and services into systems. In this review we made use of *terminological analysis*, *chaining* and *concept mapping*, methods introduced by Webster & Watson (2016).

The *terminological analysis* served as a controlled finding of search terms to spot new emerging concepts and terminology, though going in every possible direction (e.g., business economics, operations research, marketing, engineering and product innovation management). The use of broader and narrower terms brought us to a range of phenomena associated or frequently used as synonym and interchanged with PSS, such as *functional product* (Hesselbach, 2011; Maussang et al., 2008)*, hybrid offering* (Sakao, Panshef, & Dörsam, 2009; Ulaga & Reinartz, 2011), *servitization* (Coreynen, Matthyssens, De Rijck, & Dewit, 2017; Luz Martín-Peñ & Reyes, 2017), and s*ervice-dominant logic* (Helkkula, Kowalkowski, & Tronvoll, 2018; Vargo & Lusch, 2014). The study of these and more related concepts (Akaka & Vargo, 2015; Chandler & Lusch, 2015; Matthyssens & Vandenbempt, 2010; Meier, Roy, & Seliger, 2010; Nijssen et al., 2006; Visser, 2013; Vladimirova, 2015) have contributed to the foundation and our current understanding of the design research field PSS as emerging area and as a phenomenon (Mcaloone, 2011). Consecutively, we used a *chaining strategy* as search technique to check the authors' institute, website, publications and references. Finally, *concept mapping* enabled us to specify the core terms by separating concepts, organizing synonyms of the core concepts and enabling a sequenced search. Besides the more typical sources, we were able to retrieve a lot of information of the field these terms relate to, their connotation and contribution to the growing phenomenon of PSS, such as PhD dissertations (Barquet, 2015; Ceschin, 2012; Chan, 2003b; Van Ostaeyen, 2014), project reports and briefings (Cooper & Evans, 2000; Tukker & Tischner, 2004; Van Erp, 2011; Visnjic, Turunen, & Neely, 2014).

A more extended overview of the PSS related terminology following this concept-centric approach can be found in **Appendix IV** and was also used as part of the discussion with the experts. Similar to the academic scene, practitioners do not seem to have a consistent terminology regarding PSS. Rather, the experts adapt their terminology according to the situation or person faced. Therefore, the choice of terminology on product-service systems is not on the 'what', but more dependent on 'who' you talk to and the respective connotation they put on the former or the latter component in the system, i.e., product or service. Connecting to the specific knowledge and involvement in PSS design projects, the experts apply the subsequent terminology in descending order of relatedness to PSS:

- *Product-service combinations* are self-explaining, e.g., an organization is delivering products, but what if it adds a service component to add more value to the customer; not only after sales, but also providing services before sales; etc.
- *Product-service, Product-service mix* or *system* and *hybrid product-service* fall under the same category of understanding. However these terms are slightly less in scope or profound than *PSS* itself, where the focus is on the integrated system.
- The terms *hybrid product-service* and *Industrial PSS* seem to be interpreted with a rather technical connotation.

- *Integrated solutions* as a term is also a good alternative to use. Integrating the service part in the solution makes it easier to talk about experiences and satisfaction by means of e.g., the customer journey.
- A known term and used occasionally, but evoking some controversy is *servitization*, because of unfamiliarity to SMEs and manufacturers due to its association with total cost of ownership. Some argue that servitization is the process in which you develop PSS, others do not associate servitization with PSS under any circumstance or at least not exclusively.
- Because of a more clear connotation to the service and linkage to management and marketing fields, following terms are associated with PSS; *service economy, service engineering, service/product engineering, service economy, service-dominant logic* and *functional (total care) products*.

2.3.2.2 PSS drivers and transition dynamics

An integrated PSS approach tends to open up knowledge and empathize with the user and his/her context. It strengthens, professionalizes and supports the innovation process and makes it more adept to technological, economic and societal trends. The idea of PSS is to gain or create a broader space in the (early) strategy making of a company, involving the company in more human centered, meaningful innovation. Nonetheless, it implies a different organizational mindset to formalize and establish a vision and strategy for innovation that understands - different levels and perspectives on - value, integrating both products and services. Comparing our empirical findings on categorization theory (Haase et al., 2017), the benefits that drive PSS are foremost economic and competitive. Every organization has clearly developed an interest or willingness to bridge product and service to boost its value creation and noticeably (Table 2.4) the motivational aspects set a focus on the user and his/her experience.

Table 2.4 | PSS drivers derived from the expert-interviews

- Fulfil user needs in a new way, with an added value opposed to solely answering to customers' demand, a rather incremental, market pull situation.
- Appear more disruptive and innovative for the more demanding customer.
- The competitor (abroad) drives the market and sets a new standard to follow.
- Creating value and competitive advantage through the better offer, the customer's need is better fulfilled thanks to the added experience.
- Human insight drives organizations to improve and diversify through PSS to secure and expand their market situation.
- Improvement of image by consistency, branding and design management.
- The PSS enables the user to interact more frequently with the company.
- Important for the brand and its related experience - in the sense that it bounds the user to the company - uplifting loyalty.
- In order to keep existing customers for a longer period and attract new.
- Involve technology, meaningful to people without a too technological or industrial connotation.

Despite the fact that more and more companies are actually delivering bundles of product and service elements, there is no coherent picture of how these are to be combined during the design process (Spring & Araujo, 2009). It remains uncertain if current typologies and their categorization are actually driving PSS design as addressed in Table 2.4. In our opinion, one of the most frequently used and referenced PSS typologies by Tukker and Tischner (2004) falls short. The main idea is to evolve away from the pure product toward the service side, using their eight types of PSS that range from product-

oriented, over use-oriented, to result-oriented service integration. It does enable companies to plan the growth of the PSS, what it is right now and even more how it develops over time. Nevertheless, it's hard to believe that companies base their PSS management and design on unidirectional thinking. Another often used transition model is the one of Vargo and Lusch (2008), which describes a potential growth on two foci (Figure 2.4). A first relies on a strategic product-service mindset and integration (servitization), a second is to underpin the innovation-through-services transition that places the user's perspective central as a motivation for innovation (toward the service-dominant logic).

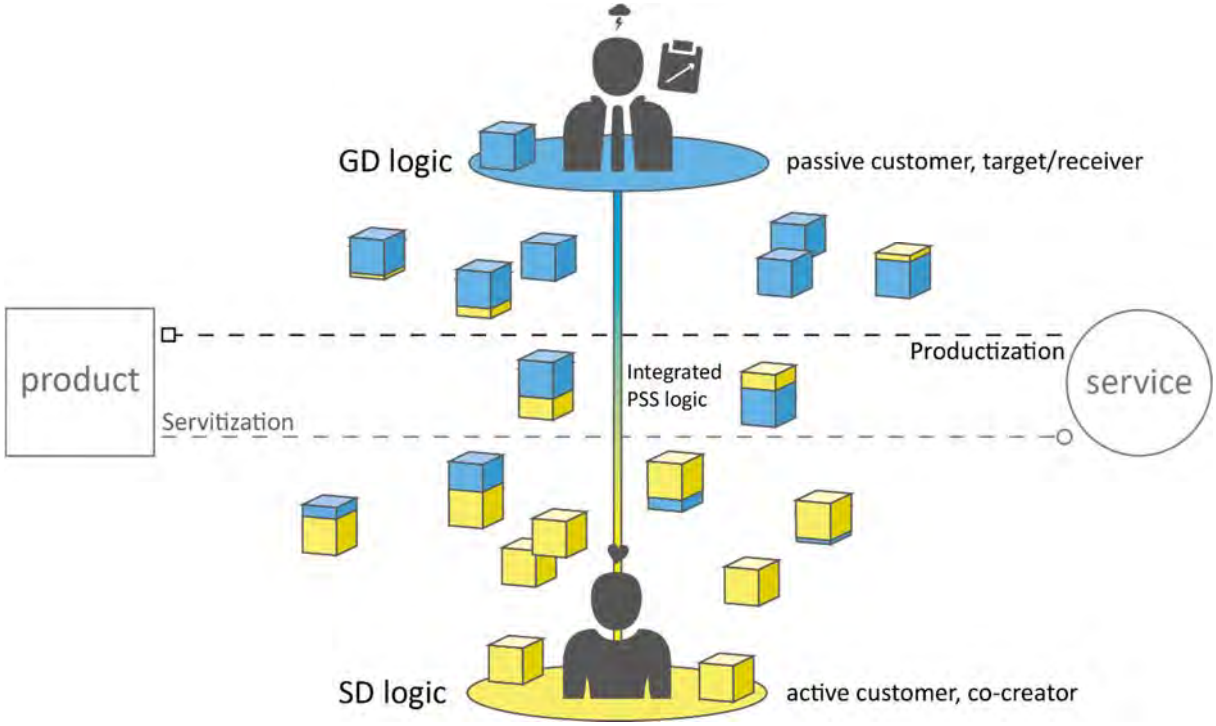


Figure 2.4 | A transition model; Integrated PSS logic shift, adapted from (Dewit, 2014)

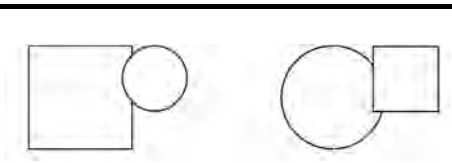
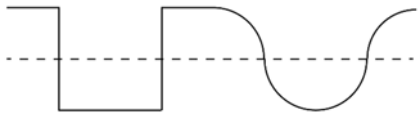
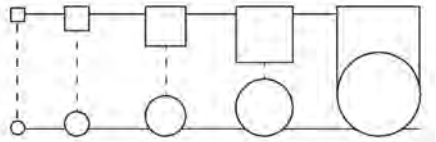
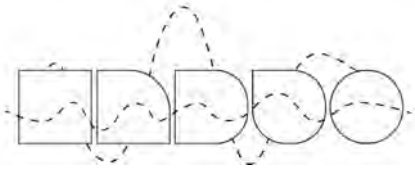
However, we have made small adjustments to streamline this model (Figure 2.4) that were confirmed by the experts during the interviews. Companies from both sides are actually horizontally evolving toward the center, to an integrated PSS logic rather than a unidirectional transition such as servitization. Thus, we therefore added a second horizontal line that indicates a possible 'productization' as well (Baines, Lightfoot, Benedettini, & Kay, 2009; Gokula Vijaykumar et al., 2011; Kowalkowski, 2010; Penttinen & Palmer, 2007; Sakao, 2011; Smith, Maull, & Ng, 2012). Not the distinction in terms of product versus service is of importance, but the emphasis of the product relative to the service, including the context, is (Chan, 2003a). Vertically, goods-dominant logic is making a transition toward a service-dominant perspective, which characterizes a constant interaction and co-creation of value between the producer and its consumers (Valencia, Mugge, Schoormans, & Schifferstein, 2013, 2016). Incorporating human centeredness is one step in the right direction, nonetheless the point is to evolve toward a state between logics, an integrated PSS logic or synthesis approach. It remains equally important for organizations to adopt customer-centric service design methods, as to adopting product design methods. However, we need deeper insights that systematically enable us to integrate of both product and service, in order to increase the breath of the offering (Dewit, 2014; Kowalkowski, 2010; Ryan, 2013).

Based on our insights so far and confirmed by the experts, we have described different pathways that a company can undertake in the transition toward PSS (Dewit & De Roeck, 2014), or at least

acknowledge their current way of developing PSS (Table 2.5). Instead of the mere addition of the counterpart *(sequential pathway)*, or even designing separate elements *(nested pathway)*, more opportunities lie in how product and service work together in the early stages of the design process *(parallel pathway)*.

Though very clear for the experts, related to projects they are facilitating in practice, there is a fourth pathway missing from the list. They envision and would actually prefer an *integrated pathway*, one that results from a design process of a system that iteratively and modularly - more product or service - grows through cross-functional and multi-disciplinary stakeholder input, constant discussion and convergence, and that really brings an experience to the user. In this research, the *integrated* development perspective will form the starting point for the conceptualization of PSS.

Table 2.5 | PSS process dynamics, an extension of Dewit and De Roeck (2014)

sequential		The company already has the product and/or service and you want to add, combine or develop the other part [servitization | productization], frequently this addition comes in later stages
nested		Developed from scratch, the design process starts from the product side and stepwise iterates to meet the necessary service aspects [or vice versa]
parallel		Product and service component sides remain, clear interdependency, work closely together, iterate regularly, add newness through its combination and confront it with the user
integrated		The PSS iteratively grows [constant discussion | convergence], the design process strategically [cross-functional & multidisciplinary] integrates product and service in experience to the user

2.3.3 The conceptualization of PSS

Coming up to this point, we have developed an insight into the terminology used in relation to PSS, drivers and transition dynamics. However, in order to support the PSS design process as such, we first need to build a thorough understanding of the concept itself.

Therefore, we brought together forty-six PSS definitions and connected the related theory, each with its typically sustainable-, economic- or user-oriented focus. Obviously, these three foci put a different type of emphasis on various priorities and expectations of PSS (Mont, 2004). However, since sustainability is a possible benefit of a PSS but not a necessary element for the system to be a PSS (Haase et al., 2017), we rule out the sustainability-oriented definitions. Regularly intertwined, it was less obvious to separate economic- and user-oriented definitions and approaches as two different goals, therefore both streams have been taken into this review. Justified by a systematic literature review on PSS definitions by Haase, Pigosso and McAloone (2017), we see a clear convergence regarding two key characteristics of PSS, the integration of *product and services* as well as the focus on *customer needs.* We will move forward with definitions similar to those, as coined in Table 2.6.

Taking a closer look at PSS, in 1977 Shostack (1977) suggested *marketable offerings* for combinations of products and services. Twenty years later the term product-service systems first appeared in a publication of Goedkoop et al. (1999), extending the definition with "capable of jointly fulfilling a user's need". In 2003 Manzini and Vezzoli (2003) added and described PSS "as an innovation strategy, shifting the business focus from designing physical products only, to designing a system of products and services which are jointly capable of fulfilling specific client demands". And although many authors in the field of PSS contributed, no general accepted definition is formulated so far (Haase et al., 2017). This is why we explore in greater depth the structure of the multiplicity of PSS definitions, and more specifically (Section 1.2.2) this research will outline the importance of products and services, integrated and designed to advance the user experience (Gemser, Kuijken, Wijnberg, & Van Erp, 2012; Stacey & Tether, 2015; Tischner & Vezzoli, 2009) in the early stages of PSS design.

Table 2.6 | PSS definitions or related concept descriptions

Author	**PSS definition or related description / concept**
Cooper & Evans, 2000	With 'product-service' we simply want to indicate a **value proposition that derives its value from a significant part from both the product- as service element**.
Manzini & Vezzoli, 2003	PSS is understood as the result of an innovative strategy that shifts the center of business from the design and sale of (physical) products alone, to the offer of **product and service systems that are together able to satisfy a particular demand**.
Manzini & Vezzoli, 2003	The PSS business model is based on a new interpretation of the concept of 'product': the product of a firm is not the physical result of an industrial process of production but the product of a firm is an **integrated whole of mutually dependent products and services that focus on meeting demands from customers** (both business and final users).
Tan, McAloone, & Matzen, 2009	PSS is a shift in business strategy from a **product-oriented to a service oriented focus**, where instead of the product itself, the activity, its utility and performance associated with the use of the product are considered to be of **more value to the customer**.
Smith, Maull, & Ng, 2012	Servitization has led to the emergence of **complex combinations consisting of both products and services in order to create more value for the customer** and at the same time to distinguish itself from the competition. Within this transition are combinations of both products and services, which are better known as product-service systems.
Ceschin, 2012	PSS can be described as an **integrated system of products and services**, delivered by one or more socio-economic actors, and designed to **fulfil a specific customer need**.

The experts confirm the pursuit of a more economic- and user-oriented focus, and obvious from the interviews, they leave out every phrasing that refers to sustainable aspects. According to them, it is not the distinguishing factor to strategically engage in, unless enforced by law or public awareness and related pressure. They do also recognize the two key characteristics, the *integration of product and service*, and the *user experience.*

Organizations might tackle a need apart from any experience at all and work purely on performance. But without the focus on the user, it's bound to end up in technology or market driven products. Fortunately with the rise of PSS - especially recognizing the service part in the transition toward PSS - more interaction comes into play between people, beyond user friendliness or usability. With services and less(er) tangible components (Young, 2008), the experience has become more important because once it is about human interaction and emotion, e.g., sharing economy concepts are more than just a cost argument or a reduction of the amount of products sold, it also a way to involve and engage people. It's constantly about the experience the users may have, interacting with each other, product and service side and trying to keep that as positive and as long as possible.

The user experience clearly has an intermediate role, hence it requires a necessary presence throughout the entire process. Nonetheless, it's important to understand how this product-service

integration takes place throughout the process. We therefore continued our search by means of a semantic analysis, looking for characteristics and recurring (key)words within the definitions of PSS and its related terminology (n=46) relevant in the PSS design process (e.g., Baines et al., 2007; Brezet et al., 2001; Ceschin, 2012; Edvardsson et al., 2005; Goedkoop et al., 1999; Vijaykumar, Hussain, Roy, Tiwari, & Evans, 2011; Manzini & Vezzoli, 2003; Maussang, Brissaud, & Zwolinski, 2007; McAloone & Andreasen, 2004; Mont, 2002a; Morelli, 2002a; Raijmakers et al., 2012; Roy et al., 2009; Sadek & Köster, 2011a; Chan, 2003; Tan, Mcaloone, & Andreasen, 2006; Tan et al., 2009; Tischner & Vezzoli, 2009; Tukker & Tischner, 2004; Wild, 2009). Elaborating on characteristics defined by Vijaykumar and Rajkumar (2012), we connected its relevance to the context of PSS design and have built a concept-matrix, resulting in six clusters that emerge from the review: 'value constellation'; 'evaluation criteria / selection'; 'integration'; 'scenarios'; 'product/service definition'; and 'user centered', apparent in the left column of Table 2.7. According to us, these clusters form the building blocks for a good understanding of our concept, PSS. During the interviews, our experts also gave their personal definition of PSS or described the concept according to their experiences in practice. The recurrent elements from their descriptions are mapped in Table 2.7 corresponding to the ones derived from the PSS definitions in literature.

- A 1st cluster '**value constellation**' articulates opportunities for development of innovative business models and creation of (new) business. Using existing or creating new (information) networks enables companies to formulate a new value proposition from different perspectives. Multiple stakeholders can then decide on their part in the provision of infrastructure and responsibility that builds the value constellation.
- The 2nd cluster '**evaluation criteria / selection**' focusses on the benefits for the different stakeholders in the system. Product-service systems evoke different expectations of the output, this is why new criteria are necessary to evaluate expectations and user experience with the parts of the system.
- A 3rd cluster '**integration**' stresses that the integration of products and services into a unique offer should already be applied as early as possible.
- The 4th cluster '**scenarios**' has two components; a first considers the aspect of interaction, the other entails the aspects of time. Scenarios consider a predesigned experience with a planned purpose. It holds the formulation of key elements of the offering, associated to the user and activities, where exchanges between the product-service system, its users and provider become explicit. Another aspect is the flow of events to be designed, e.g., the use phase, which can best be described as a sequence of multiple, interrelated touchpoints. It tries to determine utilization and reaction to the product-service system with regard to the side effects.
- The 5th cluster '**product/service definition**' discusses material intensity, creates substitution options between the product and service elements or components and its respective added value. The aim is to extend products and services to increase value and advance the user experience with this new interpretation of the concept 'product' and being able to offer a unique solution.
- A final 6th cluster '**user centered**' sets a primary objective to satisfy customer value. This can be attained by considering early (stakeholder) involvement and co-creation.

Table 2.7 | Concept-matrix - recurring elements in literature (left), and in practice (right)

Building blocks	Recurrent PSS definition elements	Contextualization by experts
Value constellation	Innovative (new) business model creation, value proposition, system of infrastructure, network, different perspectives, responsibility, property rights actors, and stakeholders	Ecosystem; value proposition; end user and other people's characteristics within (affected by or affecting) the context or system (as is)
Evaluation criteria / selection	Innovation strategy, business shift, competitive (advantage), differentiation, effective and efficient, (added) value in use, for all stakeholders	Context (project brief) dependent; discussion and convergence approach; both components add value (criteria); checking perspective affected/-ing
Integration	Mix, integration, system, (complex) combination, whole, joint development, bundle, mutually interrelated / dependent, configuration	The process of getting products and services combined in the system; providing a solution regardless of its components
Scenarios	Predesigned, planned purpose, sequence of interrelated life cycle phases and activities, determining utilization of product/service side effects, executional interventions (interactions between product/service, user and provider)	The transition from 'as is' toward 'to be'; enabling the solution to come about and grow naturally; it holds something more complete, the system, a story
Product / service definition	A new interpretation of concept 'product', 'everything is a service', combining non technological and technological parts into offering, solution	Briefing or defining the specifications of the to be solution, whatever the designed components (touch points) might be - affecting the context
User centered	Satisfying the customer, fulfill (social) demand, consumer market(ed), perspective, needs, value(s), targeted, personalized, co-created, an experience	Verifying a user's perspective (central) throughout the entire process; bring a valued experience to those affected by the as is / to be context

Using the characteristics from the building blocks in Table 2.7, multiple configurations of PSS definitions are possible. We bring forward our personal version that adds to and to some extent redefines PSS:

PSS design is a constant discussion and convergence approach to understand, explore and define different perspectives on value of those that affect the context and others that are affected by it. Regardless of the distribution of product and service components in the solution, the PSS aims to sustain the ecosystem and allow continuous growth, essential to keep the PSS alive and enable the transition that goes beyond the design itself, toward meaningful innovation. It's not about the design of the solution itself, but the enablers that make the envisioned change come about naturally (Dewit et al., 2016).

We continue to build on these building blocks and delve deeper into the process of designing PSS, to understand the preconditions that are necessary to support that process before actually building the PSS design toolkit.

We used the same sources for a second part of the analysis, and unraveled the theory behind PSS and its related terminology on the basis of the different integration approaches (Section 1.2.2.3). This made it possible to make the similarities of products and services apparent (assimilation approach). Furthermore, the literature review clarified a range of differences between products and services on their respective characteristics when it comes to the design, development, process and methods.

Principally, based on what the product is, the service is not (demarcation approach). Though, we have to take into account that these highlighted differences and similarities are frequently dependent on (1) the type of approach to analyze product and service innovation, and (2) the research that has been executed accordingly. So by acknowledging these dis/similarities, the context boundaries and peripheral characteristics of PSS become more obvious. Integrating product and service will bring neglected characteristics of innovation to the surface that are relevant for products as well as services (synthesis approach).

Our earlier defined clusters from Table 2.7 served as a basis to bundle the characteristics. In addition and in order to arrange them, we related to an overview of activities being performed in the Front-End of Innovation (Jacoby, 2012). Based on different process models in innovation context, Jacoby (2012) clusters these activities into three - generally agreed upon - major domains: *exploring activities, idea generating activities,* and *product and project defining activities*. Arranged per activity level, as a clear focus and iterative support alongside the design process, the first five clusters ('value constellation'; 'evaluation criteria / selection'; 'integration'; 'scenarios'; 'product/service definition') will be used to describe the gradual integration of product and service, and form the basis for the list of preconditions. The remaining sixth cluster 'user centered' will be kept at the center throughout the entire design process. In this way, our PSS design process will be based upon an explicit understanding of the user, the value in use - what the user wants to do with the system - and the context of use, the environment in which the product-service system is used.

Based on this, we have described the characteristics derived from literature as a preliminary list of preconditions (**Appendix V**) alongside the three domains of the FEI (exploration, ideation, definition), and used it as a research instrument to discuss and justify this list with the experts. They have verified and contextualized each of the original twenty-four preconditions on that list, grouped them according to their respective FEI level, and recommended some evident changes that resulted into the definitive list of 21 preconditions. Ultimately, we want to develop a toolkit that is practice oriented, therefore we consciously use the terminology as expressed by the experts, because together with the design students, they will be using it.

The changes to the preliminary list of preconditions were made based on terminology of the clusters, i.e., 'evaluation criteria' changed into 'evaluation mindset', 'evaluation/selection' into 'selection approach' and 'product/service definition' into 'product-service system'. The FEI-levels were adjusted to *understand, explore, define*, which has no influence on the process, but allows for a better alignment with the PSS design toolkit in Chapters 3-6. 'Understand' expresses the first level better, being about the context, 'explore' is a broader term than 'idea generation' when looking ate the preconditions for this level, and 'define' replaces 'definition'. Also, all three of them are verbs and call for action, opposed to rather descriptive terminology. Other adjustments influenced the sequence of the preconditions and its relation to the design process, i.e., precondition 24 came more to the front, enabling the selection of the concept before the definition of the PSS. Finally, precondition 6 was deleted based on similar content, preconditions 21 and 22 were removed because they resembled a trait of the process, rather than being a precondition. Together with the contextualization by the experts, we were able to adjust the list of preconditions (Table 2.8) and visually represent the definitive list of twenty-one preconditions related to the PSS design process in Figure 2.5.

2.4 PSS design process preconditions

A PSS process or approach - depending on the project - has to start from the beginning onward to see it as a whole. According to Jacoby (2012), the innovation processes of products and services depend to a large extent on the input for the process, the reason why we focus on the early stages or Front-End of Innovation (FEI). Pointed out by prior research (Langerak et al., 2004; Reid & De Brentani, 2004), FEI decisions impact both product and service parts in the supposed offer, decisions taken in the development phase can only have an impact on partial aspects of the product or service (Dewit, 2014).

New products and services show increased complexity and put additional pressure on an approach that holds not only the design of separate elements but also the integration of products and services and how they work together. When products and services are not coordinated and connected enough, it leads to sub-optimal results (Tischner & Vezzoli, 2009). Therefore, these preconditions enable a synergy between products and services when thinking about innovation strategies. More specifically, it aims to ensure that the product and service parts and their characteristics are addressed in the front-end of innovation.

If there is a strategic intent to innovate with the PSS, companies need to pay attention to PSS specific innovation capabilities in the FEI (Karlsson et al., 2017). The twenty-one preconditions can be seen as drivers for innovation that are of relevance for products as well as services and that may positively affect early stage PSS design, depending on the type and extent of adoption. These preconditions refer to an organization's general disposition toward change, and its willingness for innovation with the aim to develop and introduce more innovative new products and services (Nijssen et al., 2006). An organization’s success is determined by the existence of organization-specific unique resources (Maier, 2007), core competences and its dynamic capabilities. Figure 2.5 and its related Table 2.8 suggests an approach to judge these organizational *propensities* for innovation (Mosakowski, 1998; Nijssen et al., 2006) specific to the PSS design process.

Table 2.8 presents the theoretical descriptions of the twenty-one preconditions and their respective expert contextualization. When it comes to a strategic mindset and tactical support for PSS design, the experts assert that these preconditions can work as a typology of decisions to be taken on different levels. Operationalized, it provides a staged process to integrate and design products and services in close relation to whom it was designed for, the people. The process preconditions can be seen as a solid ground, to which people can look, discuss upon, and position themselves in the transition toward integrated logic. The experts state that organizations would considerably benefit from a clear set of PSS characteristics that can be used alongside the PSS design process (Valencia et al., 2015). These characteristics could then be used for evaluative purposes, to look how criteria are in place now and whether they are still relevant after some time (Dewit, 2014, 2016). This PSS design preconditions framework can thus be used as a kind of checkbox, as such the organization can judge whether the preconditions are met, before they decide to go to the next level in the process. Subsequently we summarize and visualize the twenty-one preconditions alongside the PSS design process in Figure 2.5 (enlarged in **Appendix VI**) for readability purposes of Table 2.8.

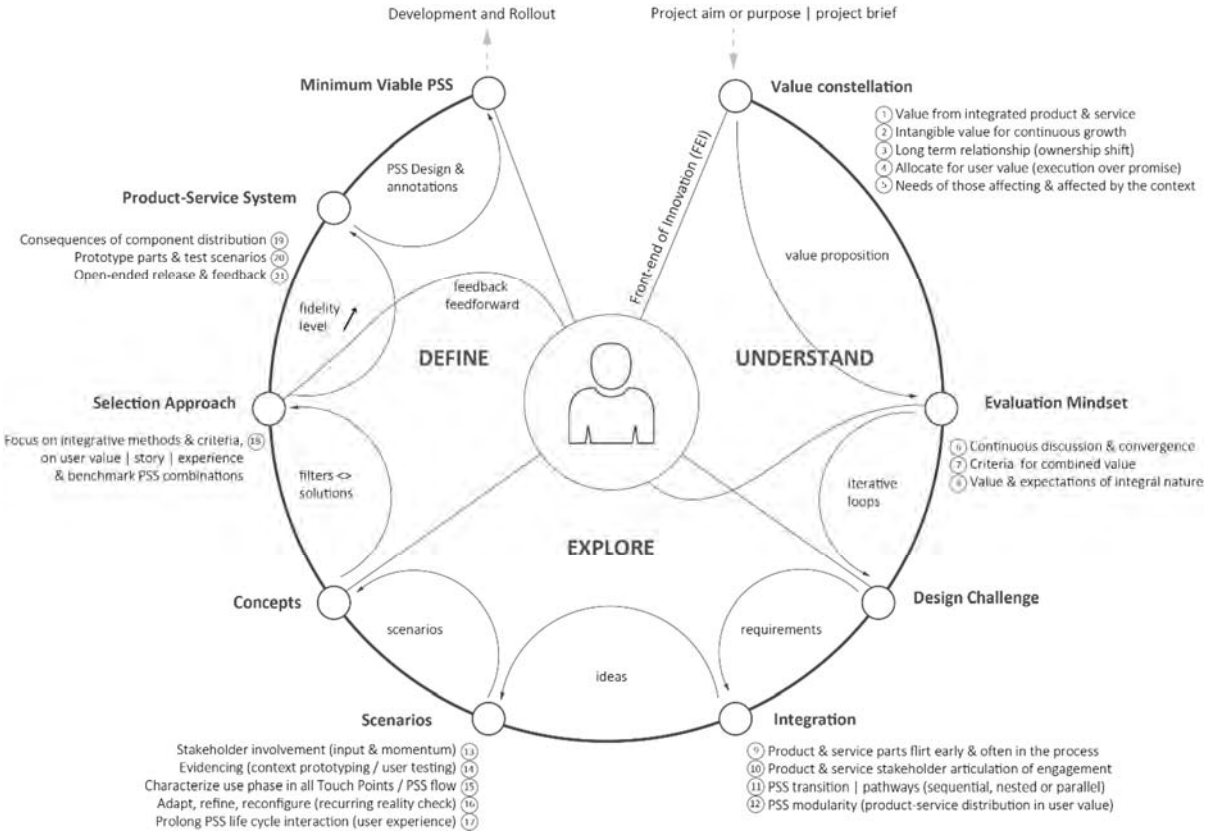


Figure 2.5 | PSS design preconditions framework

The empirical data based on our interviews provided us with more contextualized information and showed us that we should be using different terminology on several topics, changing the sequence for some of the clusters (e.g., evaluation/selection should come before product/service definition), and after discussing on each precondition, we were able to refine and adapt the preconditions to their final version. Respectively, the (practical) experts' contextualization follow the (academic) preconditions derived from literature on PSS. Depending on the type and extent of adoption of these 'pracademic' preconditions, they positively affect an organization's general disposition toward an innovative product-service transition (Nijssen et al., 2006) and the resources, capabilities and competences in each of the PSS lifecycle activities to enable that (Maier, 2007). The in-depth interviews elaborated on the organizations' process preconditions that support planning, design, development and management when unifying product and service components in cooperation with the members of the ecosystem (Johnson & Mena, 2008; Mont, 2002b). Besides the typical drivers, e.g., market demand, branding considerations, and technological innovations, companies might envision a more holistic notion of user experience (Verganti, 2008, 2009), with direct implications for PSS implementation, operation, evaluation, and management.

Table 2.8 | PSS process preconditions, an extension of the original list of preconditions (Dewit, 2014, 2016)

Precondition	Description	Contextualization by experts
	UNDERSTAND	
	Value constellation	
1 | Value from integrated product & service	Recognize PSS potential and think more in terms and opportunities of product service systems (Tukker & Tischner, 2004).	A transition toward PSS is about creating more value for people, the ecosystem and society. A clear understanding of the concept of PSS (value from product and service) and its systemic (design) approach is necessary; on C-level management for hierarchical organizations and widespread involvement for flat structures.
2 | Intangible value for continuous growth	State early 'freedom to operate' requirements for an IP strategy, constructing good contracts with other providing stakeholders in the (eco-) system (Tukker & Tischner, 2004).	What is in it for them (to buy-in)? You cannot (up-front) know the real advantage of the PSS and where the value comes from. Services, interactions and experiences are hard to patent (usually influencing the offering in a positive way) - making entropy, continuous growth and innovation (of the ecosystem) inherent and essential to keep the PSS alive *(e.g., patents could have the tendency to kill that entropy)*.
3 | Long term relationship (ownership shift)	Discuss and explore a possible longer or different pay back. Modern business PSS no longer have linear supply chains made up of producers, assemblers and distributors, but by groupings of firms that operate in what authors have termed value constellations tied together by a business innovation strategy (Normann & Ramírez, 1993). The PSS flow is therefore not directly linked to the money flow, making it difficult to compare costs, benefits and economic reward (Cantamessa, 2011; Cooper & Evans, 2000; Johne & Storey, 1998; Nijssen et al., 2006).	Because of the evolving nature of the system over time, long-term thinking is indispensable. However, due to short-term accountability, everything is still short term thinking, few are busy with what is going to happen in 5 years. The *capital-intensive argument*; extent of engagement and profit sharing among actors that participate in the development and provision of the PSS. Not every company considers shutting down their primary source of income. Stepwise grow toward secondary sources of income *(e.g., renting, leasing, sharing, pay-per-use, etc.)* impacting financial structure and business model. The *cultural driven argument*; the degree of innovativeness, risk taking, etc. is decisive. Also, bear in mind that a shift in ownership has consequences on the relationship of the user with the PSS beyond the exchange *(e.g., exposure, knowledge, general resources, time, etc.).* Can you own a service or an experience?
4 | Allocate for user value (execution over promise)	Allocate means for a higher brand execution (design) versus lower brand promise (marketing) (Tukker, 2004; Vandermerwe & Rada, 1988). Often organizations create the story of a product in isolation from the actual creation of that product. This disconnect has led to customers buying products and services only to be disappointed that their experiences don't match the stories they've been told. (Merholz et al., 2008)	Smaller companies are closer to the money and therefore more easily prepared to allocate differently, which provides a big opportunity for SMEs. Larger companies have more difficulty with this, (re)allocation is rather structurally embedded. Furthermore, frequently sales and marketing are closer to the C-level management, which has a rather sales-driven, short-term effect on business *(e.g., incentives policy, sell more of what sells well and often it is not that different from the competition)* and this market pull situation tends to dictate R&D (brand promise). However, blurring boundaries between marketing and design are favorable to a more long-term user lock-in (brand execution), integrating product and service far beyond the sale.
5 | Needs of those affecting & affected by the context	Consider co-creation in a broad sense, build strategic relations with executors, actors, stakeholders, customers, clients, (information) network(s) and a range of separated disciplines for the design of PSS (Van Erp, 2011; Drejer, 2004; Morelli, 2002; Tukker & Tischner, 2004). The	In order to design PSS, user experience and human centered approaches are of utmost importance for 'co-exploration' on this level. If you want to improve aspects of someone's life (ensuring value delivery), you have to keep the user (and his/her) experience as the focus of your effort *(e.g., personas: the paper users, day-in-a-life)*. This implies the necessary inclusion of those affecting the context and those affected by it

	multiplicity of needs and inputs are essential elements in the front-end of PSS development and design (Müller, Kebir, Stark, & Blessing, 2009; Van Halen et al., 2005). User centered and service-dominant principles are vital to ensure that the design addresses the whole user experience.	*(e.g., nobody likes the perspective of moving to a nursing home, but everybody wants to stay at a hotel, however vague the border).* Align all stakeholders from the beginning onward, providing a variety of angles on the problem/opportunity to hopefully result in a combined/shared vision on how to conceive a solution together. Noteworthy, they are easier bought-in after ideation - because of unfamiliarity with the creative process and related insecurity - when they see a more tangible version of the PSS.
EXPLORE Evaluation mindset		
6 | Continuous discussion & convergence	Since a precise separation between products and services is not feasible during the development or during the delivery phase (Meier et al., 2010), decide on similar project gates for products and services. In order to integrate product and service design processes, the same semantics that are used to describe product attributes should be used for service attributes. It is vital that managers and engineering designers recognize both the differences between product and service design and the strategic linkages between the two areas (Kindström & Kowalkowski, 2009).	Products are more easily comparable, but opposed to product development (and process) efficiency, the 'raison d'être' for services is at larger risk and the mistakes for (new) services still have to be made to close the feedback loop. For product and service (project) gates, the process of continuous discussion helps convergence (from multiple) toward a (one) solution, agreed on by everyone *(e.g., with their signature)*. You need milestones to take decisions, but not really Go/No Go. It is iterative, using different lenses with frequent intermediate checks to enable faster and constant user testing and iteration, especially for the service part *(e.g., hiring 5 employees with a specific profile toward customer friendliness, opposed to the cost for an injection-molding prototype and testing)* and always forward. Building up a project dictionary helps to merge disciplines and semantics, because a more SD logic, service, brand and (user) experience vocabulary comes into play. Visualization and (early) prototypes also provide a way to overcome the language barrier, respectively the filmic service part merging the interactive product part.
7 | Criteria for combined value	Include explicit evaluation and selection criteria (Gokula Vijaykumar et al., 2012), there is more at stake than a trade-off between function and cost of realization only (Isaksson, Larsson, & Johansson, 2011). Go/No Go decision criteria should also include immaterial value created by PSS (e.g. market position, convenience, customer relation) (Tukker & Tischner, 2004).	Problematic for brainstorms 'as-usual', is the inability to evaluate and select what is on the table afterward. These up-front criteria lend to discuss and understand the PSS, its specific elements or different (but equally successful) combinations throughout a more formalized PSS evaluation process; (1) criteria derived from the business strategy, *e.g., financial, logistical, distribution channel, organizational*; (2) criteria linked to the project playground and feasibility, *e.g., how far you can go within existing or less/more resources like time, budget, machinery, employees;* (3) criteria recurrent for each project they encounter, *e.g., how far away from actual proposition*; (4) criteria formed throughout the process, together with the gradually growing PSS concept and (5) testing it with the user, over and over.
8 | Value & expectations of integral nature	Expect differences in testing a PSS idea, because intangible aspects (e.g. user experience) set different expectations on product and service part in the offering (Tukker & Tischner, 2004). The aim here is to enable them not just to evaluate alternatives (a better body of knowledge), but especially to experience the world in	User experience and human centered design tend to put a focus on different value(s) subject to the context, frequently busting traditional assumptions. Therefore, an external facilitating role is able to put a specific focus on that *(to counter e.g., facial expressions from the R&D department)*. Bear in mind that after an ideation, you will have some good ideas that do not match the criteria, but you still want to pick up. Establish criteria up-front and attach weight, but be flexible enough! Do not use only one way to evaluate, vary *(e.g., selection matrix, value*

	more and richer ways. (a greater capacity for experience) (Simon, 1997).	*innovation, power interest grid, BM canvas)* because the integral character of the idea is important. The real calculations should be performed after the PSS scenarios and concepts roll out *(e.g., the offering does not have to be cheaper, but the better experience opposed to the competition. That is the differentiator, the impact and real value for the user).*
	EXPLORE Integration	
9 | Product & service parts flirt early & often in the process	Acknowledge the integration of how product and service work together instead of designing of separate elements (Johne & Storey, 1998; Sadek & Köster, 2011; Van Erp, 2011). Companies still regularly design a product and then a service, afterward they put it together.	When product and service meet at the first user test, it's too late. Both disciplines should match their work and iterate as often as possible, a continuous process of diverging, converging and cooperation toward milestones to check the project's performance and progress (without setting the condition for accountability). If it has to be an integrated offering, you need an integrated design approach. Obviously, there are different (path)ways to undertake PSS design, affecting the type of cooperation and integration of both product and service (side).
10 | Product & service stakeholder articulation of engagement	Consider product-service interdepend-dencies already in the front-end of PSS development (Gokula Vijaykumar et al., 2012; Kowalkowski, 2010; Müller et al., 2009; Sadek & Köster, 2011).	At the moment of the strategic planning of the project, both product and service side stakeholders should articulating how (far) they want to engage, better understanding the aim of the project and its purpose. This enables modularity in PSS later on.
11 | PSS transition | pathways (sequential, nested, parallel or integrated)	Decide whether the product has to be designed to meet the service aspects and vice versa (Sadek & Köster, 2011; Tukker & Tischner, 2004).	It's an interesting point of view to have the product or service adapt to each other, enabling essential diverging and converging *(e.g., unfortunately, habitually the service adapts to the product, in later stages and because of cost considerations)*
12 | PSS modularity (product service responsibility for user value)	Recognize differences in the design and strategic linkages between products and services (Johne, 1993; Kindström & Kowalkowski, 2009; Kowalkowski, 2010; Nijssen et al., 2006).	For the provider there are some differences in the metrics for services versus products. It is interesting to know to what extent product and/or service are responsible for value to optimize different options or recalibrate PSS combinations. For the customer, the PSS is one solution, the difference between product or service side is not apparent, thus making the feedback process probably the same in terms of experience *(e.g., the value of "today people thought of you 55 times" can be translated into a product or service requirement.)*
	EXPLORE Scenarios	
13 | Stakeholder involvement (input & momentum)	Co-creation on different levels, actively involves different actors and stakeholders in the front-end of PSS design. Put customer needs and input central in different stages of the development process, according to user centered and service-dominant logic principles (Drejer, 2004; Morelli, 2002; Müller et al., 2009; Tukker & Tischner, 2004; Van Erp, 2011; Van Halen et al., 2005).	You should co-create from day one with a vast array of involvement and stakeholders types *(e.g., serious play, body storming, and customer journey)*. Terminologically, stakeholder involvement in the ideation phase could be called 'cogeneration' instead; you are not creating anything yet. However, companies' belief in 'co-creation' in its pure form has strongly diminished *(e.g., co-creation after the FEI becomes more difficult for the product part; having their own skills seems enough to guarantee the quality of the PSS scenario; the fear for loss of image to the customer when creating expectations they cannot live up to).* Nevertheless, the PSS process requires a steering and user committee that makes sure those efforts are 'coordinated', creating a momentum and the acceptance for the PSS through recurrent user testing.
14 |	Provide insights in front and back office implications and their lines of visibility	Evidencing is an important issue in the ideation stage, because front and back end implications come into play. There is always

Evidencing (context prototyping / user testing)	(Edvardsson & Olsson, 1996; Johne, 1993; Johne & Storey, 1998; Lievens, 2000; Menor, Tatikonda, & Sampson, 2002; Nijssen et al., 2006).	something happening - the context, another user or an employee - that makes the connection and defines the interaction with product and/or service. If the company takes it into account, they should postpone their judgement, otherwise you put constraints where you should actually just develop and prototype the concept. Once the prototypes have been tested, you can see it accepted with the user. Only then, the feasibility, costs and implementation implications should be discussed.
15 | Characterize use phase in all Touch Points / PSS flow	Characterize the use phase in PSS through planned or designed events and organize the flow (Eekels, 1994; McAloone & Andreasen, 2004; Morelli, 2002).	Using human centered design principles, the user (experience) is put at the center as early in the process as possible that makes it easier to characterize the use phase or journey. Even without a solution, it makes you see/imagine the opportunities or flaws (easier for the service part) in the PSS flow and each of its touch points *(e.g., after sales, suddenly another department is responsible, shifting the UX)*.
16 | Adapt, refine, reconfigure (recurring reality check)	Align different time frames and generate product and service in interaction with user (Morelli, 2002).	Probably easier for the service, yet prototypes trigger conversation and early customer feedback (continuous feedback loops). This should be taken into account in the definition level, by means of reality check to refine, adapt in the market and reconfigure the PSS offering. The first mover initiatives *(e.g., car sharing or clothing libraries)* don't have to be perfect, afterward alignment should allow no breach in the flow of the user experience, interacting with product *(e.g., availability)* or service part *(e.g., registration and payment)*. Think in terms of time (long term) and touch points throughout the customer journey.
17 | Prolong PSS life cycle interaction (user experience)	Aim to design for a higher brand execution (design) versus a lower brand promise (marketing) (Tukker, 2004; Vandermerwe & Rada, 1988).	If you want a consistent brand (promise) and corporate identity, you want to convey this through every touch point as early as possible, it increases credibility later in the process *(e.g., the user wouldn't care if the PSS is coming out now - as it is - or later, when the product/service part is at a better stage when introduced, s/he doesn't know and this leaves room for improvement when expectation levels go up)*. It's probably easier for the service component, but worth the discussion for the product part, growing from value-in-exchange toward value-in-use (execution) and long term customer relation (*e.g., prolonging life cycle interaction through touch points in each level: pre-experience - the experience - post-experience).*
	DEFINE	
	Selection approach	
18 | Focus on integrative methods & criteria, on user value | story | experience & benchmark PSS combinations	Use the criteria to evaluate and select the PSS concept, because the inclusion of intangible aspects set different expectations on product and service part (Tukker & Tischner, 2004).	Reconsider the criteria from condition 7, use multiple ways to evaluate and put emphasis on variation because of the integral character of PSS. Make sure that the subjective (hate/love) filter is as objective as possible *(e.g., 7 out of 10 people of the target group should find the design beautiful)*, make the criteria measurable (attach weight to them), in function of filters instead of solutions, continuous evaluation (discussion) and selection (convergence) *(e.g., Power interest grid, selection matrix, value exchange board)*
19 | Consequences of component distribution	Describe value in each part and make explicit to what extent products and services are mixed (Tukker & Tischner, 2004).	For the company it is interesting to know when to evaluate or relatively benchmark the system itself and provide possibilities for modularity - the weight of the product/service part - of the PSS. Noteworthy for companies, since society is sliding from

		products to services (away from pure ownership), the real value for the customer grows toward the overall experience, the story *(e.g., Apple: feel the music).* How can we achieve what, for who, by who, by doing what?
	DEFINE (Product-service) system	
20 | Prototype parts & test scenarios	Consider prerequisites for products and services, rather than for product or service separately (Edvardsson & Olsson, 1996; Nijssen et al., 2006). By adding products or services to the offering, consider their consequences in the design, determine utilization and reactions to PSS, effects and side-effects (Eekels, 1994; McAloone & Andreasen, 2004). Consequently ensure that all variables are catered for as far as possible (Morelli, 2002). Consider that provision of services involves a number of tangible and intangible elements, the supply of products relies on culmination of a chain of services (Cooper & Evans, 2000; Tukker & Tischner, 2004).	Lacking the core competences to add the service part or vice versa has its consequences on a proper component distribution, sliding the PSS concept alongside the product-to-service continuum might target a completely different customer segment *(e.g., a company can sell a product, but sharing or selling a service has very different effects on the current business model)*. Coherence and consistency of the PSS can come in later on as a differentiation strategy in the market, because end users grow toward standards, the norm and the expectancy level goes up. Service (design) input is delivered throughout the process, the research, the interactive sessions and creation process and usually takes utilization, effects, and side effects into account. Firstly, it depends on all iterations of the PSS concept and grows with the project. Secondly, the company should consider the nature of PSS, its typical growth over time and could already plan for addition or modification later on *(e.g., mobile payment, if it is not compatible with let's say Apple, people might lose their belief in the payment system in general)*. For the product part, this does not come back enough later in the process, because of a value-in-exchange focus. For PSS design, this comes in later and really depends on all iterations. It grows, you can really see if it attaches to the real needs and wants, formulated and agreed upon in the original design challenge.
21 | Open-ended release & feedback	Enable possibilities for early prototyping and open-ended releases, providing a means for a better assessment of the outcome. The most appropriate design for a PSS cannot be achieved without iteration.	Far easier for the service part but commonly agreed upon, early prototyping provides early customer feedback. You can get people to touch and feel it, then you can adapt it, and so on, *e.g., cardboard, plasticine, narratives, process maps etc.* If you have something tangible, it's better to discuss upon than an abstract idea in words, *e.g., make belief, pretending the prototype works; appropriate fidelity prototyping, some parts are more detailed than others depending on the goal of the prototype.* If the company needs additional input, it can launch the PSS open(-ended) into the market, testing parts or the scenario, already enabling your customers to lock-in really early and refine and reconfigure the product and/or service part. Optimally you; design, prototype, test, release, improve and integrate feedback loops from the customer side to continuously improve the PSS concept, *e.g., "I would like to have this, change that, too difficult for me"*. PSS design and development should be more open so that other elements can join / connect later in time, *e.g., Apple's app store, NIKO Home Control is thinking what to connect to their domotics.* The prototype (with necessary annotations) allows testing its intended delivery of (user) experience value, essential in times of growing standards and expectancy levels.

2.5 A plea for PSS

In this section, we summarize our empirical findings and experience in interacting with organizations' projects in a PSS context. We pay specific attention to its relevance for practitioners.

There is a clear shift toward intangibles and the addition of service components to the current offering, pure product development evolves toward (product and service) design in innovation. However, it loses its integrality if organizations cannot design a product and then add a service to it or vice versa. A PSS process or approach - depending on the project - has to start from the beginning onward to see it as a one whole. According to the experts, 'PSS' as such doesn't frequently appear in a company's strategy, however more often specific wording of product-service - the addition of its components and the design - and intangibles do.

It merely reflects society, that evolves from manufacturing, alongside and intertwining with the omnipresent share of service provision in an ever more growing experience economy (expert).

Right next to intangibles, strategies frequently integrate user centeredness as well, at least to be able aiming for a better customer or user experience (UX). Ideally, UX should be central throughout the design process and result in product and service specifications, but in reality, it is still very much used as a marketing tool to appeal aesthetically and emotionally to potential buyers.

However, choosing for 'PSS' would affect the typical project briefing. In that case, the organization does not choose to design a product and a service, they deliberately choose to design a system. Without this distinction - product or service - companies grow toward a better design challenge and actually start designing a system. What rolls out of the process later on - product and/or service components - comes to the surface during the development of scenarios, where one finds out which needs are better solved by a product or by a service, and combined into the system. However regularly the organization already has a certain set of facilities, a portfolio, a market and related expertise, and unfortunately this leads to vague project briefings and an ill-defined problem definition to start from. It's particularly difficult to design and evaluate a good service, product-service or experience when (1) a company is not clear on what they want and (2) evaluation criteria are still very product-driven. Moreover, managers tend to link their strategy to making something concrete; a product or a service. However, clearly emerging from the interviews:

If you get managers to link with Service-Dominant logic, you can get them to think about the needs, a more intangible talk (e.g., aging) that links the innovation strategy to a long-term horizon (expert).

With the integration of a service component, the way we look at the design briefing is changing or at least bound to change. Product-service systems are evaluated differently, the same criteria for product and service do not work. Adding a product or service component sets other focal points in the strategy and asks for different questions during exploration and ideation. The process should be more in function of filters - continuous evaluation and selection - instead of in function of solutions.

Besides (e.g., product) appearance and usability, the whole service provision (sequence of touchpoints) is important in every aspect where the user's experience - strategically - is to be kept as optimal and as long as possible (expert).

A lot goes wrong when implementing PSS, due to the difficulties of bringing theory in practice. Inside the company, everyone should also agree on the principles of human centered design (HCD), but the

profundity always depends on the project and its context. The deeper it goes, the more you involve people into the process, which makes it evolve toward co-creation. That is why specific tools and their unique purpose come into play (e.g., context mapping, customer journeys, scenarios, etc.).

The danger is to pull the user linearly through the process, which has absolutely nothing to do with the user experience (expert).

Undisputed by the experts, co-operation is the core of PSS, a facilitated multidisciplinary effort supports the incorporation and internalization of the knowledge and competence to the core-business of the company, if not present. This hybrid implementation starts with the right amount of PSS design expertise, possibly together with a design agency that facilitates a specific set of tools and enables collaboration between the company itself and the other stakeholders in the ecosystem. Short follow-ups have shown that companies can deliver some preliminary work themselves (e.g., preparation of personas), necessary to really push the internalization of PSS (design) knowledge, and necessary because the company will continuously have to adjust the service part.

It's not the product anymore that you can put on the market that's good for three years. Services are alive, they are the people, and if that is not embedded in the culture of the company, it will not work (expert).

Facilitation should not be mistaken for complete outsourcing. The company will end up with something that is not theirs, relying too much on that external partner's knowledge. The design or consultancy agency might (appear to) be doing too much their own thing, instead of learning the people in the organization how to do it on their own. It depends on what the company wants, and external agencies get paid by them to execute what they ask. This frequently makes the result too incremental, connecting too closely to the core business in order to reduce risk and accountability issues - rather than creating a completely new business, an exploitation versus exploration discussion. Thus, a facilitating or mediating role in the PSS design support during introduction and start-up of the co-operation works really well aligning mutual benefit.

There is a big difference in having the right tools, having the competences to act on them and being able to question the overall approach independently (expert).

In current practices and due to accountability, middle management is confronted with a mere focus on implementation (e.g., industrial release) and performance (e.g., production process), not on change. PSS helps to rule out hidden agendas, when people have their own stake, interest and outcome already in mind. Typically for PSS, it's important to open up the design brief and (re)define the problem definition at the beginning of the project to guarantee a good quality design brief to start with. It is necessary that everybody understands the (primary) question and all variables. This new design brief might point toward different projects and priorities.

If the organization really is curious to know what customers or users want and say, than they just cannot start with a specific solution in mind for these kind of projects (expert).

2.6 Conclusion

Applying the synthesis approach to this research complements the current product-service transition and adds to the field of PSS. It ensures a synergistic interaction of products and services in the system with a focus on creating more value for the customer. In order to pursue 'integration', we advocate a FEI approach for PSS where the UX has an intermediate role throughout the entire process.

In this chapter, we had the objective to provide appropriate support for an operational integration of the product and service side in the PSS design process. For this purpose, we merged our perspectives on a 'synthesis approach', 'user experience centricity' and the 'front-end of innovation' and systematically combined theory and practice to develop an understanding of product-service systems. With these foci in mind, we have put an effort, in delineating product-service terminology and drivers, and characterizing the accompanying transition processes. However, an integrated mindset requires actionable prescriptions that lever effective PSS design and rollout. Therefore, we introduced four pathways for PSS, twenty-one PSS design process preconditions and its related framework to enable this shift and its necessary support.

It is undeniable that we are evolving toward an integrated logic, where intangibles reflect society's omnipresent share of the product-service provision in an ever more growing experience economy. Furthermore, with a focus on the system in PSS, all stakeholders come into play; the one(s) providing / affecting the context, the ecosystem and those affected by it, the user - and his resulting experience through interaction with the system's components.

The PSS pathways visualize the transition dynamics an organization can choose to integrate product and service. In order to do so, this research provides an understanding of the PSS design process preconditions (Table 2.8) and its related framework (Figure 2.5), a demonstrative process to consecutively create this integrated mindset and support the design of PSS. It offers an as-is situation of an organization and can be applied as a checklist before moving on. But it can also be used as a discussion tool that considerably supports to the PSS design process (Valencia et al., 2015), and serves to establish a change in the current process of designing new products or services and how it could develop over time.

We conclude our Research in Design Context (RIDC), and link back to the main research question.

The systematic infusion of literature and interviews in Research Cycle 1 (RC1) leads to a better understanding of PSS, complements the current product-service transition, and advances integrated PSS design. Respectively, it resulted in an integrated mindset and process support as a strategic and tactical foundation for an actionable toolkit and process (essential for PSS conception that goes far beyond the mere operational addition of product and service), described in the following chapters.

CHAPTER 3

PSS design toolkit | Iterations

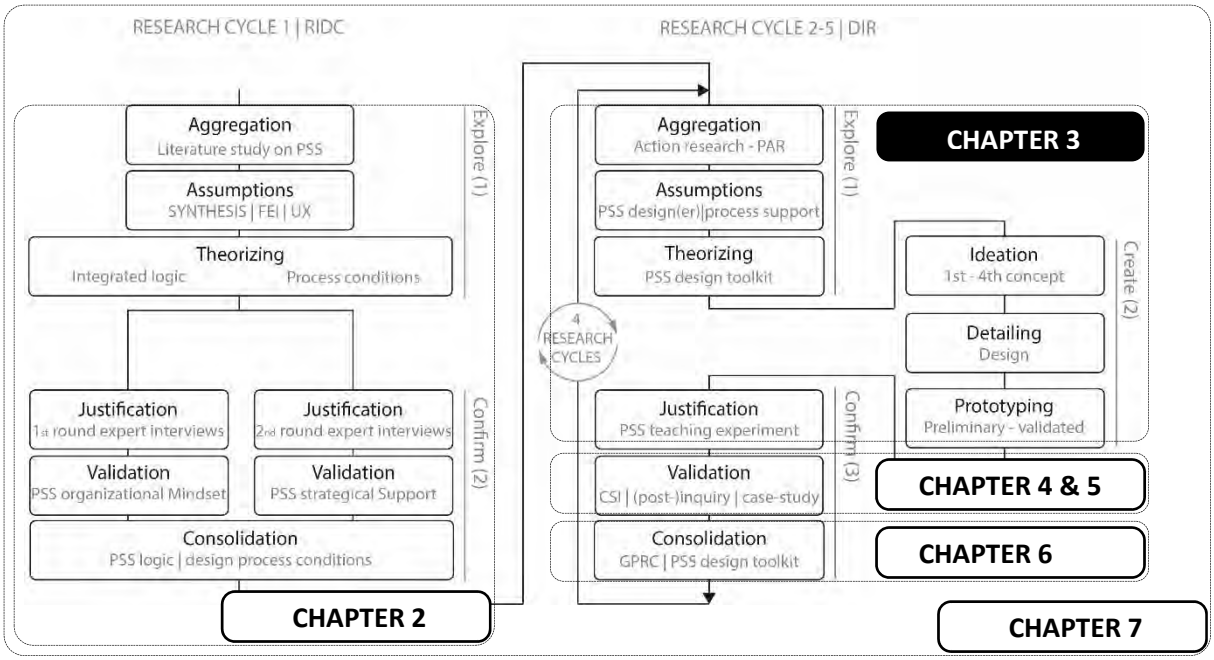


Figure 3.1 | Research design - chapters

3.1 Research framing methodology | DIR

Design inclusive research (DIR) embeds 'design' as a research means, the PSS design toolkit in our case. The goal of inclusion is to create new opportunities for generating new knowledge, which cannot be derived otherwise. In our case, the goal of this embedded design process is to achieve a better understanding, inventing new methodologies, and providing a better solution through creating pilot versions and various instantiations of a PSS design toolkit. It should be also noted that this toolkit allowed designers to complete the designing exercises by themselves, as were they simultaneously involved as subjects in this design research.

The **PSS design toolkit** was developed to facilitate and study the integrated PSS design process in the Front-End of Innovation. Based on student feedback, observations and expert panel discussions, this chapter - using the synthesis approach to map the ideal process - stepwise describes the decisions that resulted in the PSS design toolkit and how much it is useful for the design educational practices.

For Research Cycles 2-5, the process flow model is shown in Figure 3.2 below and described more extensively in the subsequent paragraphs. DIR decomposes into to three parts: a first phase of explorative research actions, a second phase of creative design actions, and the third phase of evaluative or confirming research actions. The first phase 'explore' is about aggregation of existing and new knowledge about a specific phenomenon, formulation of a critique of the current understanding and existing approaches, as well as the goal to optimize the theoretical framework that in turn will produces a better toolkit. Compared to *Research in Design Context* (as discussed in Chapter 1 and 2), DIR integrates a second 'create' phase addressing the problem, design-testing-redesign cycles that ultimately result in the design component: the PSS design toolkit. The third phase 'confirm' verifies and validates the constructed preliminary theory and the outcome of the design processes, but also consolidates the results by matching them against the existing body of knowledge, and by generalizing them toward other applications (Horváth, 2007, 2008).

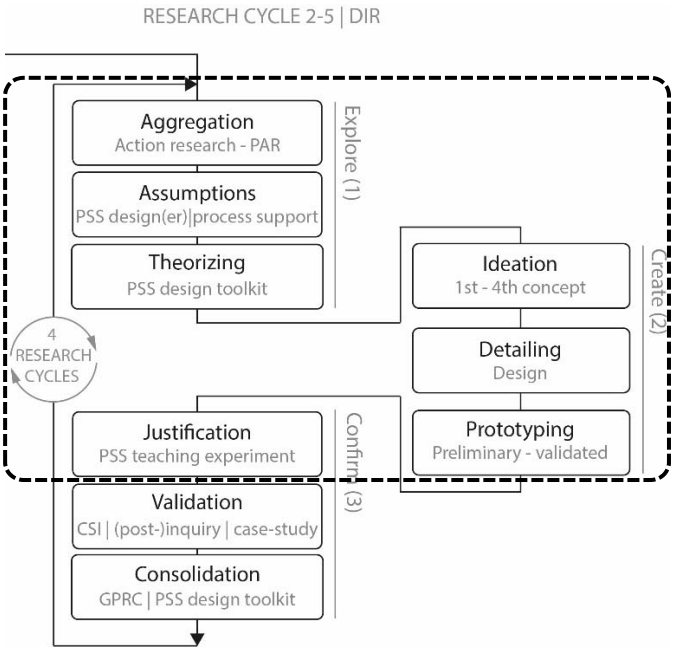


Figure 3.2 | Research Cycle 2-5 | DIR

1st phase – Explore (1)

The first stage of the research cycle concentrates on gathering relevant knowledge that results from the research problem and its surroundings (i.e., product-service systems in the context of design) as a basis for ***aggregation***, indicating the actions needed in addition to Research Cycle 1. In addition to compiling knowledge, the goals of the explorative activities also served to formulate a critique of the current understanding and existing approaches (i.e., the Service Design Toolkit), identifying opportunities for progression. The specific findings of the exploration build-up the following research ***assumption*** that becomes the foundation for the second stage working hypothesis: *A synergistic interaction between products, services and people in a PSS requires a reinterpretation of existing design approaches that (a) positively influences the design process, (b) the designer and (c) ultimately the design itself*. The third stage of the research cycle proposes a motion to develop a preliminary ***theory***, which is able to fill in the knowledge gap of the studied phenomenon in design context. The theory generated at the end of the explorative stage explains what information a design prototype should be based on. DIR enables to specify possible interventions to evaluate changes, identify interrelationships of input, output research variables, and establish reasons therefore.

2nd phase – Create (2)

Specifically from the second creative phase, recurrent involvement of design processes contributes to an evolving theory building in context. The research means manifests in various forms of the PSS design toolkit, conceptualized and detailed in this creative (2nd) stage, and then used in the confirmative (3rd) stage to support data elicitation and collection. Our prototype, the PSS design toolkit, acts as a dual-face tangible hypothesis, which is proper and useful for doing research, as well as for designing - respectively interrelated in this design research. This way, DIR makes it possible to gain access to research data that cannot be obtained and tested without having an abstract or tangible implementation of the object of design. Thus, DIR incorporates research and design to achieve a better understanding of the PSS design methodology and its inextricably linked new concepts. Ultimately, it leads to a better solution by creating pilot versions and various instantiations of the design research means; referring to the four iterative teaching experiments with the PSS design toolkit at the core. The research means - the PSS design toolkit - dynamically evolves and provides immediate feedback for the researcher and influences the research actions.

3rd phase – Confirm (3)

We dedicate the fourth stage to a logical and conceptual ***justification*** of the theory. In case of DIR, justification happens by involving operationalization of the constructed theory and the outcome of the creative activities, embodied by the PSS design toolkit applied in design education - IPO Project: Integrated Systems.

The fifth stage, ***validation*** will be discussed in Chapter 4 through a triangulation of methods, i.e., creativity support index (CSI), post-inquiries, and two case studies in Chapter 5. The sixth stage, ***consolidation*** is specifically discoursed in relation to the GPRC label that academically and professionally enhances applicability of the PSS design toolkit in Chapter 6.

* This chapter is based on one P1 Proceeding (E&PDE14) and one MA2 Book as author (2016).

3.2 Research and justification methods

Based on Chapter 2, the experts deemed it as a prerequisite to connect the PSS preconditions framework to create a more actionable and hands-on approach to actually get the job done.

In chapters 3 to 6 we will go beyond the organizational mindset (integrated logic) and strategical support (design process conditions) for PSS, and thus make our approach (based on our three foci: synthesis approach, FEI and UX) more actionable for the designer. In general, product-service system (PSS) design requires that products and services are designed as a combined value carrier. To support a valuable inclusion or transition, there is a need for new and adapted tools in order to explore the opportunities provided by emerging PSS concepts. Because of its integral nature, PSS design requires a structured process with a broader scope in mind and projects often involve process visualization, a demonstration of the intangible value and its relevance. Following DIR as framing methodology, we created various versions of the so-called 'PSS design toolkit'. Participatory Action Research (PAR) was used as a research method to reflect on four iterative teaching experiments with four iterations of the PSS design toolkit. Ultimately, the PSS design toolkit aims to revise, adapt and add to the current PSS design tools and to better support future generation designers for deep exploration and management of the complex design process.

This chapter explores, creates and justifies the PSS design toolkit (Figure 3.2), and shows how the methodology and the tools are a temporary result of a concept in constant evolution. Below we present the results of four years of Participatory Action Research, applied in the repeated effort of the teaching experiments and the redesign of the PSS design toolkit. Every research cycle has been subject to testing and retesting the way the PSS design toolkit supports the process, therefore the tools are always adjusted and yield significant changes.

For justification purposes, the methods used in the confirmative stage relevant for this chapter are:

- inquiries regarding the individual tools have resulted in immediate usage feedback.
- weekly checks with the expert panel (see Section 3.2.3 below).

However, evaluating something big and complex as the PSS design toolkit is a challenge and there is no single way to do this evaluation. Thus, we have been taking an approach of multifaceted evaluation, the methods used are addressed in Table 3.1 and show in which chapter they will be discussed in detail.

Table 3.1 | PSS design toolkit evaluation methods per year

Confirmation Methods	**2013-2014**	**2014-2015**	**2015-2016**	**2016-2017**	
Individual tools inquiry	x	x			Chapter 3
Expert panel	x	x	x	x	Chapter 3
Post-inquiry	x	x	x	x	Chapter 4
Creativity Support Index (CSI)	x	x	x	x	Chapter 4
Case-studies	x		x		Chapter 5
Peer reviewed content				x	Chapter 6

The blue dotted line in Figure 3.3 below shows the scope of this chapter throughout RC 2-5.

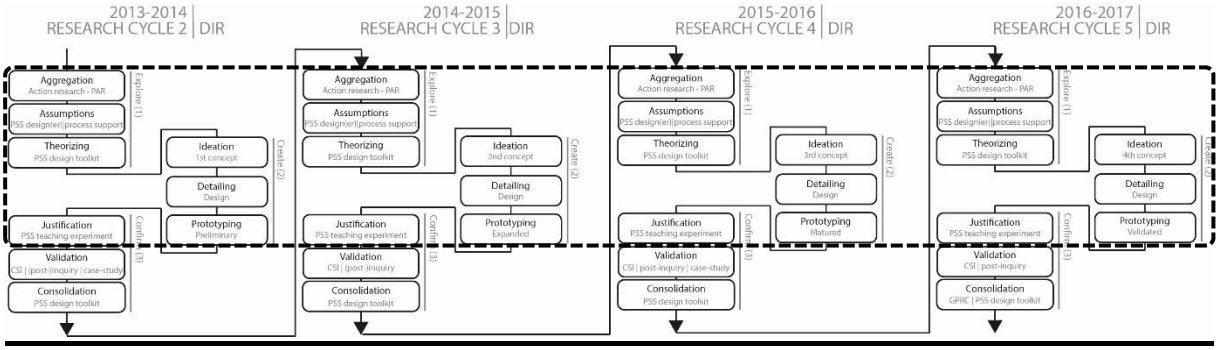


Figure 3.3 | Research Cycles 2-5 | DIR

3.2.1 Participatory Action Research (PAR)

Participatory action research (PAR) was used as an operative research method for data and theory generation. Action research is a convenient method for bridging theory and practice, as it involves both critical reflection and evaluation, an approach commonly used for improving conditions and practices (Koshy, Koshy, & Waterman, 2010; Lingard, Albert, & Levinson, 2008). It also engages the students and practitioners to engage with the research (Meyer, 2000). Meyer (2000) maintains that an action research's strength lies in its focus on generating solutions to practical problems and its ability to empower practitioners, by getting them to engage with research and the subsequent development or implementation of activities. Meyer states that practitioners can research their own practice to identify any problems, seek and implement practical solutions, and systematically monitor and reflect on the process and outcomes of change.

By iterating on the PSS design toolkit, we were able to produce new insight on how students approach the task of integrating products and services. Our sample of 197 students (over a period of four years) took part in the course titled *IPO Project: Integrated Systems*, as part of their educational program. The aim was to upscale their skillset from managing and designing the NPD process toward integrated PSS design. We were able to look for patterns, in terms of PSS drivers, meaning and contextual barriers, and compare the PSS design toolkit, the design process, and the students' outcome with sufficient depth (and variety) by aggregating data throughout this longitudinal approach.

This method was used as a step-by-step process to monitor the subject(s) during a period of four years (four times twelve weeks) using different data collection methods (Table 3.1), allowing feedback to be translated into concrete suggestions for action. Leading to necessary and actionable modifications, directional changes, and redefinitions, PAR intends to bring lasting benefits to the ongoing process itself rather than to some future occasion (Cohen, Manion, & Morrison, 2011). The degree of researcher participation was balanced between being an insider and outsider, whereby the researcher(s) participated in some activities but not fully. As articulated earlier, the purpose of action research is to learn through action leading to personal or professional development. Action research is participatory in nature, therefore the researcher takes the initiative and responsibility for the design and implementation of the PSS design toolkit. In addition, the proposed actions or designs are discussed with the expert panel and other knowledgeable practitioners, leading to better and more relevant practical implications. Since the common process of testing the value and validity of an academic research contribution through peer review is a comparable process (Beck & Stolterman, 2016; Cross, 2006), we have also included this into our research in the confirmative stage of our DIR (e.g., GPRC). Within a DIR framing methodology, PAR proves to be particularly useful as research method and enables to specify possible interventions to evaluate changes and identify interrelationships. Our research means dynamically evolves in the teaching experiment and provides immediate feedback for the researcher and influences the research actions (Horváth, 2008).

For instance, during and after the design process, the researcher would focus on asking the questions, steering the conversation along the topics of the research, systematically follow-up and reflect on the process, but in the same time challenged the students with new methods and tools during workshops as part of the course. This form of collaboration between academic researchers and practitioners is useful in encouraging the business applicability of new methodologies (Vasantha, Roy, Lelah, & Brissaud, 2012).

3.2.2 Inquiry into the individual tools

Based on an inquiry, the students gave opinions, preferences and arguments to determine what the individual tools contributed to the process. Having done the entire course, they would definitively have something to say on the matter. First year master students in product development have prior knowledge on the design process and tools supporting exploration, creativity and design management. This means they should be able to reflect on their own experiences with design methods and processes and formulate expectations about the PSS design tools through their usage.

Opposed to asking the students individually (n=52 in 2013-2014 and n=36 in 2014-2015), we asked them to fill in the inquiry together as a team. The teams (n=17 in 2013-2014 and n=12 in 2014-2015), three students each, were the same teams as those from the design course. The decisions they have made as a group during the course influenced the way they dealt with the tools together and should reflect in the answers as well. Considering PSS design to be a huge task, it requires collaboration within the group, we therefore deemed it necessary for the student teams, going through the inquiry together to reflect on their design process and the use of the individual PSS design tools. Although some items remained blank, the results remain sufficiently comprehensive for qualitative analysis.

Moreover, the PSS design toolkit was continuously evaluated during the IPO course with the expert panel (see section 3.4.2, Creative Support Environment). This constant discussion made it possible to adjust where necessary and expand on the results from the inquiry as input for the following iteration of the toolkit.

As discussed in Table 3.1 we showed how and when different methods were used to triangulate on the effectiveness of this toolkit. Parts that are discussed in the following chapter and mainly contribute to the validation of the PSS design toolkit, cover some aspects of justification as well, and are thus taken into consideration in this chapter. It involves data with respect to the individual tools and overall process flow, partially drawn from a post-inquiry, made by the same students one year after each research cycle in retrospect of the usage of the PSS design toolkit. The results of the Creativity Support Index as another way to look back at the results from each iteration and make adjustments based on weighted factors that support creative processes.

3.2.3 Expert panel

During this design course, an interdisciplinary team of five people guided the students. The team consists of three to five professors in product development that provided educational guidance and design input. The author, as one of regularly two active doctoral researchers weekly supported in the design of PSS, the first with a focus on the design of PSS and its resulting user experience, the other on interaction design and prototyping. In addition, at least one professional member from the service design agency Namahn[1] was included to introduce and monitor service and systemic design principles and tools during the full length of the design process. Each year we were supported by multiple product, service and system design agencies to guarantee external validity and generalization. On several occasions, they provided input and feedback on the PSS design process, its tools and the design outcome.

[1] http://namahn.com/

3.3 Explore

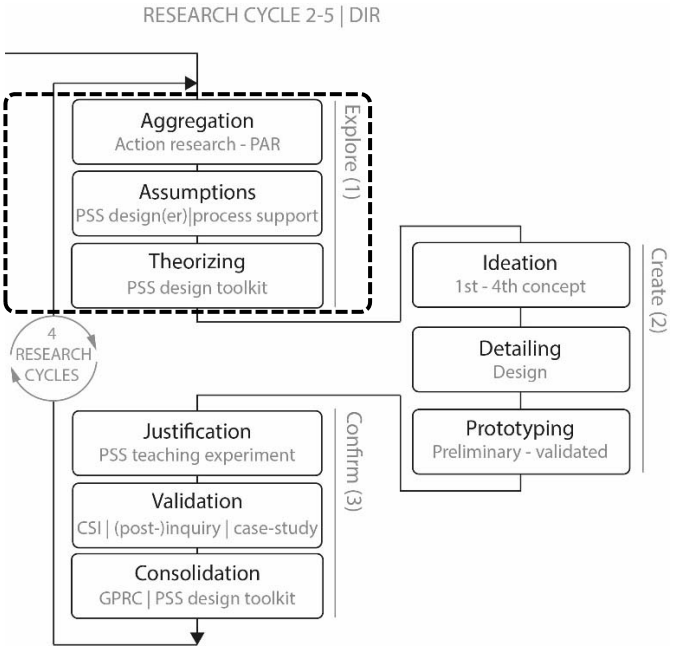


Figure 3.4 | Research Cycle 2-5 | DIR | Explore

3.3.1 PSS design(er) process support

The past few years design academics and practitioners have worked hard sensitizing product-service systems (PSS). Ever since, servitization, service innovation and service design have gained ground and help manufacturers to extend their businesses by adding, redesigning or creating new services to their products. In addition, service providers enhance their offering through tangible elements in order to maintain or gain competitive advantage. However, due to a lack of expertise, the newly required skills for product-service innovation often come from outside the organization.

There has been elaborated research on PSS (design) toolkits and methodologies (Ceschin, 2012; Costa et al., 2018; Gokula Vijaykumar et al., 2012; Tukker & Tischner, 2006; Wild, 2009). To strengthen the argument of using these strategies in today's competitive business environment, the authors are clear about PSS fulfilling the customer needs more than with traditional processes. In this process of transformation toward PSS, industries require support in terms of tools, techniques and methods. Several tools and methods to support PSS design already exist in different formats, however often a specific focus on sustainability and business model innovation determines the design outcome. Within this variety of existing methodologies for PSS design, Mourtzis, Fotia, & Doukas, (2015) address the issues in current PSS design methodologies that require further development. In these categories, we see a clear contribution with our PSS design toolkit and focus from RC1: an integrated, model-based approach that supports PSS designers to generate PSS concepts; integrating stakeholder's preferences and portray human behavior in determining PSS components; the consideration of mutual influences of products and services; the importance of representation of PSS; and the role of designers during PSS design (opposed to the development of conventional products).

By using the synthesis approach we are able to integrate the artefact, the intangible service component with a systems perspective and this always in relation to people (Costa et al., 2018). In our case, the PSS design toolkit provides the opportunity to create innovative interactions between consumers, the products and services they use and the providers offering them. An approach that doesn't tend to

overlook the customer experience (Stacey & Tether, 2015; Valencia et al., 2015). In contrast to traditional services related to products, the service component of a PSS significantly adds value to the experience of the consumer and the system component has made it possible to combine products and services in innovative ways through apps, platforms and multiple organizations providing them in a consistent cooperative effort. PSS introduce new elements to a design process, which in its turn requires a thorough rethinking to support a valuable inclusion of products and services as a combined value carrier. Besides the main challenge for designers to cope with this increased complexity, they are required to manage the variety of underlying design processes, where early representation and communication are key for the design phase enabling a more successful strategic rollout of the PSS concept.

Connecting our knowledge from Chapter 2, we build further on the assumption that a synergistic interaction between products, services and people in a PSS requires a reinterpretation of existing design approaches that (a) positively influences the design process, (b) the designer and (c) ultimately the design itself.

3.3.2 The origination of the product-service system design toolkit

The success of PSS is - partially - due to a trend in **service design** and some of its relevant principles. Service design terminology in terms of user research is what now can be referred to as design thinking. **Many people are interested in the tools and its hands-on approach**, allowing them to go further than determining or redesigning only one or two physical touchpoints. The aim is to extend to a completely new customer journey with all necessary touchpoints of the user in interaction with the organization, providing the possibility to create the whole story. A **PSS approach** tends to open up knowledge and **empathize with the user and his/her context**. It strengthens, professionalizes and supports the innovation process and makes it more adept to technological, economic and societal trends. **The aim is to perform research and create relative knowledge, externalizing it throughout the organization to make it more implementable**. Often - even with a small SME budget - companies can have some quick wins by applying the tools, with or without external collaboration. The idea of PSS is to gain or create a broader space in the **(early) strategy making of a company**, involving the company in more human centered, sense making or meaningful innovation, design and development. It implies a different organization and mindset to reshape the innovation strategy of the company toward PSS. However, instead of reinventing the wheel for every process, it is necessary to work toward **standardized processes** and a qualitative and quantitative **set of tools**, e.g., customer analysis; market trends analysis; competitor analysis; value analysis; service blueprint; persona development; etc. This helps to **formalize** and establish a sense of urgency, highlights the need for change, developing a vision and strategy for innovation **integrating both products, services**, and to initiate a mind shift that understands - different levels and perspectives on - value. Whereas now manufacturers too often see service integration as something that creates loyalty, customer satisfaction and is just a necessary cost factor to stay in contact with the customer in order to increase purchases.

As a basis for creating more complete solutions that combine product and service components, we integrate the human-oriented perspective of service design with an organizational network-oriented perspective of product-service systems (Costa et al., 2018).

What every designer wants, is to ultimately improve the world. PSS enables a deep understanding of human behavior and organizational structures. Likewise, its processes and the systems themselves allow us to go to the essence together with the client/organization and user to find solutions - products and services - that provide the best possible user experience. (expert)

As said, the rise of PSS is connected to the success of service design, its tools and its hands-on approach. Because of an incorporation of service design and several other disciplines, a PSS approach enables to perform research, create relative knowledge in close relation to people, and externalizing it throughout the organization to make it more implementable. Often, it implies a different organization and mindset to reshape the innovation strategy of the company toward PSS. A standardized processes and a formalized set of tools that integrate both products and services initiates that mind shift. Below, we describe how the PSS design toolkit was conceived, and how it was justified by means of multiple instantiations.

In order to start from a given set of tools, collaboration was set up with the design agency *Namahn*[2] that is specialized in user centered, service and systemic design. Together with *Design Flanders*[3], the service design agency updated their existing *service design toolkit*[4] in the context of the spider project, which supports public service innovation using design in European regions (VVSG (Association of Flemish Cities and Municipalities), 2013). The service design toolkit was the result of an Interreg IVB NWE project that funds transnational cooperation with the aim to find innovative ways to make the most of territorial assets and tackle shared problems of Member States, regions and other authorities (i.e., UK, Ireland, France, Switzerland, Luxemburg, the Netherlands and Belgium). Ultimately, the toolkit was translated and launched via the European SPIDER project website[5].

Figure 3.5 | The service design toolkit

We already discussed the topic of service design in Chapter 2, and introduced its relevance for this research at the beginning of this section. The service design toolkit (Design Flanders & Namahn, 2013) contains a set of ten service design tools (SDT) and related templates (Figure 3.5). Together with the design agency Namahn, this service design toolkit was modified with a specific focus on PSS, enabling user centeredness and early interdependence between the product and service aspects, rather than maintaining the demarcation approach.

[2] http://namahn.com/
[3] https://www.flandersdc.be/nl/gids/tools/service-design
[4] http://servicedesigntoolkit.org/
[5] http://pdronline.co.uk/Portfolio/SPIDER and https://www.oecd-opsi.org/toolkits/service-design-toolkit/

3.4 Create

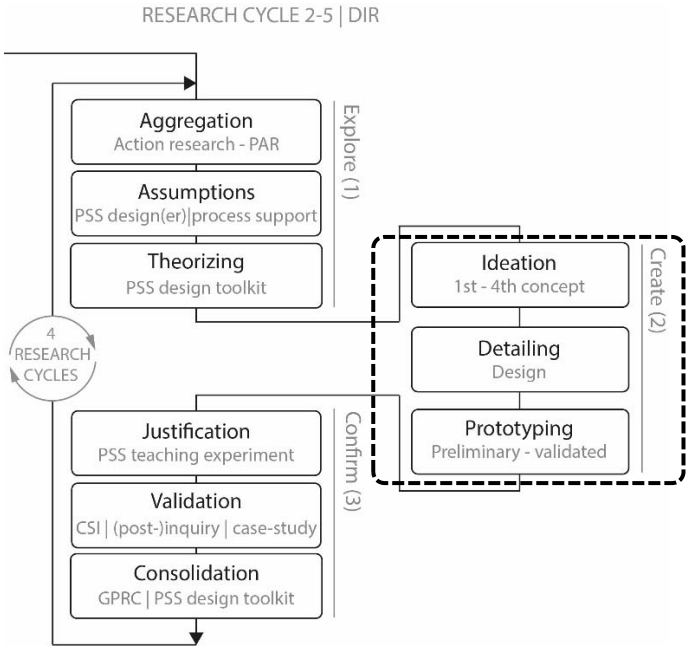


Figure 3.6 | Research Cycle 2-5 | DIR | Create

3.4.1 The PSS teaching experiment | IPO Project: Integrated Systems

As a research means, the PSS design toolkit has been iteratively built-up alongside the design efforts of first year Master students in Design Sciences | Product Development, participating in the design course entitled 'IPO Project: Integrated Systems'. This interdisciplinary design course was used as a way to explore how existing design tools - iteratively modified with a specific PSS focus and new tools can be introduced in the early stages of PSS design. The design course represents a workload of 12 ECTS (European credits, i.e., 360 hours per student), is compulsory and runs over the period of one academic semester. The course is now running its sixth year, however this research describes four datasets, totaling 66 projects from 197 students.

The 'IPO Project: Integrated Systems' focuses on the development of competences in product-service system design. To achieve the objectives for this twelve-weeks lasting design course, student teams are expected to generate user insights, explore new opportunities, define and design a relevant PSS concept for a given context, we used prompts such as 'milestones in life', 'physical and digital traces', 'tackling obesity' and 'smart city sharing'. Finally, an innovative business model related to the PSS concept should fit the original goals to fulfil the final customer needs optimally, enable upscaling and sustainable growth.

There are three large FEI phases the students will go through in this project, understand, explore and define. For this we have built on the knowledge from the theory described in Chapter 2 and were inspired by work by Tan & McAloone (2006) performed with design students in a similar teaching experiment on PSS. Connecting to that, we structured our very first PSS design process guideline (see below) alongside our preliminary PSS design toolkit (2013-2014 in Table 3.2), which was the first adaptation of the service design toolkit, modified with a specific PSS focus. The goal was to support the exploratory research and interdisciplinary analysis, resulting in user insights, design requirements and innovative PSS concepts. A roadmap of student activities was set up and every week a set of design tools was introduced, each tool having a specific goal in the PSS design process.

Understand - Integration builds a better value constellation

Think in terms of PSS and its potential. Integrate rather than designing separate elements. See the early product and service interdependencies and strategic linkages. Involve stakeholders. Explicit your evaluation and selection criteria for (in-)/tangible value.

- Get out there, listen to what people whisper about, and shadow them in their actions, frustration and excitement. Triangulate your findings using more than one tool to create the realistic body of knowledge to scientifically add to your desk research.
- Create a visual context analysis, the actor-network (the system) is a visual representation of the connections and exchanges of various stakeholders with the system (product-service) and the user experience (effects) this causes.
- Show how the understand phase was conducted and which methods were used, frame your insights and present the design challenge.

Explore - Scenarios

Involve stakeholders. Provide insights in front- and back office implications and different lines of visibility. Characterize the use phase (planned or designed events, organize the flow, sequence). Align the different timeframes and define the product and service in interaction with the user. Pay more attention to the brand execution rather than the brand promise. Prototype early and test it to reach better outcomes, evaluate and select.

- Identify the requirements and value provided by the product and the service component
- Presentation of ideas in a visual way (e.g., storyboards, photo novel)
- Identify and sketch the customer activity cycle - visually map the customer's user experience (e.g., using storyboards, acting out)
- Describe, sketch and prototype at least 3 partial concepts, the (in)tangible(s) that are necessary to deliver the PSS that fit the context, make a whole (storyline) and viable concept.

Define - Product-service system

Describe value and prerequisites for each part in the system, explicit to what extent the product and service are mixed, consider the consequences of adding products or services to the offering, determine utilization, effects and side-effects, ensure that all variables are catered for as far as possible, translate needs/requirements into clear product/service attributes and use the same syntax/semantics to describe them. Make sure that the design of the service meets the aspects of the product and vice versa. And focus on the user experience of the new product-service system.

- Prototype, (re)test, and visualize the PSS with a clear buy-in purpose for customer and client.
- Describe your PSS offering based on Tukker & Tischner's typology (product-, use- or result-oriented) or any other to characterize the benefits and dimensions of value delivery.
- Define attributes, specifications and architecture for product and service in one concise design brief, enabling new product/service development (NPD/NSD).
- Provide a project presentation that comprises the big picture, the whole interaction of the user with the system. Use visuals, mockups, (interactive) prototypes, videos to make a domain expert or nonprofessional user fully understand your newly designed system. Both need to grasp the interaction(s) the user will have based on the proposed product-service combination.

3.4.2 Creativity Support Environment

Referring back to the expert panel, this design course was supported by an interdisciplinary team of people, providing the students with educational guidance and design input. During the full length of the design process, we introduced service, systemic, user experience, interaction and prototyping design principles and tools to the students, and monitored their progress, with weekly consults, presentations, guest lectures and occasional jury's. Using the templates provided by the PSS design toolkit, student teams discuss a standardized visualization of their projects, allowing a comparison between the different project groups, their design process and progress. Each year we were supported by multiple product, service and system design agencies (e.g., Studio Dott[6], ShiftN[7], Knight Moves[8], Antwerp Management School (AMS)[9] - Expertise Centre Business Design & Innovation, industrial companies, service providers and governmental institutions (E.g., Colruyt[10] (FMCG) followed our progress on 'tackling obesity', DELA[11] (insurance for the deceased) participated on 'digital and physical traces', the City of Antwerp[12] and NOKIA BELL LABS[13] engaged when designing for 'smart city sharing').

3.4.3 Research population

We have done this course for four years, each year with a different set of students - evenly divided in three students per group - on average fifty each year. In total we have data from one hundred ninety seven (n = 197) first year Master students in Design Sciences | Product Development who have used the different iterations of this PSS design toolkit (the CST in this research). The individuals are novices to this matter, none of the students have taken this class before, are in the Master program for the first time and do not have experience with designing PSS. They have not been working in industry (having experience, but aspiring an official credential). Genders are quite equally divided. On an individual level, it is a five-year program for each student, they just finished their Bachelors' degree after a three year program and the design course 'IPO Project: Integrated Systems' is programed in the first semester of the first of the two year master program. Flemish as language limits our students to come from Belgium and the Netherlands. Overall, resulting in a rather homogenous population.

3.4.4 The development of the PSS design toolkit

This PSS design toolkit (Dewit et al., 2016a, 2018) has iteratively grown (Table 3.2), each year being able to support the designers and address the challenge more adequately. Section 3.5 will discuss in detail how we started with ten tools in the academic year 2013-2014 and justifies why we have gradually built-up the PSS design toolkit with more, different and adjusted tools and techniques over the following four years. Figure 3.7 provides a concise illustrative view of the PSS design toolkit iterations.

[6] https://studiodott.be/
[7] http://www.shiftn.com/
[8] https://knightmoves.be/
[9] https://www.antwerpmanagementschool.be/onderzoek/expertisecentrum-business-design-innovatie/
[10] https://www.colruyt.be/nl
[11] https://www.dela.be/nl
[12] https://www.antwerpen.be/nl/home
[13] https://www.bell-labs.com/connect/global-locations/Antwerp-belgium/

Table 3.2 | Various instantiations of the PSS design toolkit

	2013 - 2014 **Preliminary toolkit**		2014 - 2015 **Expanded toolkit**		2015 - 2016 **Matured toolkit**		2016 - 2017 **Validated toolkit**		2017 - 2018 **Peer reviewed toolkit**
1	Stakeholders journey	1	Framing	1	System map	1	System map	1	Context map
2	Context & objectives	2	System mapping	2	Stakeholder dimensions	2	Context map	2	Stakeholder dimensions
3	Research question	3	UX interview template	3	Research questions	3	Stakeholder dimensions	3	Research questions
4	Stakeholder interview	4	User dimensions	4	Perspective interview	4	Research questions	4	Observation
5	Persona dimensions	5	Solution areas	5	Experience interview	5	Observation	5	Interviewing the perspective
6	Persona	6	Design challenge / requirements	6	Personas	6	Interviewing the perspective	6	Interviewing the experience
7	Actors map	7	Moodboards	7	Factors and themes	7	Interviewing the experience	7	Personas
8	Design challenge	8	Free brainstorm	8	Rich pictures	8	Personas	8	Factors and themes
9	Design requirements	9	Lotus blossom	9	Design challenge	9	Factors and themes	9	System map
10	Lotusbloem	10	System map v2.0	10	Paradoxal thinking	10	Universal themes	10	Value proposition
11	Prototype/service script	11	Lego serious play	11	Lotus blossom	11	Rich pictures	11	Rich pictures
12	User testing	12	PSS (idea) selection box	12	Meta-examples	12	Intervention strategy	12	Intervention strategy
		13	User journey map	13	Bodystorming	13	Design challenge	13	Design challenge
		14	Story telling techniques	14	Selection matrix	14	Paradoxal thinking	14	Business ideation canvas
		15	Prototype/service script	15	Serious play scenarios	15	Lotus blossom	15	Paradoxal thinking
		16	User testing	16	Touchpoint matrix	16	Meta-examples	16	Lotus blossom
		17	Touchpoint matrix	17	Leverage points	17	Selection matrix	17	Meta-examples
				18	Blueprint	18	Solution spaces	18	Selection matrix
				19	To be system map	19	Serious play scenarios	19	Solution spaces
				20	Conceptual model	20	Bodystorming	20	Serious play scenarios
				21	Interaction moodboard	21	Customer journey	21	Bodystorming
				22	Narrative	22	Touchpoint matrix	22	Customer journey
				23	Process map	23	To be system map	23	Touchpoint matrix
				24	Low-fidelity prototyping	24	Conceptual model	24	Product-service system map
				25	Medium-fidelity prototyping	25	Interaction moodboard	25	Conceptual model
				26	High-fidelity prototyping	26	Interaction metaphors	26	Interaction moodboard
				27	Stakeholder test	27	Narrative	27	Interaction metaphors
						28	Process map	28	Narrative
						29	Appropriate fidelity prototyping	29	Process map
						30	Low-fidelity prototyping	30	Appropriate fidelity prototyping
						31	Medium-fidelity prototyping	31	Low-fidelity prototyping
						32	High-fidelity prototyping	32	Medium-fidelity prototyping
						33	Provocative prototyping	33	High-fidelity prototyping
						34	Make belief	34	Provocative prototyping
						35	User test	35	Make belief
								36	User test

Figure 3.7 | Schematic sequence of the PSS design toolkit iterations

3.5 Confirm | Justification by inquiry

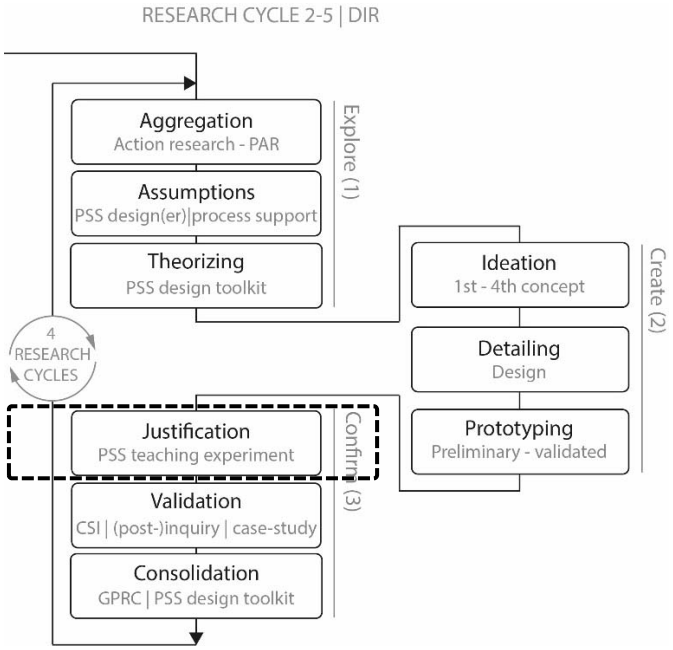


Figure 3.8 | Research Cycle 2-5 | DIR | Confirm

In this part, justification happens by involving operationalization of the constructed knowledge and the outcome of the creative activities, embodied by the PSS design toolkit applied in design education. It involves the question: *'Are we building the PSS design toolkit right?'* and mainly relies on the inquiries into the individual tools that have resulted in immediate usage feedback during Research Cycles 2 and 3. The inquiry reflects upon the individual tools in the PSS design toolkit being used during a particular task or activity, by the student teams in particular. The method is described more in detail in Section 3.2.2 above.

Subsequently, we will discuss each version of the PSS design toolkit in detail, why and how it was modified, and the logic we followed when it was extended, compared with the previous version of the toolkit. In each version, we have also indicated which tools originally come from the service design toolkit with 'SDT', and those that emphasize the systemic character have been underlined. Finally, some student statements on specific tools have been added in *"italic"*. Every iteration is based on operationalizing the PSS design toolkit in the IPO Course during one Semester, the outcome of creative activities, and the data resulting from our multifaceted evaluation.

For more theoretical background, explanations, and insights related to the tools presented throughout the four iterations, we refer to Chapter 6, Section 6.4 that presents the (condensed) final version of the PSS design toolkit.

3.5.1 2013-2014 | the preliminary toolkit

Figure 3.9 | 2013-2014 | the preliminary toolkit

Practically every tool used in this first version of the toolkit originated from the service design toolkit (SDT).

The **stakeholders experience journey** supports the majority of the groups in the analysis of the experience of the user, and gives an identification of the key stakeholders with respect to their specific context. It also allows to map the key moments for each stakeholder, what the person is doing and thereby feels, positive or negative. However, it was slightly more difficult for the groups to choose a user/provider combination of the product-service, some groups felt not enabled in any way. *"This tool comes too early in the design process and might not support for broad contexts." (student)*

The **context & objectives** tool provides a first step toward the product-service promise and creates a moderate understanding of the providers' goal, main needs and motivations of the user, different thresholds and values. The tool gives less support to the majority of the groups in understanding the user-provider combination(s). It also does not really help the team to better prepare the field research. Nor does it help groups to understand the trends, limitations and conditions of the product-service. *"It was too unclear and needed more guidance. Quite strange questions early in the design process, hard to provide answers depending on the context the teams explore. The context & objectives tool should come later into the design process. Too hard, too early, really context dependent! So change order of the tools, put at later stage." (student)*

The **research question** tool hardly helped teams in preparing the interviews, nor did it support the groups to think about the type of user they wanted to query or the event stage. At this point in the process, design teams were not supported in thinking about the context of the experience, the other stakeholders and the activities that took place. The additional up-front questions were considered to have only moderate, low or no support. "*Creating your own kind of interview is easier. Determine the interview yourself and all really depends on the subjects' sensitivity to the context, you can dig deeper in your own way. The research question tool is a repetition, not useful do this differently!" (student)*

For the **stakeholder interview,** nearly all participants feel highly or moderately supported by the stakeholder interview template in defining the user, event stage and context. Important, the tool serves to test previous assumptions from the stakeholders' experience journey and gain new insights. Similarly, the tools' additional questions facilitated teams in discovering underlying reasons on the most positive and negative experiences. This feels more like a guideline and works very well as tool template. *"The structure was sometimes unusual, why start with the stakeholders experience journey before the stakeholder interviews? It seems more logical in reversed order. It remains hard to recognize*

patterns in five to ten interviews. Change the order of the tools, gut feeling / interpretation that this gives better results." (student)

Persona dimensions enable the design teams to make 360° personas and capture the users' (more extreme) needs. The tool helps students to identify opposite user attributes that affect the PSS and enables to determine realistic combinations of dimensions that can form a fictitious person. However, the selection of these attributes is harder. *"The tool doesn't bring new insights, you have to create them yourself. The tool makes you think about opposite attributes, however … extremes are often not or less realistic." (student)*

Personas support the groups in defining the target audience and create different user perspectives, the goals and most important needs of the future product-service system. However, the support is rather moderate to low. *"A list of extra characteristics could work handy to get some inspiration. Good to get an idea of the users and stakeholders in play." (student)*

The **actors map** provides the teams with a clear picture of everyone involved and the role they play in the system. It helped to create a detailed mapping of the activities and actors that play in different event stages in the system and the value exchange that occurs. It also supports the groups to spot promising product-service combinations, somewhat easier in a later stage. Still, depending on the characteristics of the tool, three to four groups felt not supported by the actors map. *"We didn't use the provided format as it was too chaotic with all the lines. You easily spot opportunities by drawing the current situation, but it gets quite untidy. A circular visualization could be handier. Has to come earlier and maybe revisit later." (student)*

A **design challenge** enables the groups to rephrase the initial product-service promise into a clear design challenge and got more focus on what to design in the next phase. The tool supports in characterizing the PSS with certain key values and helps to decide on the boundaries of the project. The students questioned the tool's usefulness in visualization methods on how to create a personality for the product-service. *"We feel skeptical about specific parts in the tool (e.g., the Chinese portrait feels patronizing for the designer), and it works restrictive in our visualization. Rather use the human drives cards (or something else), with more freedom, brain sketching, etc." (student)*

Design requirements feel a high support in determining the opportunities for innovation from the design challenge. The groups are even more pronounced in their judgment on support in the translation of opportunities into requirements concerning context of use, interaction, rational and emotional objectives, services and product components. *"It helps to select the most important requirements from the list. We often re-used our key design requirements throughout the process. It makes you think about the different forms of requirements and entices you to formulate a design challenge. Keep using the templates throughout the design process." (student)*

Lotus blossom aids the groups in retrieving important characteristics through inspiring examples in different contexts and combines them with the eight most important requirements from the design requirements tool. The characteristics of the examples provide input for a product-service ideation and definition. Some groups did not feel supported and feel that ideation should come in earlier too. *"We looked for inspiration in another way and choose to search for examples in the same context as ours, more relevant for us." (student)* We noticed that there are multiple ways students were using this tool (same context as benchmark and other context as inspiration) and provided a second alternative.

For **prototyping and service scripting,** we did not support the students adequately in this version of the toolkit, and left it mostly to the students with the idea that this stage was 'known' to them considering their background. However, we should put more effort in the next iteration when it comes

to expressing their ideas by means of visualization and prototyping to end up with a result that matches with the effort to get there.

User testing was integrated in the beginning, but there should be a way to involve the stakeholders throughout the different phases of the design process, in order to reassess every elaboration (from idea, to concept, scenario and prototype). Now (completely at the end) it just makes verification harder, especially when the time for prototyping/service scripting was not in balance with the analysis part of the process. More contextualized organizational support would be interesting to get access to the customer base. Students asked for a consistent way of approaching and communicating with users and other stakeholders.

3.5.2 2014-2015 | the expanded toolkit

Figure 3.10 | 2014-2015 | the expanded toolkit

A similar approach to 2013-2014 has been undertaken for immediate feedback from twelve student teams in the PSS design process (see above).

This brought us to the following order of tools (see Table 3.2), and the necessary adaptations that took place in the expanded 2014-2015 toolkit. Several new tools were integrated from the service design toolkit, in case we felt they could support the process (as indicated above).

In this version, instructions were provided in a manual-like form, and consistently formatted tools were introduced for its communication purpose. What follows are the newly added and adjusted tools, compared with the previous version of the toolkit in Section 3.5.1.

Framing (originally context and objectives) had changed, and was brought to the front with the purpose to get all parties around the table. By scoping the project and strategy together with the companies that were collaborating on the course. *"It is too difficult to use, even when involving companies - who should have actually done the exercise before the start of the course." (student)* Even if provided, the scoping was not explorative enough, but rather focused on exploitation. (We eventually transferred this tool template to the PSS Strategic Rollout side.) SDT

System mapping was integrated to support framing and to understand the larger context (system). It was supposed to create a visual hierarchy, distinguishing the details and the whole. However, besides mapping the stakeholders, places, activities, products and services, it seemed rather difficult for the students to recognize patterns. *"We need tools to recognize patterns in the interview information." (student)*

A user experience interview template replaced the stakeholder interview and became integrated with the research questions to be of direct support during interviewing. SDT

The persona was deleted in this version because of low support or low additional info, it didn't really add much info for the students. The persona dimensions tool was renamed to **user dimensions**, which would be the tool to bring the insights of the interviews together.

We added **solution areas** because of the necessity to visualize and characterize possible patterns from earlier research from the understand phase.

The original design challenge was regarded as superfluous (represents the tool design brief in the SDT) and was deleted in this version. We decided to keep the **design challenge / requirements**, especially

because the students needed to converge their insights into one concise sentence and its eight most important requirements, clearly providing input to the next phase in the design process. *"Interesting because it makes you think about different types of requirements based on one core sentence. We often reused the requirements throughout the design process.*" *(student)*

Mood boards were added to allow for quick designs and preliminary ways to test (e.g., design challenge, its requirements) with the users and represent the experience one wants to deliver.

We integrated a **free brainstorm**. *"We need more time and tools (idea and concept generation) to open up creativity and think more out of the box." (student)*

System map v2.0 was introduced to integrate feedback loops in the process and to check original goals. The purpose is to explore the potential of the earlier solution areas, for both the user and the stakeholders.

Among the students, we noticed a need for a first verification after a broad ideation, together with stakeholders. Therefore, we added the **PSS (idea) selection box** to get support in evaluation and selection after the ideation stage. This tool was adopted from the service design toolkit. SDT

The stakeholders' journey changed into the **user journey map**. It was quite logical to bring this to a later phase in the process. It is an elaboration on the solution areas, the system map, and can give an overview of the future PSS experience.

We provided more time for prototyping with several extra tools from the service design toolkit. SDT

LEGO serious play was added for 'role-playing' the users and other stakeholder's environment. Also other possibility for **story telling techniques** (e.g., stop motion, video sketching, and role-play) were introduced to elaborate on the scenario of the concepts and to support prototyping / scripting.

As a last tool for this iteration of the toolkit, we added the **touchpoint matrix** as an adjusted version of service concept, prototype and testing templates. This was already a part of the service design toolkit (SDT), but we made adjustments based on earlier work by Gianluca Brugnoli (2009) to verify the PSS concepts by visualizing the connections (of goals and touchpoints) between the system and the user.

3.5.3 2015-2016 | the matured toolkit

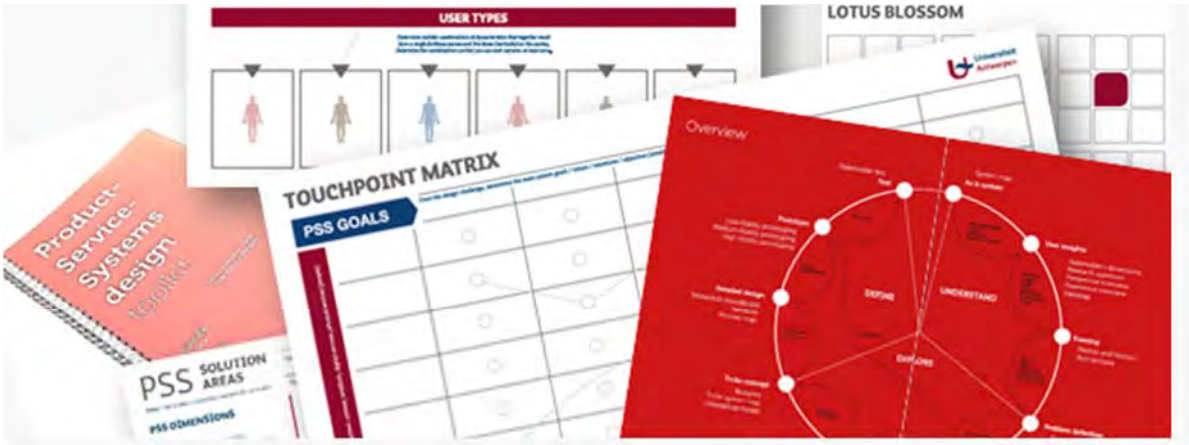


Figure 3.11 | 2015-2016 | the matured toolkit

At this point, the tools were already developed in a different format and brought together in a first booklet of the PSS design process, including images, more instructions and inspirational examples to get the students going. This was the very first comprehensive version of the toolkit, providing an overview on the entire process, clearly separating design phases and giving the students a stepwise approach, instructions and inspiration for each tool. *"We need more freedom and distribution of tools, leaving it to our specific context and interpretation. A timeline is necessary to see the sequence of the tools in the beginning of the process. To see what's missing, and creating clarity for others, we need more possibilities to express (parts of) the concept." (student)*

A significant rise in the number of tools (ten in total), was a way to allow students more freedom to use the ones that support them in the design process. A significant part of those tools were more systemic design tools (underlined below), embedded to get a more holistic (the whole) perspective on the context, its stakeholders, and a way to understand and synthesize that knowledge into the components of the 'to be' system.

System map was brought to the front of the toolkit, a way to start the research with a direct focus on the reasons for the context as-is.

User dimensions was changed into the **stakeholder dimensions**, giving it a broader description.

Research questions was brought back into the toolkit. They do still give a hint or inspiration to student teams and provide one possible way to approach an interview (other suggestions or approaches are free to explore given the sometimes very specific project context). In this version, we integrated an as-is description of the stakeholder journey in order to empathize more with the multitude of stakeholders experiences before the actual interview. This scoping exercise would be beneficial when doing the actual interview to see comparisons and complete opposites.

In preparation of the interview and together with the different types of interview methods below, we provided a technique called the **human-drives**[14]. This is a card set that can help reveal the reasons behind the experience.

Two types of interviews were introduced to give more room to students for approaching an interview in a different way. The first type is the (broader) **perspective interview**. It enables the students to comprehend the world around the stakeholder. We use a psychological model of Schwartz as an

[14] http://namahn.com/share/human-drives-card-deck/

interpretative lens. During the interview, it can serve as a conversation starter or as a method for synthesis after the interview. A second type is the actual **experience interview**, to comprehend the stakeholders when experiencing the current system.

The tool solution areas was transformed into **factors and themes** (Dorst, 2015), because the students addressed the necessity to recognize patterns in their research and creating a juxtaposing character for every cluster of patterns. *"We want more support for problem analysis after mapping our insights, being able to retrieve the most important information." (student)*

The mood boards from the earlier iteration were too general, therefore we decided to split this tool and integrate the following visual explorative tools at different moments of the ideation phase:

> **Rich pictures** were brought in to visualize the insights up until this stage, and being able to verify whether everyone has the same understanding or interpretation of the system.
>
> **Meta-examples** visualize the themes with a known metaphor, and are used to look at the state-of-the-art to 'solve' a problem (Dorst, 2015).
>
> **Interaction mood boards** come in a later stage of the process, and give representation to the different types of interactions that can be addressed by product or service components in the final solution.
>
> The **conceptual model** is used as a schematic overview of the concepts in order to make the user understand how to interact with the system.

Right after the design challenge and its resulting requirements, we introduce **paradoxical thinking** (Dorst, 2006) as a technique to set more focus on the whole, create alternative viewpoints of the situation, and creating an AND instead of OR approach. Supported with a card set[15], it opens up the students' creative memories to trigger a quantity of ideas during the lotus blossom.

Giving the students a set of storytelling techniques enabled them to approach it their own way, it was perceived as a useful way to understand the situation, the consequences of design decisions and an easier way to communicate and verify the concept. Therefore, some techniques such as **body storming** and the **narrative** were added to the list.

For the same reason, prototyping/scripting was also supported by alternative tools like: the **blueprint**, and **process mapping** (also derived from the service design toolkit), providing a connection and easy way to elaborate on the touchpoint matrix. (SDT)

In support of the PSS (idea) selection, we have aligned it with the COCD box. Two reinforcing techniques that form the **selection matrix**, a necessary convergence for students when coming out of the ideation phase.

Leverage points were also incorporated as a new 'systems' tool, going a little deeper on the selection of strategies on how to intervene in the system (Meadows, 1999).

The system map v2.0 was renamed to the **to be system map**, referring back to the first version and chosen focus. Again, its place here in the process keeps addressing the necessary feedback loops and verification of the original goals. Importantly, there has to be a visual representation of the future system.

[15] http://namahn.com/share/paradox-cards/

An additional effort was made to integrate a prototyping part, providing a stepwise insight how to get the students to evolve from a **low**, over **medium** toward **high fidelity prototyping**. There was a large amount of students indicating they require this extra step. Like this, more steps were integrated in the define phase of the design process to further elaborate on the concept and having a more balanced analysis and synthesis.

Finally, the user test was renamed to **stakeholder test**, a more correct use of terminology.

3.5.4 2016-2017 | the validated toolkit

Figure 3.12 | 2016-2017 | the validated toolkit

A quite important step in our iterations, the booklet was transformed into a prototype of a book (Dewit, Van Ael, et al., 2016), a guide or manual of what was to become the PSS design toolkit. This version had the look and feel or a real book and could serve as a reference for students to refer to when using the toolkit in collaboration with stakeholders. Together with the expert panel, we discussed how this manual should look like and its intention: students need to learn how to look at systems, learn about process thinking and take a deep dive into behavior. This resulted in the following changes in this validated version of the toolkit.

We used actor mapping in 2013-2014, it was clear that we needed it in close relation to system mapping. It resulted in the **context-mapping** tool. This would enable the students to bring the different actors, places, artefacts, and the interactions between them to the surface.

In some occasions, students rather perform an **observation** than an interview, or use a method of their own choice depending on their specific context, project and stakeholders (e.g., sensitive information, only accessible through fora, by observing, etc.).

The tool factors and themes was split up into factors and themes (using same title). But we also added **universal themes** (den Ouden, 2012) in which we address ecological, economic, psychological and sociological values on the different levels of the system: user, organization and society.

Leverage points. The tool was renamed to **intervention strategy**, giving the students an extra possibility to select how they are going to intervene in the system. This step feeds the design challenge (strategy) and its requirements before moving on to the ideation phase, important to know where you position your ideas. Adding examples was necessary to transform the abstract theory into daily practice.

Expert panel discussions have led to some changes in the order of the tools in the process, because they were not working supportive enough in the previous order (e.g., body storming, selection matrix, serious play scenarios, and touch point matrix).

"There is too little support to build character around the different themes, after the ideation stage." (student) This was a suggestion for the tool **solution spaces** (a reintegration of the solution areas in 2014-2015) and by doing so, providing another feedback loop to the factor and themes. In this tool, students have to be able to visualize different solutions (spaces), with their respective business concept, characteristics, and component distribution.

The blueprint does not work that well to align product and service interaction, so it cleared the way for the **customer journey** (integrated from 2014-2015).

Even with the extra prototyping support (in 2015-2016), the students still wanted more relative time to go more in detail when defining their concept, and different ways to do so. The expert panel discussions made sure we made considerations toward the end-phases of the course and its toolkit. Hence, we decided to add **appropriate fidelity prototyping**, **provocative prototyping**, and **make belief**.

An attempt was made to take in design for transition (structuring and planning - by means of a roadmap - the interventions necessary to reach the goal. A second endeavor was made to build a document called design specification, which describes the wholes and the parts of the system. A way to serve as briefing for the client and a breakdown of tasks for development. However interesting, we never succeeded to get to that part.

In this book, we also connected another research project on PSS (Coreynen et al., 2017) that addresses the internal levers for successful product-service systems and how product-oriented manufacturers can enhance servitization. The topic here was on service transformation in industrial companies, and therefore specific the topic was geared toward methods and tools to support the servitization shift. Together with our approach and immediately new to the entire concept of the toolkit at that point, it formed a way to approach PSS from an explorative and possible exploitative angle. This was necessary to sometimes make the necessary shift toward the actual implementation, prioritization and more business-oriented approach. We did not see this necessary for the design course, but definitely important for consolidation / generalization purposes after.

Since it was impossible for the students to provide feedback for every individual tool like the one they did before, we have built-up a multi-faceted evaluation of the PSS design toolkit from the first iteration in 2013-2014. This resulted in data from a post-inquiry, and the results from the psychometric tool Creativity Support Index (CSI), both described in Chapter 4. Based on two projects (one from 2013-2014 and another from 2015-2016), we elaborate on these cases in Chapter 5 as part of input for the process and the PSS design toolkit as a whole. The combination of these results pointed us to extra details in the process and a verification on the educational support of the toolkit.

For a final check and generalization purposes of the toolkit, the above manuscript was sent to University Press Antwerp (publisher) that assembled a guaranteed peer review commission, serving as a quality check for Chapter 6. Two (foremost academic) international experts on the topic have given their feedback. We also contacted two peers that had recently finished their PhD in the field of PSS (partly in education and afterward in consulting practices), reflecting on how this would (not) work in the industrial playground (see future research). All data put together, reworking all feedback (see Chapter 6), this resulted in the 5th and final version of the PSS design toolkit.

3.5.5 2017-2018 | the peer reviewed toolkit

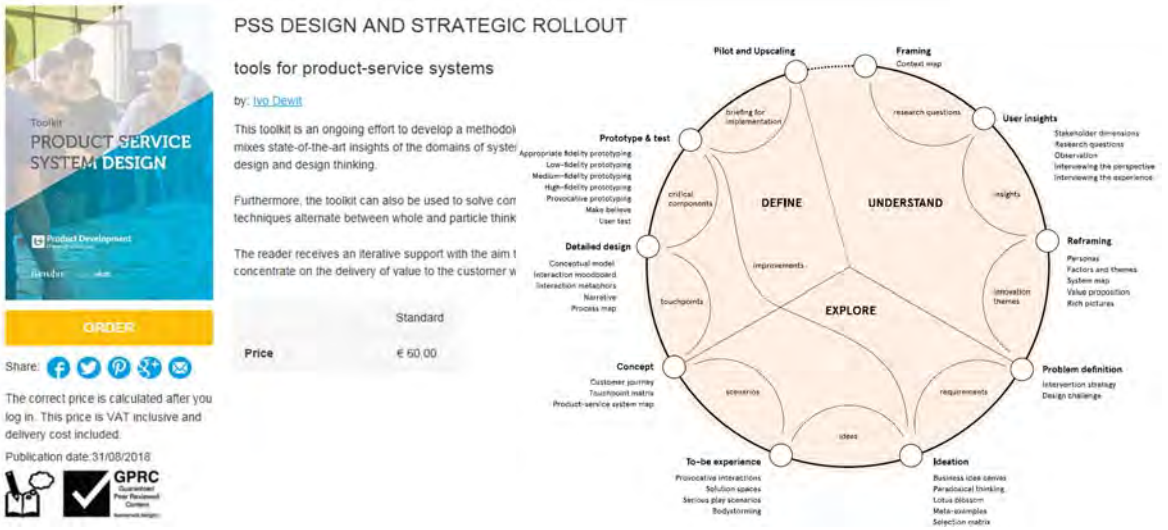


Figure 3.13 | 2017-2018 | the peer reviewed toolkit

For this step, we have also submitted our work for a Guaranteed Peer Reviewed Content (GPRC) procedure, of which the feedback ultimately results in the final version of the PSS design toolkit. To receive the GPRC label, it means that this publication has been peer reviewed according to international academic standards and has been positively evaluated. In Chapter 6, we provide more detail on the GPRC procedure, and present a concise overview of this final version (Dewit et al., 2018): **PSS Design and Strategic Rollout | tools for product-service systems**.

Considering the data of our multifaceted evaluation - but apart from the GPRC procedure - we made some final adjustments to the PSS design toolkit.

System mapping switched to a later stage in the understand phase - between factors and themes & value proposition - for synthesizing reasons. Context mapping took the first place in the framing process. *"System mapping comes way too early in the process, we need a way to map the context, rather than to understand the relations between all system's variables before the research has been done." (student)*

However not considered to take a formal part in the toolkit, the business model canvas and lean canvas were introduced for students that wanted to elaborate on business value. Nevertheless, some of the tools throughout the process can provide input for them. The option was to address one or more in-depth tools that provide input for economic value. For a first, we renamed universal themes to **value proposition** and provided students more detail on the different values in the system and how to address them. A second, the **business ideation canvas** was added to do a preliminary check on opportunities for ideas on the parts that possibly put together the system. Something that could also work on the level of the different concepts and resulting scenarios.

The to-be system map was renamed to **PSS map**, setting more focus on the parts that build the system, and making use of coherent terminology.

Figure 3.14 below shows the process of the PSS design toolkit in its last version.

Furthermore, we created the tools in a tangible version, with a clear connection to the actual PSS design toolkit (the manual). The students can use them as 'cheat sheets' during the design process, to have a first impression in preparation of how they will proceed in collaboration when using the big templates. Besides the tangible version of the tools, we also provide digital support for the students at the University's website[16]. The tools are the same, but students and outsiders are able to customize these (downloadable vector) tools to their own project.

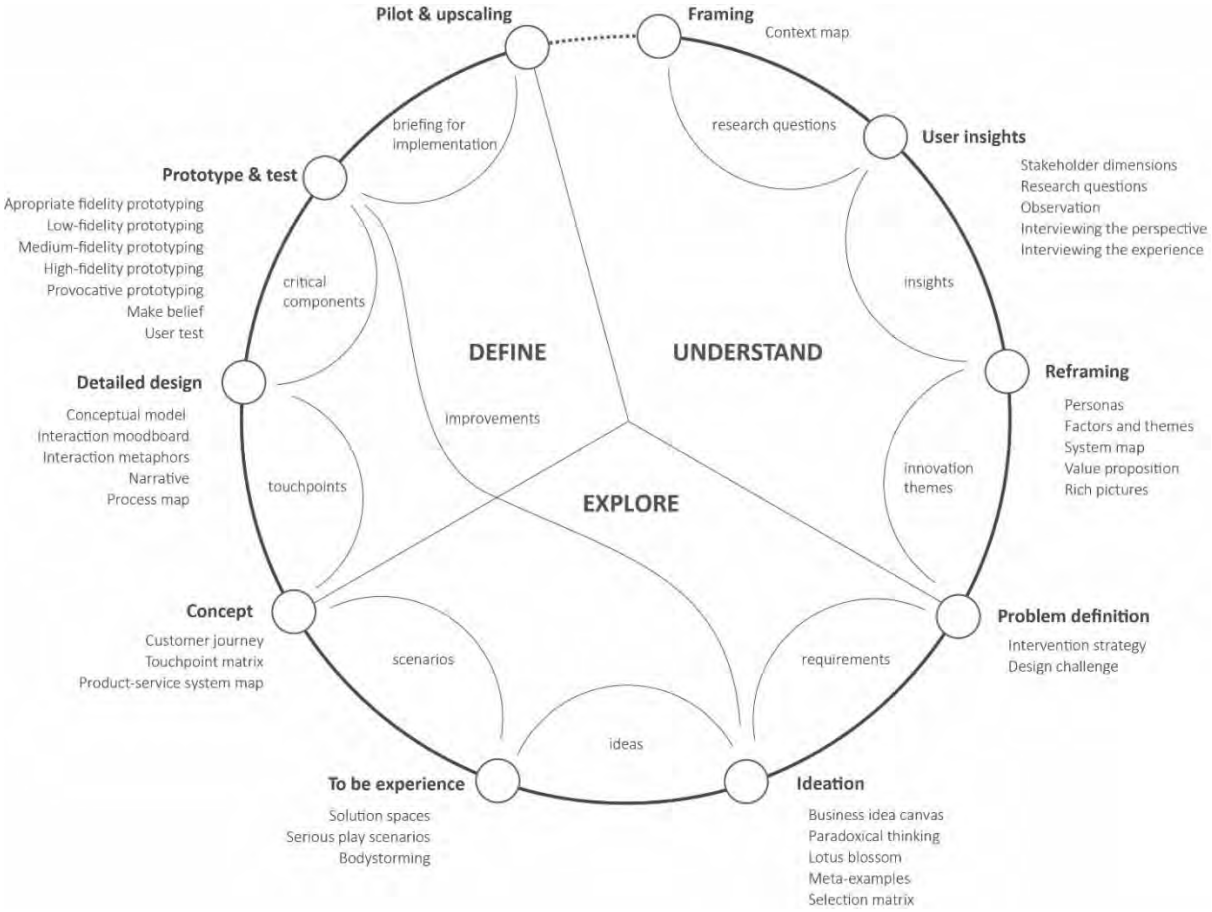


Figure 3.14 | PSS design toolkit - process

[16] https://www.uantwerpen.be/en/projects/product-service-systems/

3.6 Conclusion

In this chapter, we show the results of four iterations of the PSS design toolkit (RC 2-5) subject to justification. Based on our assumptions, we can claim having conceived a tailored approach that brings together and reinterprets existing design approaches, and ensures a synergetic interaction of products and services in the system and contributes to the existing theory on PSS.

We have described all the changes that were made throughout the four iterations of the PSS design toolkit on an individual level. Nonetheless, together they form the constituents of the PSS design process as a whole (see Chapter 6) and provides a basis to practitioners and academics for comparison, discussion and consolidation purposes.

According to the students, the key is to keep the approach flexible, following a semi-structured process leads them to a better support and outcome. However, it is essential for students to realize that it is about (the result of) the process and its steps, not about the tools as deliverable as such (e.g., “Are they sticking post-its according to the method?”; “Are they using the tool right?”). The thinking process itself (e.g., when sticking a post-it), and the discussion (e.g., exploring relations and the ideas that come along with that process) are sometimes more valuable than the output of the tool itself.

In order to build up an argumentation, present, and report that knowledge, students need to know what a specific tool brings to the process and what its relation is to other tools. Besides a continuous effort to understand relationships and interactions between the tools, students should regularly look back at earlier used tools, to check whether their conclusions were right and being able to adjust them where necessary. For this they need fixed moments in the process where they should be able to argument how insights were bundled together, organizing their structure of inference making (Klein & Moon, 2006), and the setting of problems to be solved (Schön, 1984). In this way, they should be able to systematically verify their updates with users and different other types of stakeholders throughout the design process. The design process should be comprehensible for all (Cross, 2006), so the designer’s very first conceptualizations and representations of the problem and solution are therefore critical to the procedures that will follow.

Each step in the PSS design process aims to motivate activity, which in turn will generate new goals and situations, constantly providing a fresh starting point for design activity. New prospects are opened up, envisioning possibilities and elaborating them is a valuable experience in itself (Simon, 1997). This will assist the designer to enable an exploration of constraints and requirements, in terms of converging on a matching problem-solution pair. How we are able to evaluate and select adequately grows together with our structured approach, gathering information, and prioritizing criteria. Ultimately, the toolkit supports the students to exert their abilities and increases their expressiveness throughout the design process. However, among other dimensions, this will be discussed in Chapter 4.

We conclude this chapter and link back to the main research question.

Based on Design Inclusive Research, Research Cycles (RC) 2-5, resulted in the development and application of processes, tools and techniques that aid the designer, namely the PSS design toolkit. We have investigated how our four iterations of the PSS design toolkit support students in the PSS design process. Requiring a constant reinterpretation of existing design approaches, we have mapped the ideal process that eventually created a synergistic interaction between products, services and people, strengthening synthesis.

CHAPTER 4

PSS design toolkit | Support

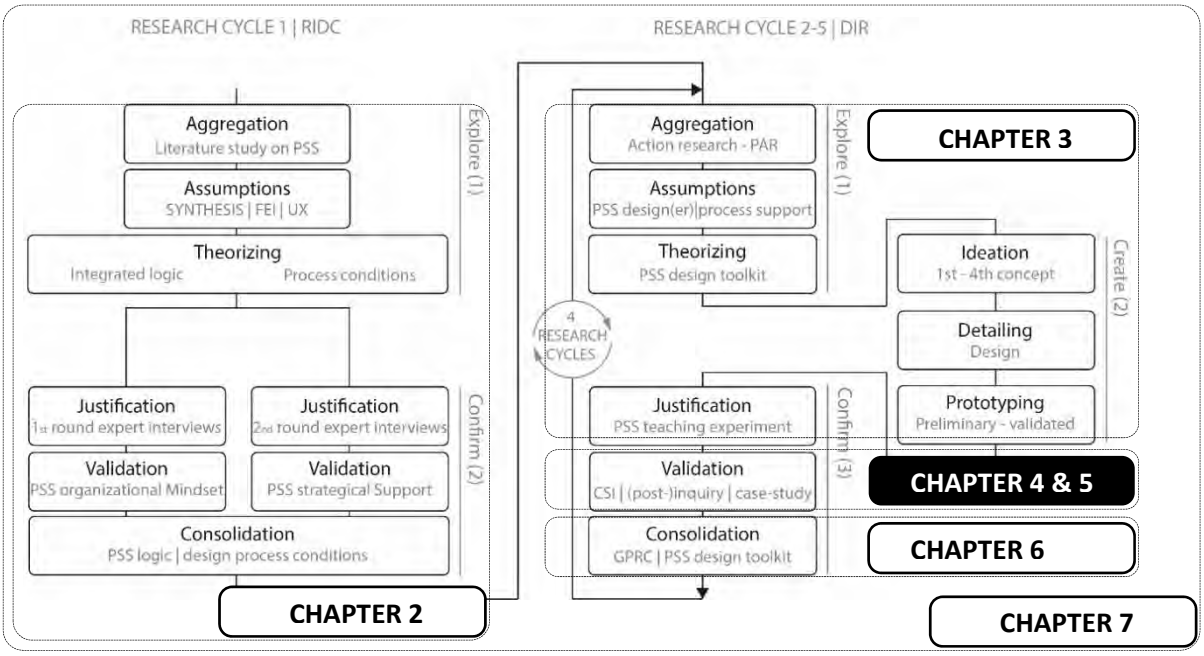


Figure 4.1 | Research design - chapters

4.1 Research framing methodology | DIR

In Chapter 3 we have ***aggregated*** the relevant knowledge for product-service systems, by means of exploration in the context of design. In addition to our current understanding and existing approaches, we identified opportunities for progression. Our research ***assumptions*** became the foundation of the proposed preliminary ***theory*** and its possible interventions to evaluate changes and identify interrelationships with the various forms of the PSS design toolkit, conceptualized and detailed in the creative stage, and then used in the confirmative stage to support data elicitation and collection. Finally, Chapter 3 was dedicated to ***justify*** the proposed toolkit, by its application in design education - IPO Project: Integrated Systems.

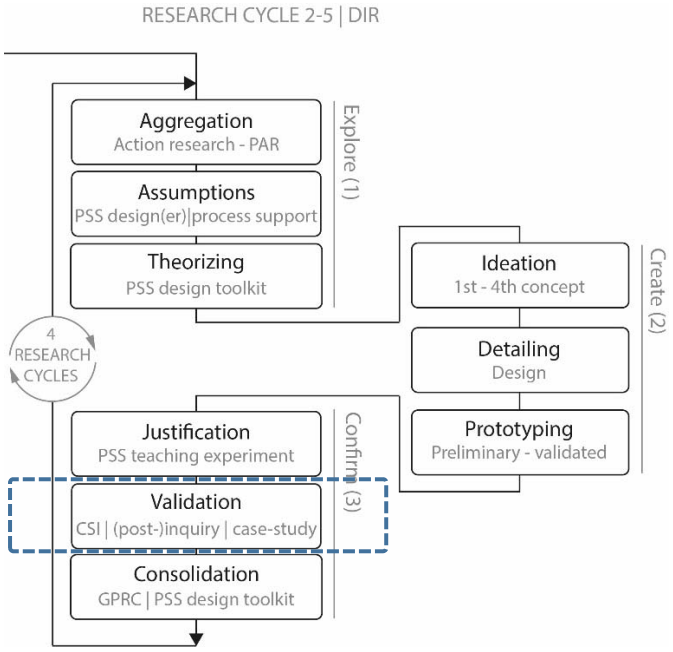


Figure 4.2 | Research Cycles 2-5 (comprehensive view)

This chapter will elaborate on ***validation***, we measure and interpret the extent to which the PSS design toolkit meets the objectives that it was intended to achieve, using CSI and the post-inquiry. Specifically we describe how much the PSS design toolkit is useful for the design educational practices. We consider our results reliable, since we tested internal validity through a triangulation of methods, i.e., creativity support index (CSI), post-inquiry and two case studies (later in Chapter 5). It is rather difficult to capture the real meaning and manifestation with this one instrument. However, to improve external validity, we will measure or interpret how much the PSS design toolkit is useful for the design practice in a broader sense and what it tells us about the real meaning of the research itself, besides the conduct and set-up. The extent to which the results of this study can be generalized, are held to be true for the recurrence - four iterations - of the experimental setting, with different people and times: on average fifty students 1st year Master students in Product Development each year.

* Parts of this chapter have already been published in one P1 Proceeding (E&PDE14) and two P3 Proceedings (A-DEWS15, ICSSI14). This chapter also presents insights, ready for a submission to the Journal of Design Research under the working title *"Using the Creativity Support Index to Evaluate a Product-Service System Design Toolkit".* Co-authors: Celine Latulipe and Francis Dams.

4.2 Research validation methods

Rather than to prove that the PSS design toolkit works, we are interested in whether we have made the right toolkit, that support the process, sparks creativity and group dynamics. For validation purposes, the methods used in the confirmative stage relevant for this chapter are:

- the Creativity Support Index, testing the support of the PSS design toolkit on six factors (collaboration, exploration, immersion, expressiveness, results worth effort, and enjoyment) as another way to triangulate on the effectiveness of this toolkit.
- a post-inquiry (a follow-up test) that was conducted with the same students one year after each research cycle in retrospect of the usage of the PSS design toolkit.

The Figure 4.3 below shows exactly where the validation methods were applied throughout RC 2-5.

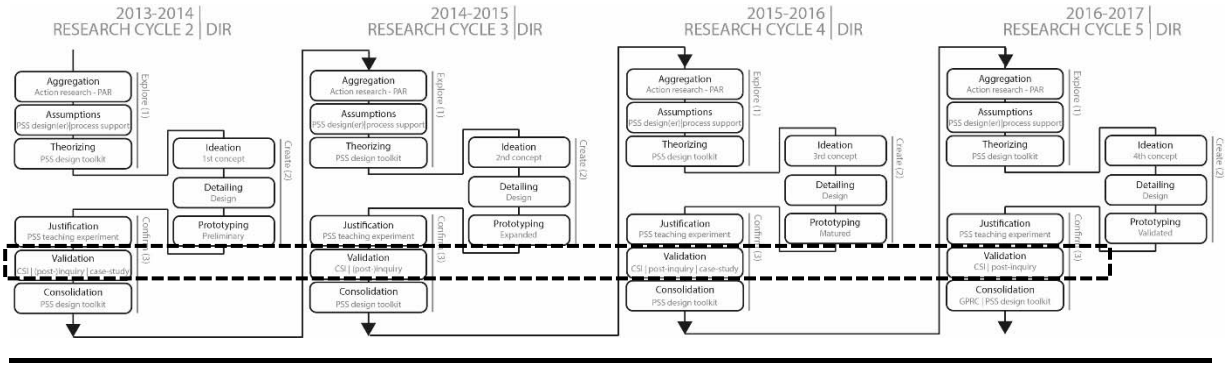


Figure 4.3 | Research Cycles 2-5 | DIR

4.2.1 Creativity Support Index

4.2.1.1 Creativity Support Tools

Creativity is revered by society as an essential human resource: it is linked to the economic principles of innovation and growth, as well as to individual personal development through creative expression, intellectual challenge, and psychological flourishing (Amabile, 1996; Csikszentmihalyi, 2013). Creativity support tools (CST) or Creativity Support Environments (CSE) can have a substantial impact on both individuals and society by improving scientific, engineering, humanist, and artistic endeavors (Latulipe, 2013; Shneiderman, 2007). CST are used by people in different domains to support a variety of open-ended creative activities, including tools designed to support programming, information exploration, data analysis, and artistic creations in visual, performing, or musical arts. Other examples of CST are Post-It Notes, Rhino3D, MatLab, Illustrator, Lightroom, WordPress, Flash, Prezi, and Lego Serious Play. The CST in this research is the above-mentioned PSS design toolkit.

4.2.1.2 The Creativity Support Index

Creativity support tools help people engage creatively with the world, but measuring how well a tool supports creativity is challenging since creativity is ill defined. With a wide range of definitions and theories, there is no single agreed-upon methodology for recognizing and evaluating creativity. This makes it particularly difficult to evaluate how well a tool supports a designer during a creative process or is actually helping a design team. Since the goal of our research was to understand which part(s) of the provided PSS design toolkit worked better than others, we chose to use the Creativity Support Index as a metric. The Creativity Support Index (CSI) (Cherry & Latulipe, 2014; Carroll, Latulipe, Fung, & Terry, 2009) is a psychometrically-validated survey designed to assess the ability of a creativity support tool to support the creative process of its users. Its theoretical foundation is grounded in literature about creativity support tools, creativity, play, and flow, including Shneiderman's design principles for creativity support tools (CST) (Shneiderman, 2007). The CSI helps researchers and designers to evaluate the level of perceived creativity support, provided by a certain tool or method while the user is engaged in a creative process.

The CSI measures six dimensions of creativity support: ***Expressiveness*** *(1);* ***Immersion*** *(2);* ***Enjoyment*** *(3);* ***Exploration*** *(4);* ***Results Worth Effort*** *(5); and* ***Collaboration*** *(6)*. Definitions of these six dimensions can be found in **Appendix VII** and are briefly touched in Table 4.1. It allows researchers to understand how well a tool supports creative work overall and which aspects of creativity support may need attention. This is particularly useful for designers and developers who are tasked with the redesign or improvement of a creativity support tool.

4.2.1.3 Research population

For the four years of this course represented in this research, we have approximately fifty students per year. Students are evenly divided into groups of three. In total, we have data from fifty-eight student teams (n = 58) that completed the CSI. In total we have data from one hundred ninety seven (n = 197) first year Master students in Design Sciences | Product Development who have used the different iterations of this PSS design toolkit (the CST in this research). The individuals are novices to this matter, none of the students that have taken this class before, are in the Master program for the first time and do not have experience with designing PSS. They have not been working in industry (having experience, but aspiring an official credential). Genders are quite equally divided. On an individual level, it is a five-year program for each student, they just finished their Bachelors' degree after a three year program and the design course 'IPO Project: Integrated Systems' is programed in the first semester of the first of the two year Masters' program. Flemish as language limits our students to come from Belgium and the Netherlands. Overall, resulting in a rather homogenous population.

4.2.1.4 Survey Administration

The Creativity Support Index (CSI) is a psychometric survey that is designed to assess the ability of a creativity support tool (CST) to support the creative process of its users. The CSI generates individual factor scores representing three things: how the tool (1) supports the user (2) in the various aspects of a creative task (3). The Creativity Support Index consists of two parts, an agreement rating scale section and a paired-factor comparison section. A screenshot of the CSI's user interface can be found in **Appendix VII**.

A first section of the survey consists of scoring agreement statements for the following six factors: Collaboration, Enjoyment, Exploration, Expressiveness, Immersion, and Results Worth Effort. For each factor, there are two agreement statements. Having two statements per factor improves the statistical power of this survey, as it allows researchers to look at the reliability for each factor by examining the similarity of the scores across the two different statements. The agreement statements are shown in Appendix Table II. Each statement is rated by participants on a scale of 'Highly Disagree' (0) to 'Highly Agree' (10). Research participants complete this section, responding to two different statements for each factor (though they do not see factor names or know there are two statements that represent the same factor). A higher factor score indicates that the tool being studied better supports that aspect of creative work.

The second part of the survey, a paired-factor comparison, consists of each factor paired against every other factor for a total of 15 comparisons. When presented with each pair, a user will choose a factor description in response to the following statement: "When doing this task, it's most important that I'm able to..." (see Table 4.1 below). In these comparisons, the participant is asked which factor in a pair was the most important to them, for the activity that they just completed. By reporting which aspects of creativity are most important to them in this particular task, the CSI generates factor counts enable a creativity support index calculation that is weighted by the most important aspects of creativity in this task. The factor counts themselves are useful data, because they indicate which aspects of creativity are most critical in a particular domain or task.

Within the scope of this thesis, these factor counts represent how participants would indicate factor importance when using either the PSS or '*any other ad-hoc tools to address the same task*'. (Carroll & Latulipe, 2009)

Table 4.1 | The paired-factor comparison test has 15 comparisons. For each pair, a user will choose a factor description in response to the following statement: "when doing this task, it's most important that I'm able to…" (Carroll, Latulipe, Fung, Terry, & Cheriton, 2009)

1. Be creative and expressive
2. Become immersed in the activity
3. Enjoy using the system or tool
4. Explore many different ideas, outcomes, or possibilities
5. Produce results that are worth the effort I put in
6. Work with other people

Besides the individual factor scores (from the agreement statements) and the factor counts (from the pairwise comparisons), the CSI application generates a single CSI score out of 100 for the tool being used, with a higher score indicating better creativity support (see Figure 4.4). The CSI is scored by first summing the agreement statements for each factor to get a factor subtotal. Each factor subtotal is then multiplied by its factor count (i.e., the number of times it was chosen in the factor comparisons). Finally, these are summed and divided by three for an index score out of 100.

$$CSI = [(Collaboration1 + Collaboration2) * CollaborationCount + (Enjoyment1 + Enjoyment2) * EnjoymentCount + (Exploration1 + Exploration2) * ExplorationCount + (Expressiveness1 + Expressiveness2) * ExpressivenessCount + (Immersion1 + Immersion2) * ImmersionCount + (ResultsWorthEffort1 + ResultsWorthEffort2) * ResultsWorthEffortCount] / 3.0$$

Figure 4.4 | CSI formula (from: Carroll & Latulipe, 2009)

4.2.1.5 CSI Usage Scenarios

The CSI can be used in a variety of study designs (Latulipe, 2013). Below we provide the scenarios that are applicable to our research.

Longitudinal Study of a CST

In our research, we were not so much using the CSI in correlation with expertise level, but with an iterating version of the CST with the same type of participants (the population), for the researcher to observe changes in particular with regard to the creativity support of the evolving PSS design toolkit.

Without Comparisons

In evaluating a creativity support tool, a researcher uses the CSI as an additional research metric, but is not interested in comparing CSI scores to another tool or to another creative task. It is simply administered as a post-experiment survey. In this case, we calculate the CSI and report it as a comparison metric for other researchers to use that are studying similar CSTs. We report the CSI results here so that others who develop PSS tools can then compare how their tools work to support creativity and use our results as a benchmark.

Individual Rating Scales

While the CSI provides an overall index of creativity support for a particular task and tool, researchers may be most interested in differences between particular factor scales (such as Immersion and Results Worth Effort). The results we report here shed light on which creativity support factors are most relevant when engaging in PSS design.

4.2.1.6 CSI Administration in the Design Course

We administered the CSI using the executable jar file application designed for research experiments[17]. Participants could easily complete the CSI within five minutes. The application scored each test automatically, saving the results in a comma-separated file, labeled with participant ID and condition number. Because the students worked in teams in the design course, we asked them to complete the CSI together as team (n = 66). Part of this choice was to ensure participation - if we had asked everybody individually (n = 197) to complete the survey, many probably would not have bothered. By giving it to them as a group activity, it was part of their course, and that helped to ensure a relatively high response rate over the four years, with fifty-eight out of sixty-six student teams completing the CSI, for an 87.8% response rate. In addition, the decisions they made as a group during the course influenced the way they felt supported and should be reflected in the CSI as well. Considering PSS design is a huge task, it requires collaboration within the group and with other stakeholders, and we therefore deemed it appropriate for the student teams to go through the survey together to reflect on their design process and group effort. Finally, by having the student teams complete the survey together, we could relate their CSI (factor) scores to their specific design projects.

[17] Link to CSI jar file on Erin Cherry's web page: http://erincherry.net/

4.2.2 Post-inquiry

This evaluation method is a follow-up inquiry, made by the same students one year after each research cycle in retrospect of the usage of the PSS design toolkit as another way to triangulate on the effectiveness of this toolkit.

Online, the survey is still active for future generation designers. For its format, duration and overview of questions: http://typeform/survey

4.2.2.1 Research population

For this topic, we refer back to the same research population described in Section 4.2.1 on Creativity Support Index.

Recurrently for four years, we administered a post-inquiry after (more or less) one year and a half after the IPO project ended. The same student population (n=197) was asked to take this survey at the end of their five year program, being at the end-stages of their Masters' thesis but before graduating. Considering this, the response rate for our online survey was still relatively high and resulted in a final sample size of one hundred and nine students (n=109) on which we base our outcomes.

4.2.2.2 Research justification method: post-inquiry

We used the versatile data collection tool 'typeform' to engage our audience with a conversational form of survey, https://www.typeform.com/. This application works on every type of device, makes it easy for the user to complete the survey within five minutes, attracting a higher response rate and thus getting more data. Online, the application shows the scores immediately to the researchers and respondents in a refreshing, interactive manner. The results are automatically saved in an excel file, labeled with participant ID and administration date. The participants are presented with one page consisting of twelve questions:

1. *Where would you situate your IPO project on this scale? (scale 1 – 10, 1 being "my IPO project was mainly a physical product" and 10 being "my IPO project was mainly a service")*
2. *Are you satisfied with the obtained result? ("YES"/"NO" answering category)*
3. *How did you find the use of the provided tools? ("supportive"/"burdensome" answering category)*
4. *Choose one of the factors below in which the tools have most supported your project. (choice between: creativity support factors: exploration, immersion, collaboration, expressiveness, enjoyment, results worth effort)*
5. *Has the use of the tools helped you to better understand the project context? ("YES"/"NO" answering category)*
6. *Suppose you did not use any of the PSS design tools, would you be able to achieve the same result? ("YES"/"NO" answering category)*
7. *To what extent have your skills improved as a designer because of the PSS design toolkit? (scale 0 – 9, 0 being "no change" and 9 being "strong progress")*
8. *Have you used the PSS design toolkit after the IPO Project in your graduation project / master's thesis? ("YES"/"NO" answering category)*
9. *Has your vision on the tools evolved after the end of the IPO project? ("Yes, in a positive way", "No", "Yes in a negative way" answering categories)*
10. *Is your graduation project (master's thesis) a PSS? ("YES"/"NO" answering category)*
11. *What do you think a PSS is? (open answer category)*
12. *Do you have any reservations about the previous questions, or are there things that have not been discussed that you want to mention about the IPO project? (open answer category) The overall recommendations with regard to the PSS design toolkit from Q12 were integrated in the results of Q1-10.*

4.3 Confirm | Validation by CSI

This section presents the results of four years of iterative evaluation of a Product-Service System (PSS) design toolkit. The PSS toolkit was used in a graduate education setting by students engaged in yearlong group projects. Our evaluation was anchored by use of the Creativity Support Index (CSI), a psychometrically validated instrument designed to measure how well a system or tool supports a creative process. By using the CSI longitudinally, in coordination with other evaluation methods, we were able to focus on areas of improvement to the toolkit, iteratively developing the set of tools needed for this complex process to better support future generation designers for the challenges that come with designing these product-service systems. Given that we are presenting the CSI results across four years, a detailed description of this progression is shown below, see Figure 4.5.

	2013 - 2014 **Preliminary toolkit**		2014 - 2015 **Expanded toolkit**		2015 - 2016 **Matured toolkit**		2016 - 2017 **Validated toolkit**		2017 - 2018 **Peer reviewed toolkit**
1	Stakeholders journey	1	Framing	1	System map	1	System map	1	Context map
2	Context & objectives	2	System mapping	2	Stakeholder dimensions	2	Context map	2	Stakeholder dimensions
3	Research question	3	UX interview template	3	Research questions	3	Stakeholder dimensions	3	Research questions
4	Stakeholder interview	4	User dimensions	4	Perspective interview	4	Research questions	4	Observation
5	Persona dimensions	5	Solution areas	5	Experience interview	5	Observation	5	Interviewing the perspective
6	Persona	6	Design challenge / requirements	6	Personas	6	Interviewing the perspective	6	Interviewing the experience
7	Actors map	7	Moodboards	7	Factors and themes	7	Interviewing the experience	7	Personas
8	Design challenge	8	Free brainstorm	8	Rich pictures	8	Personas	8	Factors and themes
9	Design requirements	9	Lotus blossom	9	Design challenge	9	Factors and themes	9	System map
10	Lotusbloem	10	System map v2.0	10	Paradoxal thinking	10	Universal themes	10	Value proposition
11	Prototype/service script	11	Lego serious play	11	Lotus blossom	11	Rich pictures	11	Rich pictures
12	User testing	12	PSS (idea) selection box	12	Meta-examples	12	Intervention strategy	12	Intervention strategy
		13	User journey map	13	Bodystorming	13	Design challenge	13	Design challenge
		14	Story telling techniques	14	Selection matrix	14	Paradoxal thinking	14	Business ideation canvas
		15	Prototype/service script	15	Serious play scenarios	15	Lotus blossom	15	Paradoxal thinking
		16	User testing	16	Touchpoint matrix	16	Meta-examples	16	Lotus blossom
		17	Touchpoint matrix	17	Leverage points	17	Selection matrix	17	Meta-examples
				18	Blueprint	18	Solution spaces	18	Selection matrix
				19	To be system map	19	Serious play scenarios	19	Solution spaces
				20	Conceptual model	20	Bodystorming	20	Serious play scenarios
				21	Interaction moodboard	21	Customer journey	21	Bodystorming
				22	Narrative	22	Touchpoint matrix	22	Customer journey
				23	Process map	23	To be system map	23	Touchpoint matrix
				24	Low-fidelity prototyping	24	Conceptual model	24	Product-service system map
				25	Medium-fidelity prototyping	25	Interaction moodboard	25	Conceptual model
				26	High-fidelity prototyping	26	Interaction metaphors	26	Interaction moodboard
				27	Stakeholder test	27	Narrative	27	Interaction metaphors
						28	Process map	28	Narrative
						29	Appropriate fidelity prototyping	29	Process map
						30	Low-fidelity prototyping	30	Appropriate fidelity prototyping
						31	Medium-fidelity prototyping	31	Low-fidelity prototyping
						32	High-fidelity prototyping	32	Medium-fidelity prototyping
						33	Provocative prototyping	33	High-fidelity prototyping
						34	Make belief	34	Provocative prototyping
						35	User test	35	Make belief
								36	User test

Figure 4.5 | PSS Design Toolkit Iterations

This section brings forward several lessons learned related to the implementation of the PSS design toolkit. The results are bidirectional: we used the results of the CSI as input as we iterated on the toolkit, and we used the results retrospectively to help us to see how the major changes in each iteration influenced the creativity support scores. The CSI served as a useful analytic tool, a lens to investigate and qualitatively think through how our PSS design toolkit supports the target audience.

4.3.1 Research results

4.3.1.1 CSI interpretation

The overall CSI score is a reflection of how well that tool supported creativity for the particular task or activity the user was engaged in, in this case PSS design, and that is likely dependent on both individual preferences, and the individual's level of expertise with the tool and the task. As with most metrics, an individual score will reflect individual differences, and thus the most useful information is achieved through aggregation. In our work, we have aggregated across all the students in each year, as they were exposed to the same version of the toolkit. We have then compared across years to understand how the iterative versions of the PSS supported the creative design process.

The **Statement Agreement** score **(SA)** represents the sum of both agreement statement responses for each factor, each of which is on a scale between 0-10, with a higher number indicating that the tool better supports that factor. Therefore, the maximum score for each factor is 20. The **Priority Counts (PC)** are the paired factor comparison counts and represent the number of times that teams chose that particular factor as important to the task. Note that the priority counts also tell us something about which factors are most important for this particular creative activity (regardless of how well the tool supported those factors). The highest possible priority count for any particular factor is 5, indicating that participants chose it as more important than every other factor.

We also report an **overall CSI score** for the PSS Design Toolkit so that this toolkit can be compared to other emerging toolkits in the future. However, the agreement statements and the priority counts are the central source of data that we were most interested in, for the purposes of potentially improving the toolkit in the future and to better understand what users expect from such a toolkit.

4.3.1.2 CSI aggregated results

In Table 4.2, the aggregated CSI results are summarized for the four iterations of the PSS design toolkit. Results for the four years are presented in order, left to right, with aggregation across the four years presented in the last section on the right. In each year, the factors are listed top to bottom, in descending order by priority counts, ranking the factors from the most important factor to least important factor as judged by the respondents. Enlarged tables can be found in **Appendix VII**.

Table 4.2 | Factor agreement statements, priority counts per year and aggregated over four years in the final column.

	2013 - 2014	n=17		2014 - 2015	n=12		2015 - 2016	n=16		2016 - 2017	n=13		2013 - 2017	n=58
	SA	*PC*		*SA*	*PC*		*SA*	*PC*		*SA*	*PC*		***SA***	***PC***
Exploration	11.98	4.43	Exploration	12.67	4.00	Exploration	13.50	4.50	Exploration	13.23	4.00	**Exploration**	**12.82**	**4.26**
ResultsWorthEffort	11.43	2.80	Collaboration	12.17	3.42	ResultsWorthEffort	12.63	3.44	ResultsWorthEffort	12.38	3.69	**ResultsWorthEffort**	**11.42**	**3.06**
Expressiveness	10.26	2.62	Expressiveness	11.25	2.92	Expressiveness	10.94	2.69	Expressiveness	11.46	2.77	**Expressiveness**	**10.92**	**2.73**
Immersion	7.71	2.50	ResultsWorthEffort	8.75	2.25	Collaboration	11.25	2.00	Collaboration	12.46	2.31	**Collaboration**	**12.15**	**2.30**
Collaboration	12.75	1.80	Immersion	6.75	1.92	Immersion	7.19	1.56	Immersion	5.62	1.69	**Immersion**	**6.90**	**1.94**
Enjoyment	10.24	0.84	Enjoyment	7.67	0.50	Enjoyment	12.50	0.81	Enjoyment	11.62	0.54	**Enjoyment**	**10.64**	**0.70**

Table 4.3 shows the overall scores of the CSI calculated using the formula from Figure 4.4. The table gives the average CSI score and the standard deviation per year and over all four years.

Table 4.3 | CSI results and variability

Year	*CSI Total Score*	*CSI Standard Deviation*
2013-2014	56.3	12.6
2014-2015	54.1	8.1
2015-2016	60.1	9.7
2016-2017	57.8	11.8
2013-2017	**57.1**	**10.8**

We examined the reproducibility of the responses of each team to the agreement statements and the variability in responses to the agreement statements across the teams in one year and over the four years. The top section of Table 4.4 shows the average of the difference between the two **statement agreement** responses a single team gave for each factor. For example, the number 1.25 for Collaboration in 2013-2014 indicates that on average there was a difference of 1.25 between the two agreement statements a single team gave about collaboration. Recall that the agreement statements use a 10-point scale. Lower numbers in the top section of this table indicate that student teams are internally consistent in their responses for that factor. In general, this difference is on average below 15% of the full scale, indicating that participants across the four years were largely consistent in responding to the two agreement statements for each factor.

The bottom section of Table 4.4 gives the standard deviation from the mean across teams per year for each factor agreement score. A lower standard deviation indicates that the groups were closer to one another in their level of agreement about whether the PSS toolkit supported that aspect of their creative process. Given that the sum of the two factor agreement scores would be a number out of 20, standard deviations in the 2-5 range are also in the order of 15% of the full scale. Under the assumption that the data are normally distributed this means that 68% of the scores are within 30% of the full scale.

Table 4.4 | Reproducibility of agreement statements and the standard deviation of agreement statements across teams per factor and year

Average Differences between Agreement Scores

	Collaboration	Enjoyment	Exploration	Expressiveness	Immersion	ResultsWorthEffort	**Average**
2013-2014	1.25	0.92	1.41	1.19	0.82	1.86	**1.24**
2014-2015	1.17	1.00	0.83	1.42	1.08	1.25	**1.13**
2015-2016	2.50	1.63	1.50	1.81	0.94	1.38	**1.63**
2016-2017	2.31	1.46	2.15	1.92	0.85	1.46	**1.69**
2013-2017	**1.80**	**1.25**	**1.47**	**1.58**	**0.92**	**1.49**	**1.42**

Standard Deviation of Agreement Scores across Teams

	Collaboration	Enjoyment	Exploration	Expressiveness	Immersion	ResultsWorthEffort	**Average**
2013-2014	3.07	3.65	2.64	3.77	3.19	3.19	**3.25**
2014-2015	3.16	4.25	2.27	1.66	2.56	3.31	**2.87**
2015-2016	4.04	2.88	2.25	2.49	4.17	3.52	**3.22**
2016-2017	2.63	3.07	2.95	3.04	2.90	3.99	**3.10**
2013-2017	**3.27**	**3.81**	**2.55**	**2.89**	**3.33**	**3.70**	**3.26**

Table 4.5 gives the standard deviation from the mean across teams per year for each factor priority score. A lower standard deviation indicates that the groups were closer to one another in their level of agreement about the priority that aspect of their creative process deserves. With a full scale of 5 again we find that the standard deviation is in the order of 20% of the full scale.

Table 4.5 | Standard Deviation of Priority Counts across teams per factor and per year

Standard Deviation of Priority Counts across Teams

	Collaboration	Enjoyment	Exploration	Expressiveness	Immersion	ResultsWorthEffort	**Average**
2013-2014	1.17	1.02	0.72	0.66	0.95	1.24	**0.96**
2014-2015	1.44	0.80	1.60	0.79	1.24	1.48	**1.23**
2015-2016	1.37	1.22	0.63	1.20	1.26	1.31	**1.17**
2016-2017	1.32	0.88	1.29	1.48	1.32	1.11	**1.23**
2013-2017	**1.41**	**1.00**	**1.07**	**1.04**	**1.22**	**1.36**	**1.18**

4.3.1.3 CSI Individual Factor Results

As results are stable over the years, we analyzed the average scores over the four years and compare how well the actual agreement score of a factor matches the priority scores given by the teams.

Figure 4.6 shows the position of the six factors with respect to the average priority count given by the 58 teams on the horizontal axis and with respect to the actual performance score given by the 58 teams on the vertical axis. The error bars indicate the 95% confidence interval for the position of these averages.

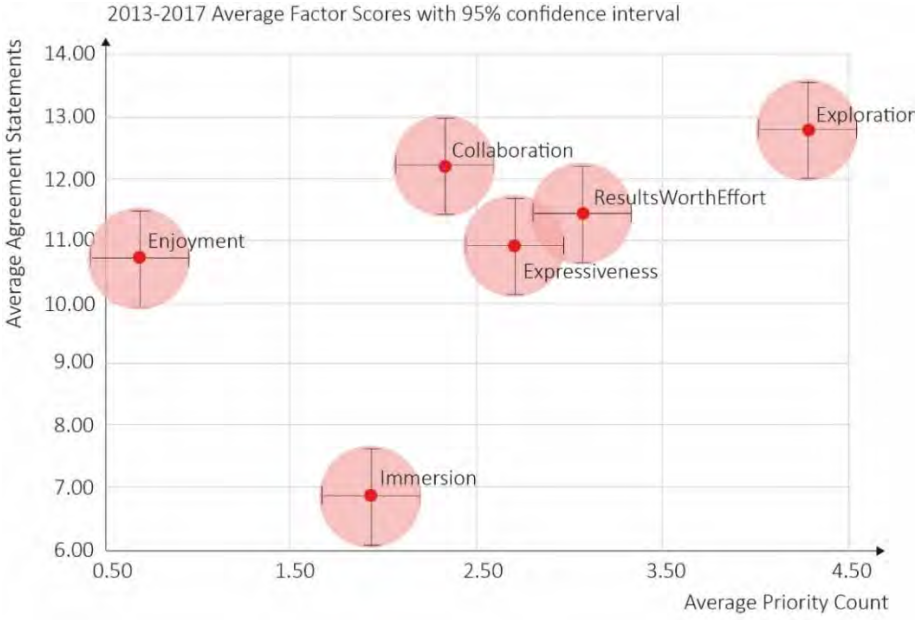


Figure 4.6 | Averaged CSI factor scores (priority versus actual performance)

The graph shows a rising profile, which indicates that the tool is fit for the demands of the given design task, as the higher the priorities match higher statement agreements.

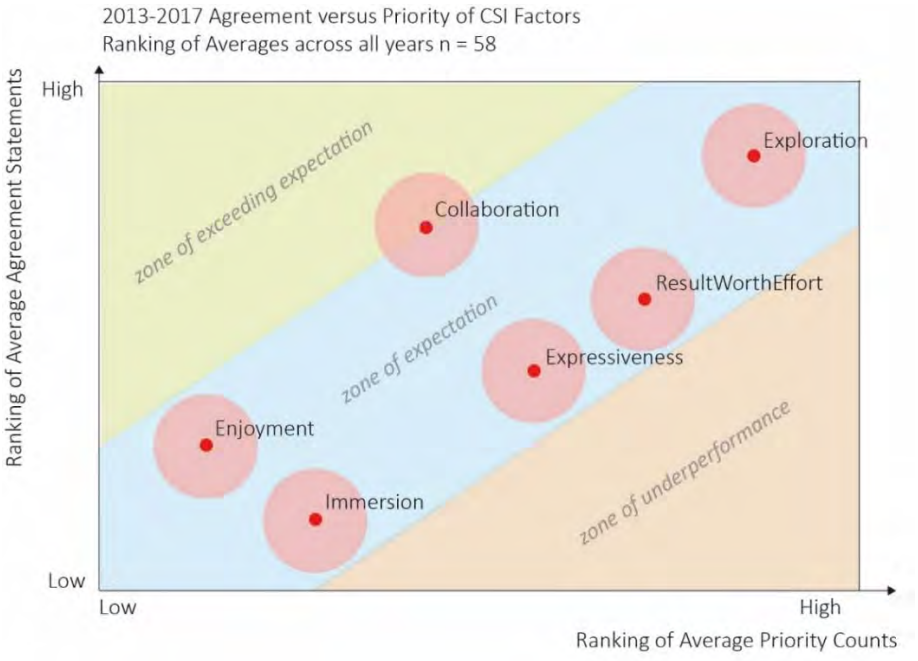


Figure 4.7 | Ranking of averaged CSI factor scores (priority versus actual performance)

Figure 4.7 shows this data presented using a rank, instead of a scale variable. The factors are ranked from left to right by increasing priority count, and they are ranked from the bottom to the top of the graph by increasing agreement scores. This way of evaluating these kind of tools shows in a visual way the degree of fit between the expected and the delivered support given by the PSS design toolkit. Factors in the upper left corner of the graph exceed expectations by 2 ranks or more, whereas factors in the lower right corner of the graph perform 2 ranks or more lower than the priority assigned to that factor by the users of the tool.

The results of the CSI (Table 4.2) bring forward insights, relevant for adaptations to the tested CST, the PSS design tool. Here we interpret the results for each factor within the context of the four years of coursework use of the toolkit. We also describe how results from the CSI prompted improvements in the toolkit over the four years.

Exploration

Exploration is critical and is seen as the most important factor by student teams engaging in PSS design. In the pairwise comparisons, the average count (PC) for exploration ranges from 4.00 to 4.50. This means that participants strongly agree that tools for PSS design should provide the necessary support for creativity by making it easy to explore different possibilities, try out new ideas and outcomes. Thus, in each phase of the design process, we made an effort to increase the number of possibilities, different ideas and outcomes that students would consider. In 2014-2015 we added tools like framing, *system mapping*, *solution spaces*, free brainstorming, and the *touchpoint matrix*. In 2015-2016, we added tools like the *leverage points* (which later became the *intervention strategy*), *factors and themes*, and the techniques *human drives* and *paradoxical thinking*. *Business ideation canvas*, and *value proposition* tools were added in 2016-2017. The reason for adding all of these tools, was to increase the variety of ideas and the search for alternatives.

The **average statement agreement (SA)** for Exploration increased from 12.06 to 13.50 over the four years. This is a reasonably high agreement and it indicates that the users could explore many different ideas, options, designs, or outcomes, using the PSS design toolkit. This suggests that the PSS design toolkit does a good job of supporting exploration, which is important because the PSS design toolkit was created to engage designers in deep exploration during the front-end of innovation. We also note that the within group variance for Exploration is quite low and the standard deviation for Exploration is also very low (from Table 4.4 and 4.5), which provides further evidence of agreement among the students that exploration is well-supported.

Results worth effort

Results worth effort captures the tradeoff in complexity of the tool, how much work is required by the tool and the quality and variety of things that can be produced using the tool. There are tools that support specific parts of a design process, but they just do not allow a person to do very much. The CSI is one of the only creativity metrics that captures the fact that the PSS design toolkit takes a lot of effort to use, it is very complex, but it also allows users to accomplish a lot. The PSS design toolkit is huge, and student teams have many exercises and tools that they have to go through. This may be kind of overwhelming and frustrating during the process because it takes so much effort. Nevertheless, in the end, because it forces the group to put in so much effort, they then end up having a comprehensive system that has been thoroughly designed. Therefore, it is interesting to see that results worth effort come out as an important factor. The average count for the *results worth effort* factor started around 2.25 and gradually built up to around 3.69. It was the second most important factor in the first, third and fourth year, demonstrating the importance to the students. This suggests that groups perceived this factor to be of moderate to high importance, when doing PSS design. In 2014-2015, we noticed a substantial decrease of this factor score, and we therefore made three choices for upgrading the toolkit

in 2015-2016. We added a number of tools to help make the results more valuable: *rich pictures*, *meta examples*, *product-service system map*, *interaction mood boards*, *narratives*, multiple types of *prototyping*, and the final *stakeholder test*. A second initiative involved formalizing all the tools into a coherent package for all students to work similarly throughout the entire process, giving the output a more professional look and feel. Thirdly, we moved from paper templates of their final designs to exhibition-like printed boards and also created a final event for stakeholders to participate in, including a more externalized, formal and consistent way of presenting all the material. All of this was designed to make the results more valuable, and thus make the effort required feel more in line with the results produced.

Even though the PSS design process takes a significant amount of time, and using the PSS design toolkit requires many steps, the agreement ratings (going up from 8.75 to 12.63) show that the student teams appreciated the plug and play diversity of the newer iterations of the PSS design toolkit. The groups were increasingly satisfied with what they got out of the PSS design toolkit. The extra tools might have reduced the personal effort required to go through the design process and the groups were gradually more satisfied with what they got out of the PSS design toolkit, growing alongside the toolkit improvement efforts.

Expressiveness

The priority counts for *Expressiveness* ranged from 2.6 to 2.92, which indicates that this is of moderate importance to student teams engaged in PSS design. Based on a comparison of the factor scores and the priority counts in the first year, we felt the need to increase support for expressiveness, therefore we added tools such as mood boards, (LEGO) serious play, and storytelling techniques before the 2014-2015 academic year. Moreover, in 2016-2017, we added multiple types of *prototyping* (*appropriate-*, *provocative-*, *low-*, *medium-*, and *high-fidelity prototyping*, *make believe* and the use of *metaphors*), again to enhance the level of expressiveness.

The high priority counts for this factor indicate that the teams expect to be able to express ideas clearly while doing PSS design. Over the four iterations, including the changes detailed above, the PSS design toolkit grows correspondingly in its SA score from 10.92 to 11.46, indicating groups became more satisfied with how the tools in the PSS design toolkit enabled them to be expressive.

Collaboration

Our PSS design toolkit was designed to support collaborative work. The PSS toolkit engages users in a long, complex process and collaboration is essential, because one person cannot complete a PSS project alone. The PC average count for collaboration increased from 1.8 in Year 1 to 2.3 in Year 4, indicating that as the toolkit expanded. Collaboration in using the toolkit was seen as increasingly important. Since the earliest development of the PSS toolkit, the integrative, multidisciplinary approach has been driven to support collaborative effort and involving stakeholders, users and other people in the design process. Thus, the PSS toolbox stimulates group dynamics and co-creation sessions with future users and potential service providers. The average groups' SA ratings for Collaboration are high, with scores from 11.25 up to 12.65. This shows that the PSS design toolkit enables the group to share ideas, designs and work easily in team(s). However, after collaboration received a slightly lower (factor) score in 2015-2016, we decided to add tools like *concept mapping* to promote earlier collaboration. We also note that the Collaboration factor had the highest variance in pairwise counts. While the student teams agreed that the toolkit supported collaboration well, the student teams did not rank Collaboration as a particularly important factor. There is a strong tendency for people to believe in the myth of the creative `lone wolf' and it is possible that these students also felt that the collaboration support was less important and that the creative inspirations were more likely to come from individual genius inspirations than from collaborative effort.

Enjoyment

The PC average factor count for enjoyment is low, ranging from 0.50 to 0.99 over the four years. This indicates that enjoyment is not particularly important to student teams when engaged in PSS design. The teams do not expect to be happy to use this system or tool on a regular basis. This makes sense, because this creativity task is a work task. The groups are not going to create an entire PSS design just for the fun of it, during their free time. Use of the PSS toolkit is creative, but it is very hard work, involving systemic design and it could be a full-time job.

Despite the fact that PSS design is not something people do for fun, we felt it was still important that the task be as enjoyable as possible. In the design of the PSS toolkit, we iteratively investigated ways to enhance the visual design and make the interaction more fun. To get the students more satisfied with the way they were engaged in the use of the PSS toolbox, we went from a digital document to a tangible book & toolkit. The final form and downloadable version of the PSS design toolkit is in vector format and can now be manipulated more easily by the groups. The student teams scored the statement agreements for the factor enjoyment at a moderate level in year 1 (10.24), but that score went up over the four years to 12.50 in year 3 and 11.56 in year 4. Again, we note that the rating in year 2 was anomalously low at 7.67, indicating that year 2 had some peculiarities in the course project process. We note that because of the lower scores early on, we were able to make iterations taking these criticalities into account. In the latter scores, the results indicate that the teams now enjoy using the PSS design toolkit.

Immersion

Immersion appears to be the least relevant factor in the CSI for PSS design. The student teams were not particularly 'immersed' when using the PSS design toolkit. The average PC factor count for immersion was overall quite low (increasing from 1.56 to 2.52), which suggests it is of less importance to groups engaged in PSS design. The statement agreement scores are also not particularly high across the iterations (ranging from 5.62 to 8.02). The teams want PSS design tools to support creative design work, but do not appear to expect a fully immersive experience during this work. This makes sense because with PSS design, there is no immediate feedback loop, as with mixing music, sketching, or other more artistic creative endeavors. In those types of endeavors, losing track of time because of deep immersion in the creative process would be more expected. However, when going through the PSS design toolkit, the teams are very aware of the process they are going through and insights that result from it. Furthermore, they have to keep track of their time in order to consciously plan and execute the PSS design process. Their attention is fully tuned to the activity, but they are never immersed in such a tight feedback loop that they can forget about the PSS design toolkit they are using.

4.3.1.4 CSI validity

Our participants in this research are a homogenous group of students from Belgium and a minority, ranging from five to ten percent coming from the Netherlands. We do not see any major differences across the participants and few differences in factor ranking across the years. The standard deviations for the factor counts (as shown in Table 4.5) are quite small. This suggests that the student teams across the four years are all quite similar in how they view the relative importance of the various factors in PSS design.

Our usage of the CSI shows stability and reliability in three ways:

1. Power in numbers: Because we used the CSI as part of a longitudinal study over four years and because we have data from 197 users, (from 58 groups), this provides significant reassurance that the CSI results we have presented are meaningful.

2. Internal validity: The way that the CSI is structured, with two questions per factor, gives the opportunity to investigate the internal validity by comparing how similarly individuals responded to the two questions associated with each factor. Table 4.4 shows that the internal validity for CSI used in this study was strong. The within group variance for each factor across the four years of study was typically below 2, on a 10-point scale.

3. Stable factor weightings: We would expect the pairwise rankings for the different factors to be consistent across the four years, because the task of designing PSS does not change. The PSS design toolkit that supports the task might be iterating and changing, but the outcome the students have to produce is similar each year. The factor counts shown in Table 4.2 demonstrate that there is no significant change in which factors participants consider important to PSS over the four years.

The CSI was designed with the intention being one evaluation tool that researchers could use in concert with other evaluation approaches. In addition to using the CSI as an evaluation metric, we gathered corroborating evidence through other evaluation methods: case studies, post-inquiries, expert panel and peer-reviews. These data were used to triangulate the effectiveness of the PSS design toolkit.

The CSI scores are dependent on both individual preferences, as well as the individual's level of expertise with each of the tools. As the students had to complete the project together, they also filled out the survey together, discussing each answer as a group and this likely limited difference due to individual preferences. Because the participants were all students new to PSS, none had experience with the provided tools (PSS design toolkit). Another type of expertise could also influence the results, namely the level of expertise in the domain. Again, individual differences should be averaged out since the groups all consisted of three first-year Masters students in product development with a similar educational background.

4.3.1.5 Study limitations

The design teams took the survey over four different semesters, and the CSI shows consistent aggregated results and a slight increase in the total CSI score. We acknowledge that these results might be biased for following reasons:

(1) The CSI survey was completed by teams (n = 66) as opposed to individually (n = 197). This felt appropriate given that the students used the toolkit together as a team, but it is unclear if the results would have been different if the students had completed the survey individually.
(2) Only 58 out of 66 teams fully completed the CSI instrument as required. Some of the student teams attempted the survey but did not save the survey correctly, some teams did not fill out the entire survey, and some team simply did not do the survey at all.
(3) In the second year, the scores for *collaboration* and *results worth effort* seem to have switched places and show a different weighting opposed to the other three very similar years / iterations. This might indicate that there was higher variance across groups on this particular scale, or results might tell something different when it comes to the standard deviation (SD). However, neither the variance across groups, nor the standard deviations across groups showed significant differences. This means that we are careful interpreting and acting on these results of the second year, but also attribute it to changes made in the second version of the PSS design toolkit, the population, and the external support. We did triangulate with other types of evaluation methods, where we looked for explanations of these differences. To ensure that *collaboration* was successful, we had each team participate in two peer reviews throughout the process, and proactively intervened when groups were not working well.
(4) The CSI was filled out before students received grades, with minor exceptions. There is a possibility that the ratings were impacted by students feeling pressured to rate the PSS highly

since the creator of the toolkit was their teacher and the one who would be giving them a grade. However, the students were assured that the CSI scores would not be looked at before final grades were submitted.

However, we have evaluated the variability of the results between the years. **Appendix VII** shows the averages and counts of the agreements statement and the priority counts by year. Therefore, we have run an ANOVA analysis to test the hypothesis that the (CSI) scores are the same over the years. Results of the ANOVA reveals some differences in the scores over the years, but shows a high level of stability in the measurements. We conclude that the values reported in Section 4.3.1 are stable over the years.

The CSI was one tool that helped us to understand how well the PSS toolkit supported the creative processes. We corroborated the CSI results with other evaluation results in order to create a more detailed and nuanced picture of creativity support provided by PSS. For instance, we provided the same student population with a follow-up survey (post-inquiry) on the PSS design toolkit, including questions such as: *"How did the PSS design toolkit affect your master thesis project?", "Is your master thesis project also a PSS?"*, and *"Did your opinion of the toolkit change after one year?".*

Together with the CSI, our evaluation methods focused on what parts of the PSS design toolkit worked better than others and whether process steps or even specific tools were missing. In addition, we related the skills and design outcomes of the project to the creativity support and evaluation of the toolkit to better prepare future generation designers for challenges that come with designing these product-service systems. The CSI was helpful in the iterative development of the tool, and could be useful to others developing creativity support toolkits in other domains.

The PSS toolkit has been used in other projects beyond the scope of this research and in other quite different contexts. Although we have to be careful with generalization of the research results, several design agencies, firms and governmental organizations assessed the applicability to real life situations leading to positive results. The positive CSI scores are supported by these external findings.

4.4 Confirm | Validation by post-inquiry

Complementary to the CSI (Section 4.3 above), we used this post-inquiry as an evaluation method. With our findings, we attempt to show the impact of the PSS design toolkit over a longer period, in retrospect of the 'IPO Project: Integrated Systems'. *E.g., Did the PSS design tools change the skills of the students? Did the students' vision on the PSS design tools evolve over time? How did the PSS design tools affect the outcome quality? Did the PSS design tools have an impact on the process quality?*

The results from the survey provide some extra insights on the process, the tools used and the influence they had. The results are also available online for the same set of students to compare their results to the overall population: https://typeform.com/report

4.4.1 Research results

The results from the survey provide some extra insights and long-term impact on competence, how the designer's vision on the PSS design tools evolved over time and how the process and tools have changed their skillset. In this particular evaluation type, we focus less on short-term impact on process quality (e.g., what is measured directly in the process, to what extent the tools have been used and what influence that had, changes that affect the quality of the process on the group more feedback loops, broadened scope, etc.) or on short-term outcome quality (e.g., did the PSS design process itself change through use of the tools / toolkit?)

4.4.1.1 Q1 - "Where would you situate your IPO project on this scale?"

The outcome of the PSS design process and toolkit, central in the design course: 'IPO Project: Integrated Systems', shows evenly distributed results in Table 4.6. The students did not situate their project as a pure product, nor did they position it as a pure service, rather they end up somewhere on the product-service continuum, comprising both product and service. Noteworthy, this continuum indicates different levels of component distribution and the emphasis (relative importance, value for the customer or client, etc.) they put on it (Table 4.7). Referring to the 11th question on the definition of PSS, students indicate clear differences between PSS, (1) as product-service combination, (2) service-supporting product and (3) product-supporting service.

Table 4.6 | PSS concept component distribution

The chart also shows the moving average of the data, identifying a trend(line) that inclines more toward the service side. Coming from a background in Product Development, these results show a clear break in the educational program, extending the skillset of the students and proving that the PSS design tools have an influence on the integrated output.

One hundred and nine students have reflected on their product-service system concept, conceptualized and finally prototyped by means of the PSS design toolkit. In Table 4.7 below, we provide a graphical representation of seventeen PSS concepts, in which we briefly described the concepts by their context, offering, interaction, intended user experience and component distribution in the PSS continuum (specifically related to this question in the survey).

Table 4.7 | PSS concept mapping

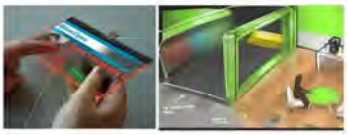
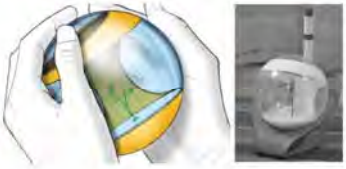
Node of life, context	Product service system (PSS)	User experience	Interaction
1 Aging, facilitating the transition to nursing home		Socially active, new contacts, lower threshold for integration in future living environment	
2 Aging, prolonging independent living at home		Supporting in patterns (diet and activity), personal interests and more efficient service	
3 Aging, retirement, sharing knowledge		Connecting the wise retired and the wisdom seeker, opens doors, collaboration, relevancy	
4 Hobbies, passionate about sports		Socially connect and engage, quantify inform and explore	
5 First job, efficient integration of new employee		Status visualization, interactive connecting to procedures, habits and people	
6 First investment, transparant communication on/off site		Eliminate language issues, monitoring contractors, work flow for investor and boost image	
7 First investment, creative agency startup		Lower stress, share startup highs/lows, connecting to network, city support in entrepreneurship	
8 First job, bridging job search and experience		Catching talent and experiences of students to build a CV and match early with companies	

Table 4.7 | PSS concept mapping (continued)

9	Pregnancy, stress reduction, interaction and communication support		Comfort through visualization of child, guidance in contractions, engage conversation	
10	Relationship grandparents and grandchildren		Passing on cultural heritage, gamification, story telling and family bonding	
11	Premature childbirth, parent support		Progress visualization, lowering guilt, fear and insercurity, involving others, mental support	
12	Aging, Alzheimer, family bounding, integration nursing home		Family bonding, understanding, smoother transition, communication, patient info	
13	Hospitalization, children, emotional care		Visualizing and supporting patient's line of well being, stimulate conversation	
14	Leaving home, foster care, interaction and (re)integration		Non-verbal, physical stimulus for communication between all parties, family bonding	
15	Leaving home, college/university, choice of study		Within flat student conversation, stability, social control, motivation and connection to study	
16	Marriage, increase the role of the city, ritual <> church		Increase city role in inhabitants' marriage, through engaging new ritual and guidance	
17	Divorce, communication and schedule		Transparency, start conversation, mindset preparation	

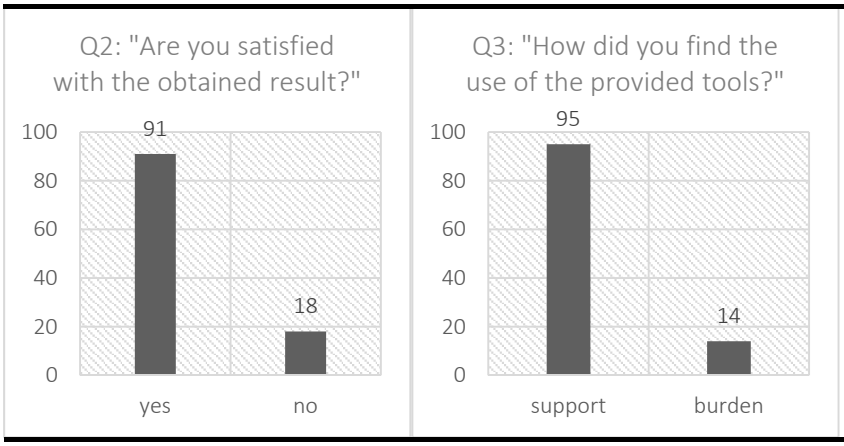
4.4.1.2 Q2 - "Are you satisfied with the obtained result?"

The second question relates to the *results worth effort* of their design effort. Table 4.8 (left graph) shows that ninety-one respondents indicate that they were satisfied with what they got out of the PSS design process and toolkit, eighteen indicated that they were not. This number corresponds with the results from Q10, where we observe that thirteen out of these eighteen dissatisfied students did not pursue a PSS as graduation project. Right after ending the 'IPO Project: Integrated Systems', all students directly received their grades. For those students, having received bad or mediocre scores, this might have resulted in a 'dissatisfaction' with the obtained result.

4.4.1.3 Q3 - "How did you find the use of the provided tools?"

In almost direct relation to Q2, the third question addresses if the students found the use of the PSS design tools more supportive (87%) or rather burdensome (13%) in the design process. More specifically, nine out of fourteen respondents in Table 4.8 (right graph) answered the PSS design tools to be more burdensome also responded negative on their end-result satisfaction in Q2. Some of those students elaborated on the use of the tools in Q12: *"The use of the tools sometimes seems a grind, only afterwards you notice how useful the tools are."; "The tools should be non-committal."; "Too many tools is not a good thing, it can become a burden, the task of the tools, the deliverable itself."; "Some quick handy tools could eventually become tools that take a lot of time."; "It would be interesting if tools can also be used online, making them interactively with an immediate digital trace and allowing easier follow-up."*

Table 4.8 | Results worth effort (left), and creativity support (right)

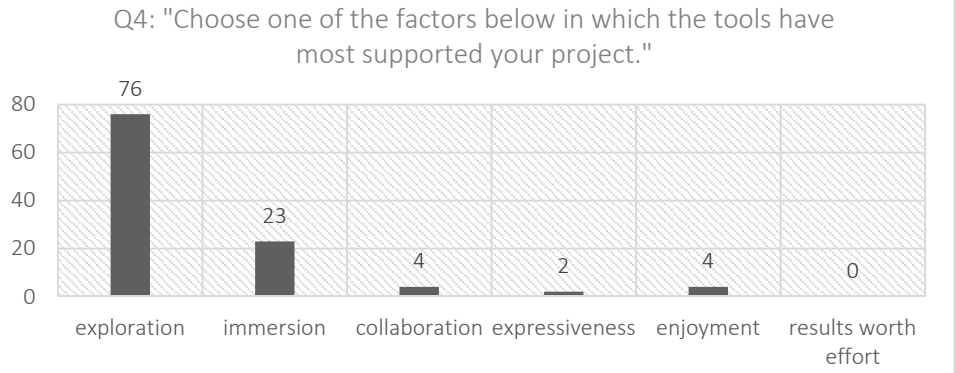


4.4.1.4 Q4 - "Choose one of the factors below in which the tools have most supported your project."

Coupling back to the CSI survey, the fourth question reports on the factors that support creativity during the IPO Project: Integrated Systems'. This question confirms quite obviously that *'Exploration'* stands out far above the other creativity support factors (Table 4.9), suggesting that the PSS design toolkit does a very good job of supporting exploration. This is an important outcome, because the PSS design toolkit has been created for (deep) exploratory purposes, during the front-end of innovation. In this post-inquiry, surprisingly and in clear contrast with the results of the CSI survey - where it received one of the lower to lowest factor scores - *'Immersion'* now also receives a relatively higher result compared to the remaining four CSI factors. Obviously, the students are no longer novices when it comes to the usage of the PSS design toolkit. This means that after some time, the students might have internalized the knowledge and understand that their attention is more fully tuned to the activity. Students elaborating on the tool support in Q12: *"The tools offer a lot of freedom and are very*

supportive for exploration, to think further about the problem and during ideation."; "I think the main thing that has done is to teach me a certain explorative approach".

Table 4.9 | The PSS design toolkit's most important CSI factor



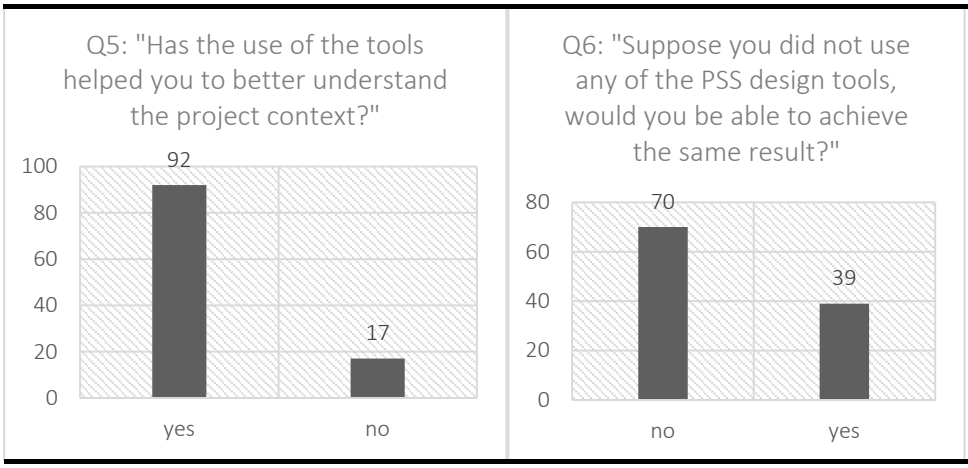
4.4.1.5 Q5 - "Has the use of the tools helped you to better understand the project context?"

Again, with no big differences in the results from Q2 and Q3, the fifth question shows that the PSS design toolkit supports the students in relating to the project context and its overarching theme (Table 4.10, left graph). This is important, because it is a compatible follow-up question on Q4. With regard to the higher outcomes for *'Exploration'* (76 out of 109) and *'Immersion'* (23 out of 109), the students are enabled to explore and immerse in the complex context, problem and its solution spaces, typically associated with systems. Students elaborating on the project context in Q12: *"The tools learn a workflow, a thought pattern, a manual where its users can choose what they want to go into but always with a clear overview of the context and feedback to the total system."*

4.4.1.6 Q6 - "Suppose you did not use any of the PSS design tools, would you be able to achieve the same result?"

The sixth question indicates (Table 4.10, right graph) that 70 out of 109 students state that they would not be able to achieve the same result without the usage of the PSS design toolkit. This number accounts for nearly two thirds of the total amount of students. Students elaborating on the results worth effort of the PSS design toolkit in Q12: *"In retrospect, I must admit my master's thesis is a PSS. The use of the tools, however, could have brought me faster to the end result."*

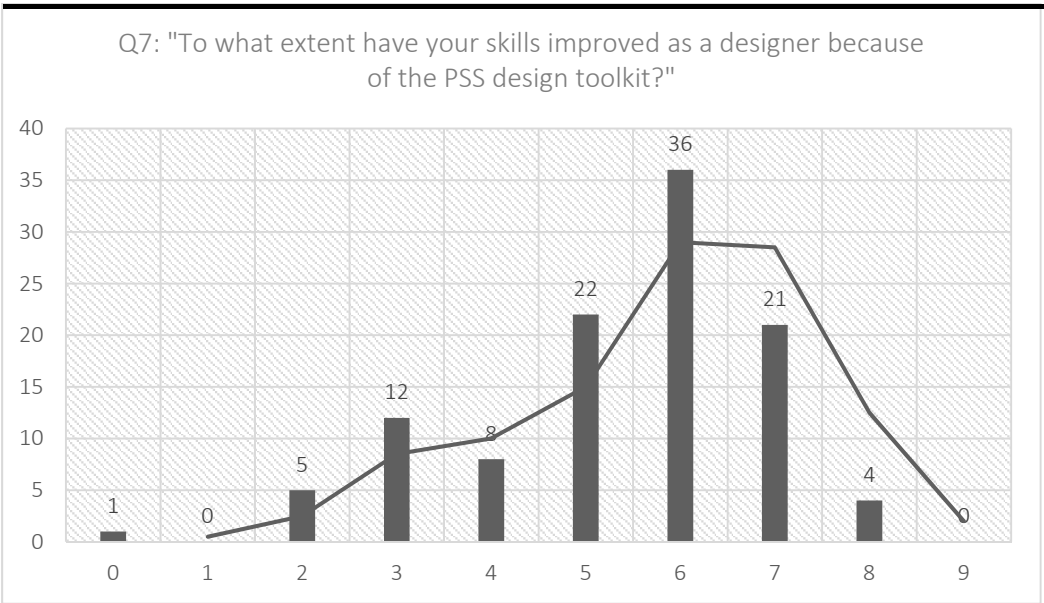
Table 4.10 | PSS design toolkit contribution to project context understanding (left), and to end-result (right)



4.4.1.7 Q7 - "To what extent have your skills improved as a designer because of the PSS design toolkit?"

In Table 4.11, Q7 shows a normal distribution of the data, and even a moderately to highly skew toward 'strong progress' in improvement of skills related to the use of the PSS design toolkit. Categories 5-9 represent 79% of the sample observations. Students have quoted on this change in mindset and elaborate on their improved skills in Q12: *"My first real knowledge with service-oriented design and got me to know the world of PSS."; "I think the tools are important for the diverging phase of a design, but especially for the converging ones because they help to make the right choices."*

Table 4.11 | PSS design toolkit contribution to design(er) skills



4.4.1.8 Q8 - "Have you used the PSS design toolkit after the IPO Project in your graduation project / master's thesis?"

As the process the students have to go through for their graduation project is rather similar, they can initially choose to use (parts of) the PSS design toolkit - for its indicated creativity support - when going through the design process. Furthermore, their final design does not have to be a PSS (see Q10), and students can choose to set more focus on the product or service component when this is deemed necessary. Still, sixty-four out of one hundred and six students have used the PSS design toolkit in their graduation project, shown in Table 4.12 (left graph) below. Students elaborating on the reuse of the PSS design toolkit in Q12: *"A fascinating way of thinking about products, it should come earlier in the educational program, and this way of teaching should be done in other courses too."; "My general idea about tools has improved during my Master's thesis because I can use them whenever I want and when it fits."*

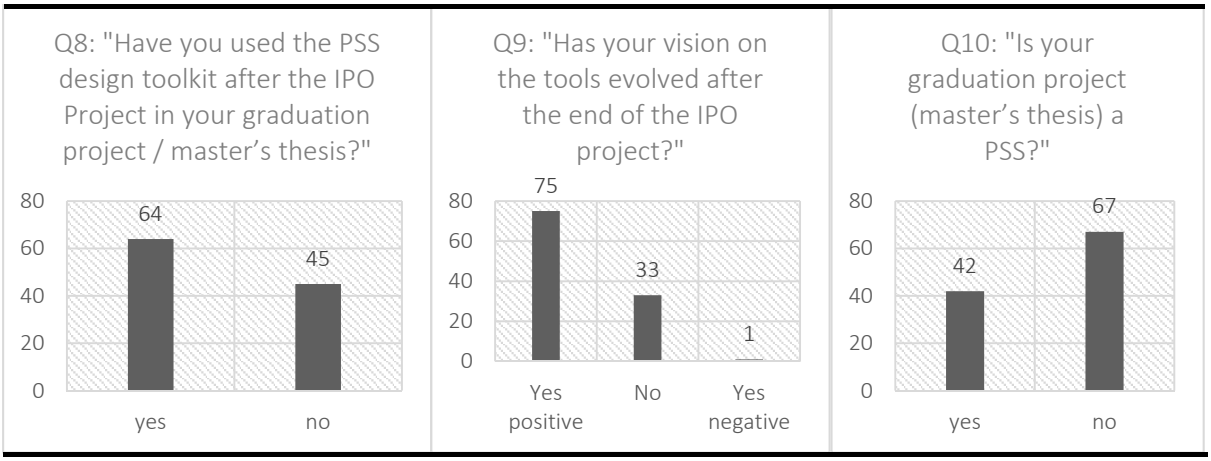
4.4.1.9 Q9 - "Has your vision on the tools evolved after the end of the IPO project?"

With seventy-five students out of one hundred and nine, question nine primarily shows (center graph in Table 4.12) a positive evolution in how they - *1 year later* - reflect on the usage of the PSS design toolkit. Thirty-three students show no change in their vision after one year, being a neutral score. Only one student has stated a negative evolution, and indicated to be dissatisfied with what s/he got out of the PSS design process and toolkit in Q2. It is no longer a compulsory assignment in their curriculum, rather they are now free to use whichever ad-hoc processes and tools they prefer. It is interesting to see that this positive evolution encourages the reuse of the tools and the graduation project being a PSS or not, respectively Q8 and Q10.

4.4.1.10 Q10 - "Is your graduation project (master's thesis) a PSS?"

Table 4.12 (right graph) shows that 42 out of 109 students' graduation projects have resulted in a PSS, indicating the complementarity of the PSS design toolkit in the skillset of the designer and an obvious choice to take a systemic approach to design.

Table 4.12 | PSS design toolkit reuse (left), evolution in vision (center), and effect on graduation project (right)



4.4.1.11 Q11 - "What is a PSS?"

As an open-ended 11th question, we asked the students for their definition of PSS. Below, we summarized the 109 definitions in five categories of answers: PSS a product-service combination, a product supporting service PSS, a service-supporting product PSS, PSS as a system, and PSS business potential. Worth mentioning, besides recurring keywords in the definitions (see Table 4.13 below) we provide some of the most descriptive definitions for each category.

When talking about *'**product-service combinations**'*, students set focus on the components of the system, describing the unison and what it contributes to. *E.g., "Opportunities in the product-service continuum, related to modularity."* This modularity can be interpreted as the relative importance of product or service in the system and can be attained throughout the design process itself or deliberately chosen up front, it ultimately characterizes and defines the components.

In a PSS where the *'**service is supported by the product**'* - rather service-driven - the students' definitions show possibilities for a *"Changing role and/or function of the service provider".* An interesting point of view, because the addition of the product changes the interaction with the system and enables the extension of the service provision. When supporting the service, the product receives more attention and a more detailed description, *e.g., "Product as negotiator, the product is rather a means to reach a specific goal, the product is not the goal itself."; and "Designing the product to meet the requirements and limitations of the service."*

When the PSS was described as a *'**product supported by the service**'*, the students defined PSS that express the service-specific characteristics. *E.g., "The service can grow together with the user and better adjust the product to his/her changing needs."; "The service provides structure."; and "The service part in the system addresses more the value to society." "Increasing intensity and intimacy, the service is the more intense link with the organization and provides more interaction, more touchpoints."*

If the definitions geared toward PSS with a clear *'**focus on the system**'*, students provide descriptions that explain possible roles for PSS in its broader context. E.g., *"PSS is an approach that sets importance to the (close) vicinity / use context of the product as much as the product itself."; and "PSS aims to bring something in a much larger context"; and "PSSs address the societal need(s) of the people".* Product-

service systems are about the whole, when students quote on PSS as being more than the sum of its parts, they add e.g., *"The product, service and the experience around it."; "The whole of products and services that because of their interaction and mutual reinforcement formulate a better answer to the customer's needs and wishes."; and "PSS is an intimate combination, necessary to be able to perform the system's functions in harmony".* The definitions also attempt to describe the design process, where product and service components meet and work together. *E.g., "PSS enables to use tools that provide more insight into the service you want to create."; "PSS combines product functions with complementary services in an all comprising system that ensures product and service to adjust to one another and align."; "A PSS can grow alongside the user, and is easier to tailor."; "PSS allows the interpretation of a need instead of offering the solution in the form of a product (getting from a to b, instead of buying a car)".*

A last category, '***PSS relates to business potential***'. In their definitions, the students formulate this economic gain as e.g., *"A PSS is a business model."; "Upgrading through the service part to make 100% use of the product's functionality, make the PSS last longer and prolong interaction."; "PSS initiates a 'shift in ownership'."; "PSS connects to the 'sharing economy'."; "Business model adaptiveness, related component distribution and deliberately choosing relative importance of product or service in the system (product-driven or service-driven)."; "A logical extension and opportunity is the combination of PSS and 'the digital'."; "The connection between stakeholders is a necessity in PSS."; and "It's better for products to connect to a service when it comes to bigger audiences".*

Table 4.13 | PSS category keywords

PSS categories	**Keywords from the students' definitions**
Product-service combination	(non-) physical, (non-) material, (in-) tangible, product and service support each other, reinforce and complement each other to better satisfy the needs and wishes of the user, intertwined, inseparable, synergy, exist because of each other
Service-supporting product	guiding usage and user, changing the role of the service provider, the product as negotiator, the product is rather a means to reach a specific goal, the product is not the goal in itself, designing the product in function of the service, designing the product to meet the requirements and limitations of the service, especially the service has to be elaborated when designing the product, the product enables, amplifies, intensifies the service, product enables the user to come in contact with the service, product enables an easier communication of the service, product simplifies the service, product lowers the threshold to use the company's services
Product-supporting service	increasing intensity and intimacy, different services allow more ways to support, custom made, tailored to the customers, service can grow together with the user and can better adjust to his/her changing needs, without the service the product loses its value or might even be useless, more intense link with the organization, more interaction, more touchpoints add value in the system, the story around the product is supported by the service, service is an added value in the 'more complete' system for the user, company and society, the service provides structure, the service simplifies the product
Product-service system	synergy, integrated, the whole, being more than the sum of its parts, added value, systemic, support acceptance, adaptive, modular, the story, grow alongside the user, easier to tailor, sets importance on the context of the user, method for more insight into the service you want to create, design to also meet the requirements and limitations of the service, interpretation of a need instead of offering the solution in the form of a product, an all comprising system that ensures product and service to adjust to one another and align, interaction and mutual reinforcement of product and

	service, coherent, intimate combination, necessary to be able to perform all system function harmonized, bring about something in a much larger context, the experience around it, addressing the societal needs
PSS business potential	PSS is a business model, offering over a longer period of time, a lasting service connected to the purchase of the product, upgrading through the service part to make 100% use of the product, change in ownership, product-service continuum (modularity) and business model adaptiveness, combining the digital, user experience, the story, better support and communication of a marketing plan, necessity of the connection between stakeholders, PSS when it comes to bigger audiences

4.4.2 Future research

A preliminary analysis of these PSS concepts (Table 4.7) points out potential new strategies or characteristics and provides new opportunities not apparent within traditional typologies. The results enable us to complement and refine within system product/service component distribution, we potentially add to existing typologies, strategies and characteristics discussed in Chapter 2. A PSS consists of product (tangible artefacts, visible things in the world) and service (intangible, digital) components, the **component distribution**. By setting a focus on product and/or service, its **consequences** can already be identified on a high and abstract level (FEI) during the PSS design process. These consequences catalyze different **experiential characteristics** that result from an interaction with product and/or service, and influence the overall type of user experience with the system.

In order to understand the effects of product and service components better, Table 4.14 below illustrates the effect of each component using PSS available on the market and brings forward a breakdown of three exemplary cases. We draw explicit attention to the first column where the blue/green scrollbar-like figure visualizes the component distribution and extends the earlier Figure 2.4 (A transition model; Integrated PSS logic shift) and Table 2.5 (PSS process dynamics).

Table 4.14 | PSS continuum breakdown

Component distribution	*Consequence*	*Experiential characteristics*	*Example*	*PSS*
Product focused 	A tangible artifact has an important role in the PSS. Without a dedicated product the PSS cannot exist.	The product carries specific aesthetic qualities and allows embedding emotion, personal meaning.	***Goodnightlamp**.com:* an internet-connected lamp. The aesthetic of the lamp is crucial during usage.	
Service focused 	The interaction with the PSS is not linked to a specific tangible product.	The PSS offers a specific functionality with a generic meaning that the user needs to assign.	***Jawbone**.com:* an activity tracker gives visual overview of a person's movement. Besides goals, users need to emotionally attach to it.	
Balanced 	Product and service are evenly important. When one of both would be removed, the PSS makes no sense anymore.	A user can decide whether s/he wants to relate more to the product or the service side.	***Estimote**.com:* beacons send messages to passersby in a retail environment. A distinctive shaped product but without the service no interaction possible.	

A deeper project screening is necessary to explore how aspirational design drivers provide requirements for interaction, product/service and the translation into product/service attributes that contribute to the user experience and its added value. However, this *component distribution* has

already been used in a Korean PSS repository project, to enrich a characterization of the 'product-service space' of PSS concepts.

Additionally, the recommendations resulting from Q12 have influenced the short-term outcome quality of the PSS design toolkit, clearly serving as input for the PSS design process, changing through the use of the tools.

For the short-term impact on process quality, we refer to the other confirmation methods that have measured the quality of the process more directly, the extent of tools being used and the influence they had on the students groups (e.g., more feedback loops, broadened scope, etc.).

4.5 Conclusion

We have shown that the CSI results help frame a cohesive story for how the PSS design toolkit works to support students engaged in PSS design. The power of the CSI lies in the factorization of creativity: rather than trying to define creativity as a whole, the CSI allowed us to collect and analyze data about the particular factors that are most relevant to supporting the creative work processes in PSS design. 'Exploration', 'Results Worth Effort' and 'Expressiveness' were ranked as the most relevant factors to PSS design. Students engaging in PSS have a large, complex task that requires a lot of creativity, thinking and experimentation, so *exploration* is important. It is a lot of work, so the *results worth effort* is important too. Another essential part of the PSS design toolkit is to represent the different steps in the design process and communicating with multiple stakeholders during the process up to the final design, which is represented by the factor *expressiveness*. The fact that these results were consistent over the four years of study shows that the PSS design process the students are engaging in is the same and they are understanding it in the same way, even as the tool support was iteratively changing over the four years.

The results from the post-inquiry provide some extra insights on the process, the tools used and the influence they had. Seventy out of one hundred and nine students indicate that they would ***not be able to achieve the same result without the usage of the PSS design toolkit*.** Consequently, opposed to a rather ad-hoc and unsystematic way, learning in a systematic process does actually support student designers. The use of more 'efficient' design processes, following the 'ideal' sequence, relates positively with both the quantity and the quality of the students' design results. This is confirmed by the level of end-result satisfaction and tool support. Designing is a form of skilled behavior, and developing any skill usually relies on controlled practice and the development of technique. The high amount of students indicating a positive evolution in how they look back on the usage of the PSS design toolkit relates with nearly the same number of students using the PSS design tools for their graduation project, one year later. The students have clearly developed a strategic approach to the overall process, whether it results in a PSS design (n=42) or not (n=67).

We conclude this chapter and link back to the main research question.

During Research Cycles 2-5, we were able to triangulate our results with the CSI and the post-inquiry to validate whether the PSS design toolkit that we have made, effectively is the 'right (creativity) support tool'. We have shown that the CSI results help frame a cohesive story for how the PSS design toolkit works to support students engaged in PSS design. The results of the post-inquiry have also proven the long-term impact of using the PSS design toolkit, how the designer's vision on the PSS design tools improved over time and how the process and tools have changed the student designer's skillset toward synthesis. Conclusively, we related the skills and design outcomes of the project to the creativity support and evaluation of the toolkit to better prepare future generation designers for challenges that come with designing these product-service systems.

CHAPTER 5

PSS design toolkit | Cases

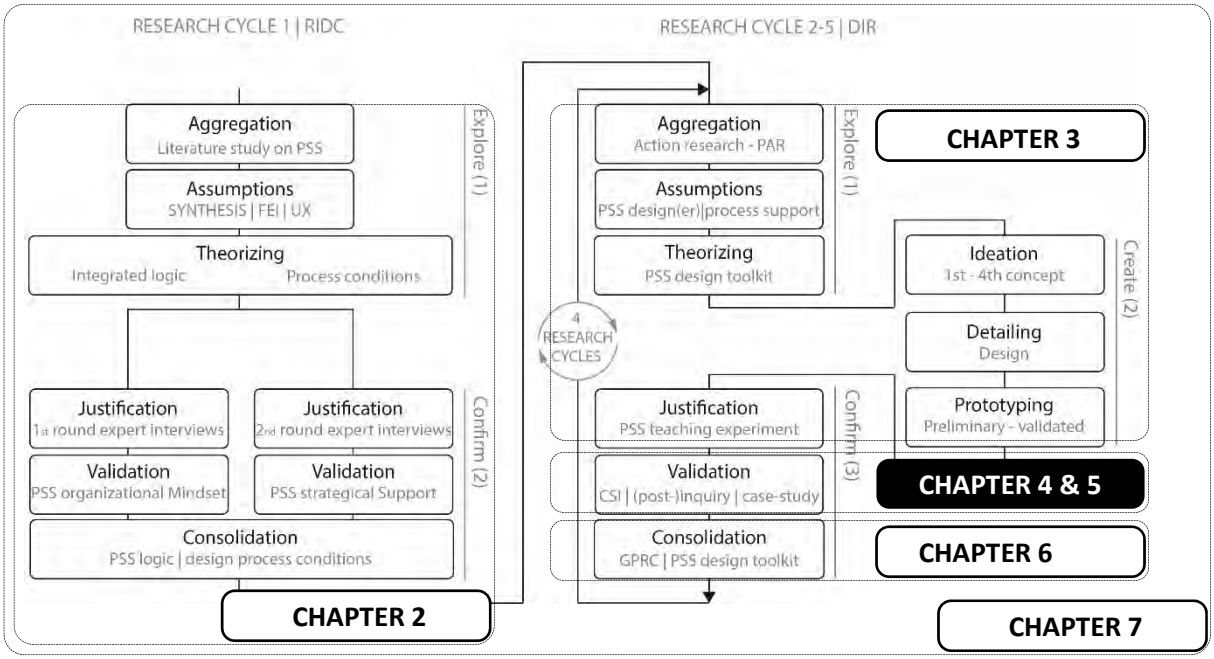


Figure 5.1 | Research design - chapters

5.1 Research framing methodology | DIR

In Chapter 4, we have ***validated***, measured and interpreted the extent to which the PSS design toolkit meets the intended objectives, using CSI and the post-inquiry.

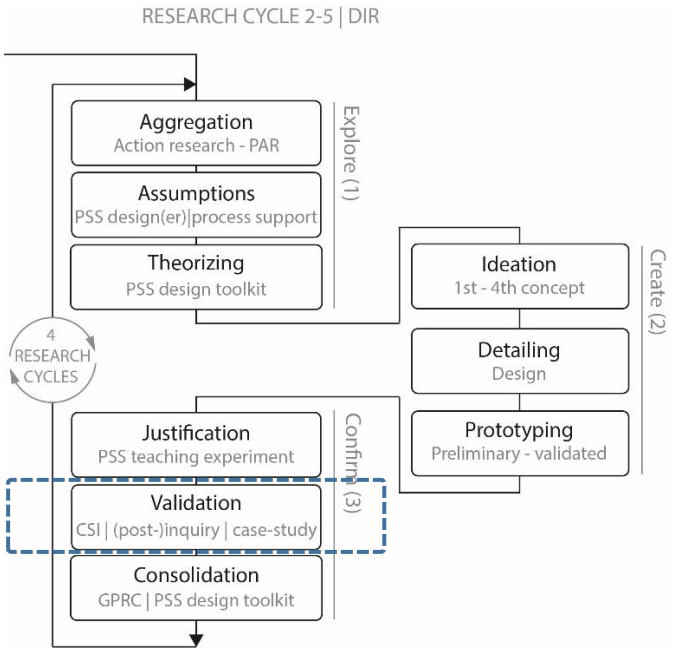


Figure 5.2 | Research Cycles 2-5 (comprehensive view)

As a part of the third stage 'confirm' in the DIR framing methodology, this chapter elaborates on ***validation***, describing how much the PSS design toolkit is useful for the design practice. The entire RC 2-5 has resulted in sixty-six developed and evaluated PSS design concepts, of which *Grand.C* and *ChefKot* are the two cases, subject to our study. We are specifically interested in how the manifestation of using the toolkit says something about the research itself. We claim that these cases can be generalized, and held to be true for the recurrence - four iterations - of the experimental setting, with different people and times.

* This chapter presents the elaborated work of two P1 Proceedings (IPSS16, D&E16), one designed system (NWO15) and connected insights from two P1 Proceedings (E&PDE14, ICSSI14) and one P3 Proceeding (A-DEWS15).

5.2 Research validation method

We are interested in the manifestation of using the PSS design toolkit, and how it says something about the research. For validation purposes, the methods used in the confirmative stage relevant for this chapter are:

- two case-studies that show a thorough analysis of how the toolkit was helpful and parts of the toolkit were less helpful in particular cases (Dewit, Cobben, Goovaerts, Van Steenkiste, & Jacoby, 2017; Dewit, Van Den Bossche, Veelaert, & Zoons, 2016).

Figure 5.3 below shows exactly where this validation was applied throughout RC 2-5.

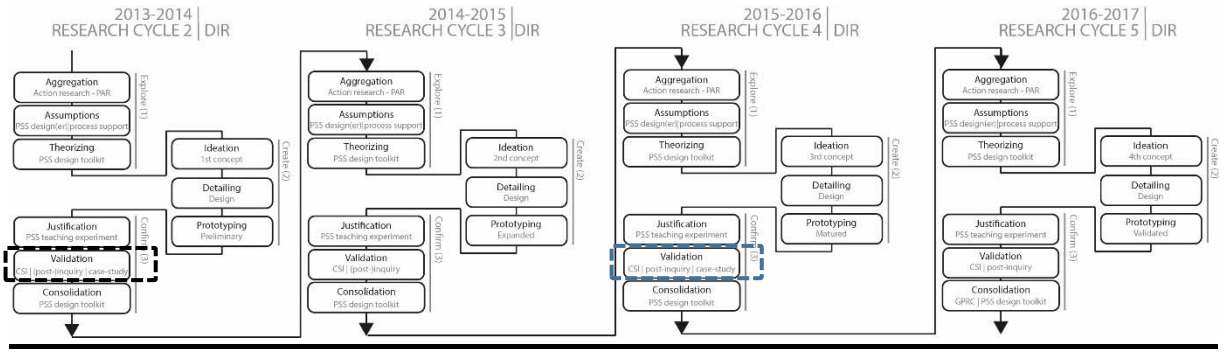


Figure 5.3 | Research Cycles 2-5 | DIR

The method used in the confirmative stage of this chapter was the case study, (in RC2 and RC4) to validate the (educational) support of the PSS design toolkit during the process and its final design outcome, and ensure small changes were made according to the data and feedback that resulted from both cases.

5.2.1 Participatory Action Research (PAR)

PAR was used as a research method throughout Research Cycles 2-5, we refer back to Chapter 3 for a detailed description.

5.2.2 Case-study

Within this chapter, we present two cases from the IPO Course: Integrated Systems. Both cases Grand.C[18] and ChefKot[19] have been submitted as peer reviewed conference paper and were presented afterward.

We do not follow an exploratory case study approach (Eisenhardt, 2011; Yin, 2016), providing specific sampling logic or a descriptive research protocol of the analysis through which research outcomes are drawn (Barratt, Choi, & Li, 2011; Beverland & Lindgreen, 2010). On the contrary, the case analyses used in our design research do not aim to develop a science of the average, nor do we want to generalize its findings. Rather, by presenting these two cases, we try to build a science of the particular and produce insight (thick descriptions) and analyses of problem, context, interventions and outcomes in what is case-specific. Collected through these two cases - in which the PSS design toolkit is

[18] **Grand.C** was submitted to the 10th International Conference on Design and Emotion under the title 'GRAND.C, beyond the temporality of nodes. Digitally and physically connecting generations through product service system design, a case study' and appeared in its proceedings right after.

[19] **ChefKot** was submitted to the 9th CIRP Industrial Product-Service Systems Conference, as title we used 'Representing a Case-Based Interpretation of the PSS Design Toolkit'. The article appeared in the Journal Procedia CIRP (Vol. 64).

contextualized and tested - the evidence supports the claim that design students are able to use and implement it with the desired performance (van Aken et al., 2016).

By examining these cases, practitioners and academics can learn from the contextualized representation of the PSS design process based on well-documented reference models. We ensure sufficient depth for each case while also maintaining enough variety between them. According to Dubois and Gadde (2002, 2014), learning is the essence of all research, partially articulated in our theoretical framework and the PSS design toolkit. Combined in the two presented cases, we explicitly present the successive steps in the learning process to the reader. We want to express that the other sixty-four cases can be built-up and reveal the PSS design process representation of the particular case in the exact same way, giving the PSS design toolkit a rather generic character and producing insight in what also can be used successfully in other contexts. This means that developing these qualitative cases allow us to produce knowledge about the way design students represent the process of PSS design in the FEI.

The results from the cases provide extra insights on how they represent the value of the PSS design toolkit, the process and its outcome, discuss its relevance for design education. We searched for patterns in the cases and its considerations as input for redesign of the toolkit itself. In one case, we briefly touch the long-term impact on competence, e.g., how the designer's vision on the PSS design tools evolved over time and how the process and tools have changed their skillset. But in particular we focus more on short-term impact of process quality (e.g., measured directly in the process, to what extent have the tools been used and what influence did that have, more feedback loops, broadened scope, etc.) and of short-term outcome quality (such as the effect of the PSS design process on representation).

5.3 Confirm | Validation by case study

In this part of the validation we are specifically interested in how the manifestation of using the PSS design toolkit says something about the research itself. It involves the question: 'Are we building the right PSS design toolkit?'

Below we present *Grand.C* and *ChefKot*, two cases (out of sixty-six developed and evaluated PSS design concepts) that can be seen as the contextualized embodiment of the PSS design toolkit operationalized in design education, and subject to our study. After both cases, we go more in detail on the specific case findings and general findings that were taken into consideration for the PSS design toolkit iterations in RC 3 and 5.

5.3.1 Case 1 | GRAND.C

GRAND.C, beyond the temporality of nodes

DIGITALLY AND PHYSICALLY CONNECTING GENERATIONS THROUGH PRODUCT-SERVICE SYSTEM DESIGN, A CASE STUDY

This part describes a case study of an early stage product-service system (PSS) design. By means of a specific PSS design methodology, we were able to include insights from various domains and their underlying processes, in order to enhance value creation. The context of this case study was to preserve and enrich the connection between grandchildren and grandparents. Throughout the entire process, PSS design tools (see Chapter 6 for detailed descriptions) enable an iterative way of involving different stakeholders that broaden the exploration of recognizable emotions during a person's life and more specifically with regard to the above-mentioned node 'becoming a grandparent'. The result, GRAND.C, is an enrichment service that allows grandchildren to snoop in the past of their grandparents and is based on an authentic user experience, free play and verbal tradition. This is presented through a detailed system map and simplified customer journey, as well as a visual prototype and photo novel. It is confirmed that the prototype in particular is a very meaningful means to reinforce the design brief and to communicate the concept to the end user.

Introduction

Product Service System (PSS) design toolkit

Advancements in electronics, information and communication technology are introducing new elements to the design process and require a systematic rethinking of how designers integrate both tangible and intangible components. “PSS“ can provide an opportunity to create innovative interactions between consumers, the products and services they use and the providers that offer these hybrids (Dewit & De Roeck, 2014). To support a product-service transition, the described PSS design toolkit is an ongoing collaboration (Design Flanders & Namahn, 2013; Dewit, De Roeck & Baelus, 2014; VVSG, 2013) and effort to develop a methodology, with tools and techniques (Figure 5.4), to design meaningful product-service systems. It includes valuable and up-to-date insights from a variety of domains and their underlying design processes: systems and systemic thinking, service design, human-centered design, interaction design, (user) experience design, product design and design thinking.

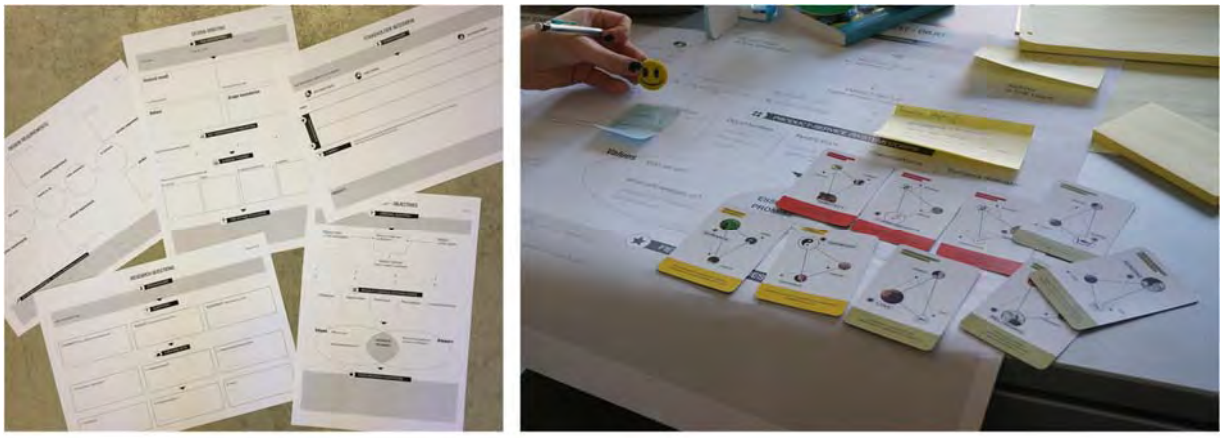


Figure 5.4 | Overview of the PSS design tools

The design challenge

This research is based on the process and findings of a PSS design toolkit put to the test by 1st year Master students in Product Development, in the context of **'nodes of life'**. These landmarks of human life are inspired by van Gennep (1960), Elton and Reid (2010) and Vissers et al. (2012); e.g., leaving home, discovery and play, education, career, love, childbirth, investment, health, growing old and death.

Depending on the above-mentioned node(s), the design process runs through exploration, ideation, definition and verification, using a combination of tools specific for each phase. The goal of the project and its approach is not to seek the next large scale ecosystems, but aims to identify recognizable emotions during a person's life and to design whole product-service life cycles by means of a specific PSS design toolkit. The described project is more design-driven, with a focus on re-interpretation of meaning, rather than on performance or problem-solving (Verganti, 2009).

GRAND.C was sampled on the basis of convenience, it represents and visualizes the process and usage of the PSS design toolkit, applied to the life-changing event of **'becoming a grandparent'**.

Social and scientific relevance

The impact of becoming a grandparent in a lifetime is not to be underestimated. At a certain age, you have to accept that your house gets invaded and you have to take care again of young children from time to time. However, an emotional bond with grandchildren is established in no time. Typically for this node is the **temporality**: “Looking back, time goes faster than you presume”.

To immerse in the theme of becoming a grandparent, an introductive literature review was undertaken in the field of **grandparent-grandchild relationships**. Partly due to demographic changes in Western societies, these relationships are posited to be more important, more intense and more prolonged than ever before, as stated in both popular and academic literature (Bengtson, 2001; Fuller-Thomson & Minkler, 2001; Uhlenberg, 2009).

This strengthening mainly occurs during the childhood of the grandchild (Fuller-Thomson & Minkler, 2001; Uhlenberg, 2009). Noteworthy, the generation in between - the parents - can either facilitate or hinder the contact between grandparents and grandchildren. Thus, they play a key role as a lineage bridge or mediators (Kemp, 2005; Uhlenberg & Hammill, 1998). Kemp (2005) states that the importance of these mediators decreases when grandchildren grow older and more independent. Hence, as adults they keep in touch with their grandparents on their own terms.

Nevertheless before reaching adulthood, the rate of contact moments reduces when growing older (Silverstein & Long, 1998). That is why Cherlin and Furstenberg (1986) state that “the grandparent-grandchild relationship is considered to be the most intense before the grandchildren have reached adolescence”. To counteract this declination, Geurts and van Tilburg (2015) indicate that “a strong bond at an early stage of the relationship may hold back a decline in relationship intensity”. This idea of the link between the bond during childhood and adulthood is supported by three different studies (Brown, 2003; Geurts et al., 2014; Taylor et al., 2005).

Building on the premise of the bond between grandparents and grandchildren that needs to be prolonged, this case study aims to motivate grandchildren to keep in touch with their grandparents more intensively. Beyond a certain age, the visits to their grandparents are perceived rather boring and obligated. Thus, once the role of the parents as mediators declines, the intrinsic motivation of the grandchildren needs to be increased.

The PSS design framework (Figure 5.5) and toolkit (Dewit, 2014a; Dewit & De Roeck, 2014) follows an affective or user (experience) point of view throughout its process, inspired on research by Gemser et al. (2012) and Ruitenberg and Desmet (2012). The framework visualizes what role the three front-end domains - exploration, idea generation and definition - play in the process of integrating and designing products and services in close relation to the user experience (Dewit, 2014a).

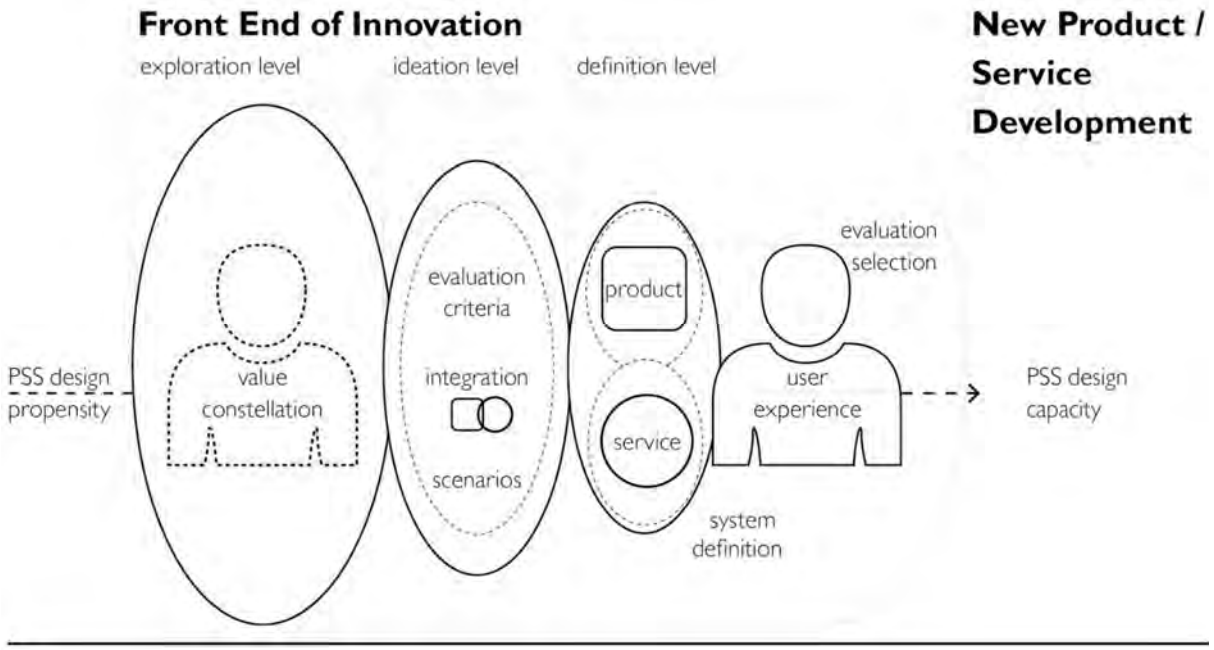


Figure 5.5 | PSS design framework

Design process

Understand

In the first phase of the design project, the students were looking for a clear value constellation. With various techniques, an exploration is done on the activities, actors and experiences that play a role in different stages in the event of becoming a grandparent. These insights will be translated into a 'design challenge'.

As mentioned in the literature review, the relationship between grandparents and grandchild is more important than ever before (Bengtson, 2001). Therefore, the combination of grandparents and grandchildren as the most important stakeholders is chosen to proceed into the exploration phase.

Participative and user-centered techniques (e.g., in-depth interviews) served as a qualitative and interrogative research methods for exploratory purpose, enabling constant involvement of the sample of six grandparents (aged 58 - 80) and four grandchildren (aged 8 - 16) throughout the entire process.

A first tool, the **Stakeholders Experience Journey** tool (Figure 5.6), visualizes a line of wellbeing based on their experience being either a grandparent or a grandchild. Several key moments are chosen and marked with both positive and negative feelings. These milestones were important during the interview since the interviewers could ask some more profound questions on these topics to gain insights on this special bond.

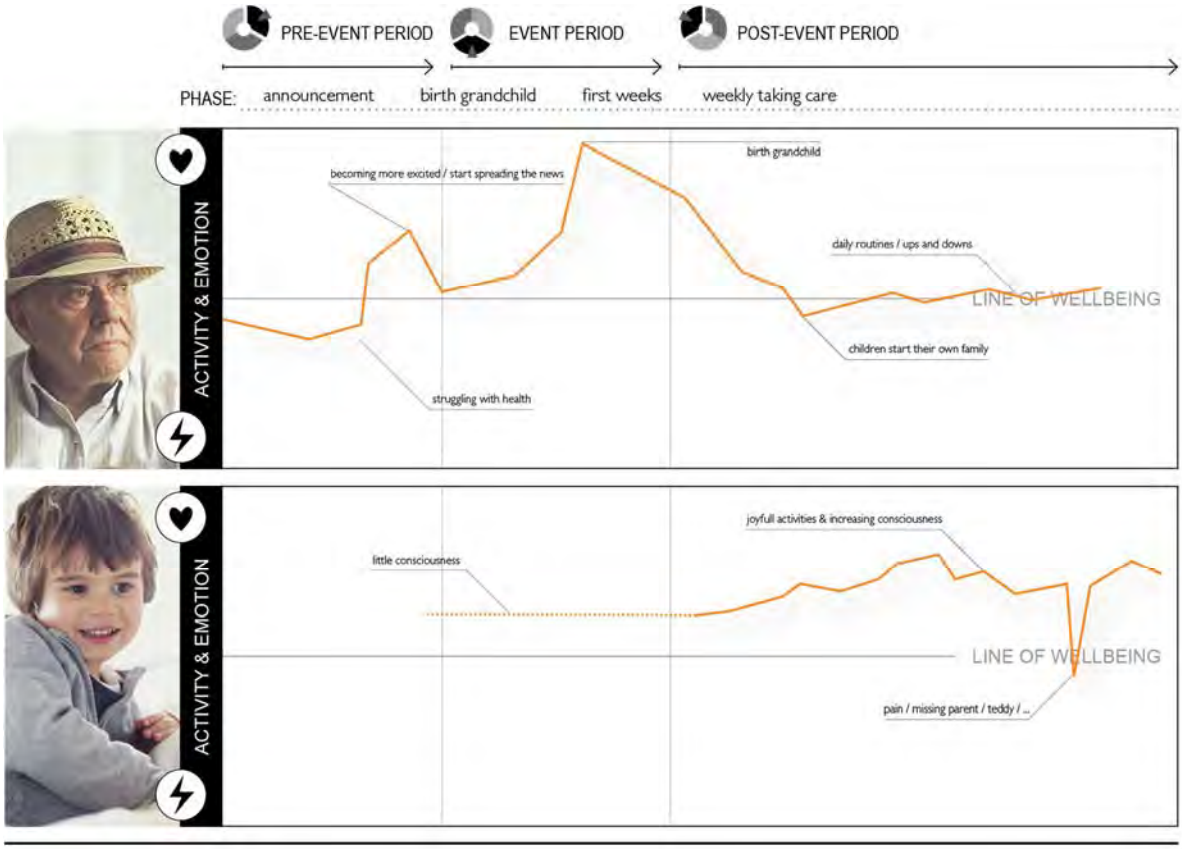


Figure 5.6 | Stakeholders Experience Journey

It can be stated that there is a similar evolution in the bond between grandparents and grandchildren, as they grow older. This confirms the findings from the literature research. The following three stages are recognized each time: care stage, transition stage, and problem stage.

- The **care stage** is characterized by an intensive contact during regular day care and thereby a deep and unconditional connection between grandparents and young grandchildren. Grandparents are a consistent safe haven with less rules and more fun. Additionally there is an extensive communication with the parents.
- In the **transition stage** the care providing function decreases and mostly the parents are responsible for visits of the grandchildren. The contact becomes rather superficial and less personal; after all the grandchildren are too young for a spontaneous visit.
- Finally the grandchildren are old enough to visit their grandparents independently, but they are so busy with their own life and unintentionally forget about their grandparents. This is what we call the **problem stage**.

Beside these three stages, the students could recognize some recurring topics in the interviews; things that several grandparents or children indicated as remarkable in their experience.

"Grandparents are the grandchild's link to the past. Grandchildren are a grandparent's link to the future." (personal communication, October 21, 2013)

First, many grandparents love nothing more than to talk about their past and family history. During the interviews, grandparents gathered various additional objects while telling their stories and soon they even show the entire house, an important insight and opportunity in this case. As Kornhaber and

Woodward (1981) stated, grandparents can enact several roles, an important one is being the family historian. On the other hand, both female and male grandchildren are fascinated and look up to these stories. They too chat about the typical things one can only find at a grandparents' house.

Another topic was the fact that grandparents feel a little pushed aside when their grandchildren reach a certain age. As stated before, from the transition stage on, contact becomes less intense. Grandparents grow older what makes it more difficult to keep up with their grandchildren that live their modern lives. This generation gap makes that grandparents feel like they do not know much about their grandchildrens' personal lives. Of course, they have pictures taken at family meetings or holidays, but most of the times this kind of information comes from the parents instead of the children themselves.

To conclude the exploration phase a **Design Challenge** is formulated: what is to be designed in the next phase? In short, it could be described as 'blending stories'. The goal will be to avoid the problem stage by already anticipating during the transition stage. The product-service will provide an opportunity for the grandchildren to communicate with their grandparents themselves, without the parents as a necessary intermediary. The outcome needs to be convenient and intuitive in use for both parties. It should be a means to exchange personal info in an unforced way, in order to strengthen the relationship during childhood. In this way, it can be avoided that the relationship intensity declines during adolescence and adulthood.

Explore

In the exploration phase, the students are working towards a viable PSS idea. Therefore, they defined **Design Requirements**, emotional and rational objectives that must be met. These serve as a starting point to gather inspiration and as evaluation criteria for the different PSS scenarios that will be considered.

In the **Lotus Blossom** technique (Figure 5.7) the students combined the eight most important requirements with inspiring examples in different contexts in order to retrieve new characteristics and ideas by means of lateral thinking.

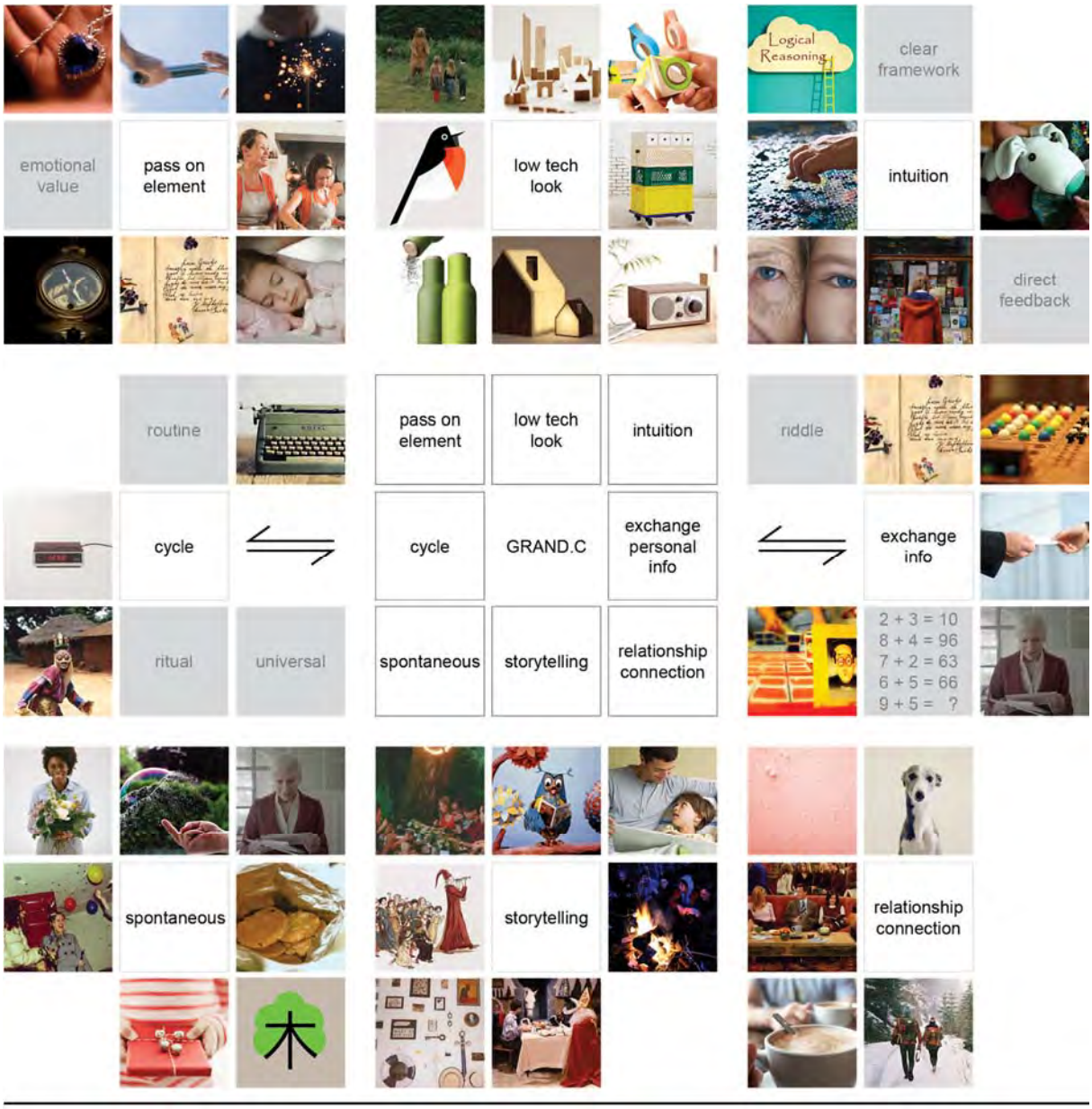


Figure 5.7 | Lotus Blossom

After completing this matrix, the student team realized that games and play are a powerful means to transform our goals into an actual design. A typical characteristic of every child, regardless of age or gender, is curiosity. Which child can say it has never been on a treasure hunt in their grandparents' house before? The idea is born to trigger and facilitate this explorative behavior in order to blend the grandparents' stories from the past with the modern environment of today's children.

A good example of a toy that allows children to explore their environment is Sniff (Figure 5.8). New technologies are used without children noticing. Instead of playing games on their parents' iPad, Sniff uses the real world as game board and can therefore be classified as a pervasive game (Johansson, 2009). In this genre new kind of gameplay experiences are created by combining different contexts and using the real world as play area to aim for physical and social interaction (Montola, Stenros & Waern, 2009).

"It is not about making society more high-tech, instead it is about making technology more social."
(MAD Faculty and KULeuven, 2012)

Figure 5.8 | Sniff (Johansson, 2009)

As observed in the exploration phase, grandparents like to show old objects to enrich their stories. It makes it easier for children to fully understand the family history. However, what if some of these objects are not available anymore? What if grandparents are living in a retirement home and had to leave most of their material belongings behind? What if grandparents want to show the fun of recording an audiotape, but their recording device has stopped working long before? These kinds of questions made us think about including a service to provide the grandparents access to authentic objects that they do not possess any more themselves.

The best place to find these kinds of items is of course a thrift shop. Often these stores receive these valuable objects and sell them at a low price. Since grandparents do not have the intention to buy old products again, this is how we came up with the idea of a rental service for old artefacts.

With this PSS concept, the students want to stimulate the long lasting connection between grandparent and grandchild. In a playful way, the concept has to encourage the discovery urge of children on the one hand, and the preservation of cultural material heritage and family stories on the other hand.

Define

In the definition phase, the student team aims to translate the previous statement into clear product and service attributes. The project is concluded with a design brief to finalize all front-end activities and to give a head start for new product/service development that takes the PSS concept into implementation. Specifications and architecture for both the product and the service part in the system are described as far as needed. The design brief consists of a detailed system map, which is also translated into a simplified, graphical representation of the customer journey, a visual prototype, and a photo novel to communicate the PSS concept and interactions, and finally a first working prototype.

The PSS concept was called GRAND.C (Figure 5.9); an enrichment service that consists of a Basic and Advanced system. It allows grandchildren to snoop in the past of their grandparents and it is based on an authentic user experience, free play and verbal tradition.

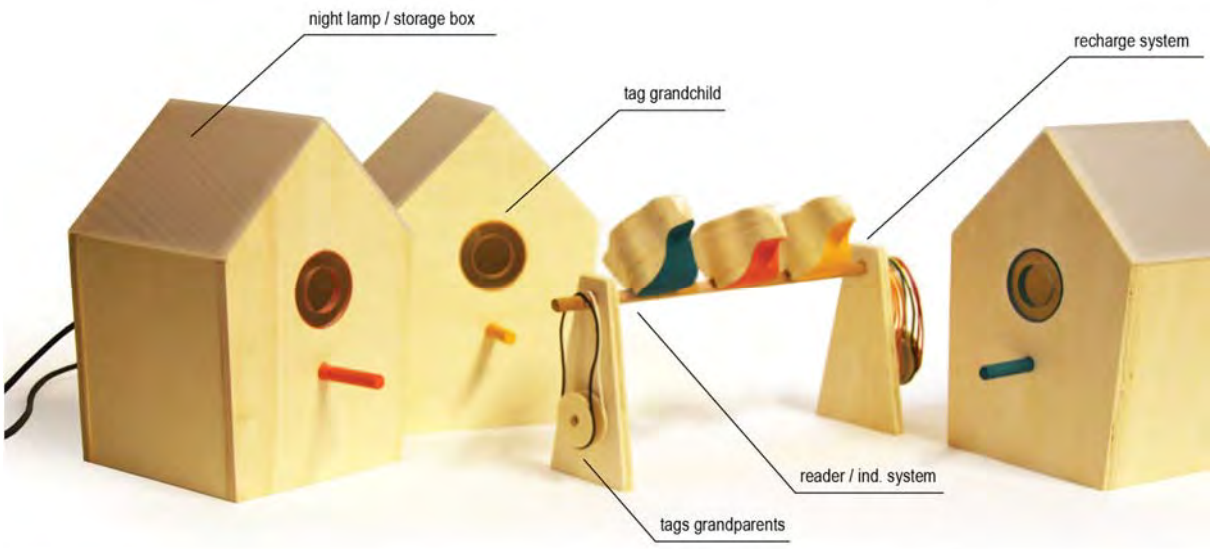


Figure 5.9 | Visual representation basic system GRAND.C

Figure 5.10 shows the complexity of the **detailed system map**, which was the basis for simplifying and refining the whole concept. It describes the proverbial journey, emotions and interactions of the users - grandparents and grandchildren - throughout the pre-service, service and post-service period. It highlights the touchpoints and channels of the GRAND.C product and service, with a focus on both tangible and intangible aspects.

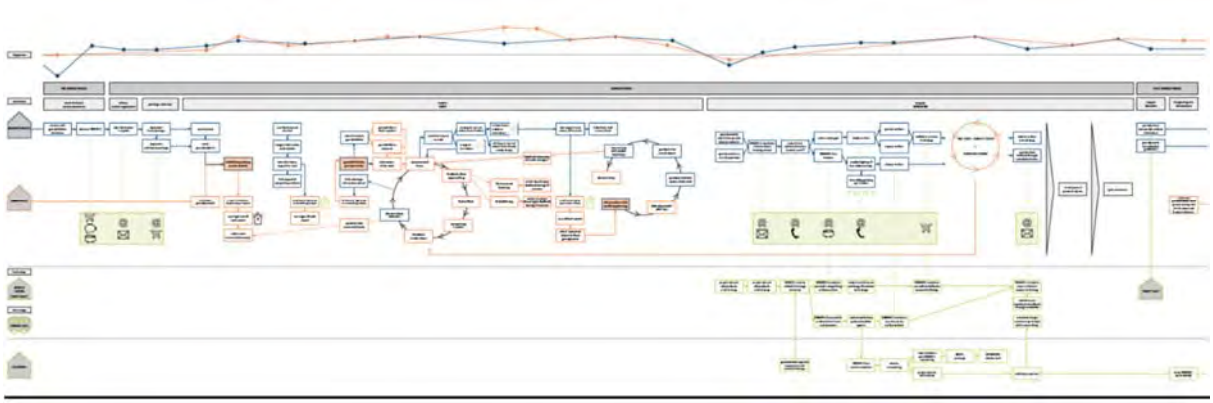


Figure 5.10 | Detailed system map

Because of its complexity, the scheme is also visualized in a simplified **customer journey**. The basic product system (Figure 5.11) contains a bird (reader), tags and a birdhouse. When one or more grandchildren come over for a visit, grandparents can prepare a quest. They hide the colored tags together with old objects of value. Through visual feedback, the birds help the grandchildren to locate the different tags (Figure 5.12). When a tag is found, grandchildren discover a meaningful artefact and can ask their grandparents for more information. Of course, the grandparents love to tell some anecdotes. Therefore, the artefacts serve as a trigger to support the personal stories of the grandparents. Via GRAND.C children explore their family history in a playful way. When going home, the grandparents can pass on small mementos (e.g., the recipe of grandmother's famous pudding), which they can collect in their personal birdhouse.

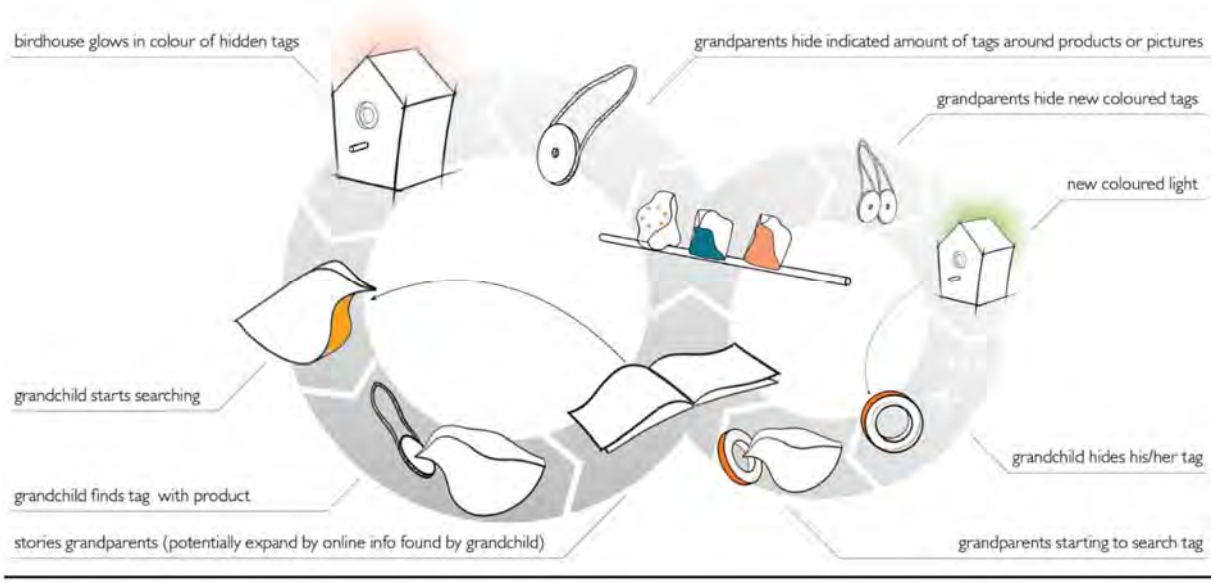


Figure 5.11 | Customer Journey of GRAND.C Basic product system

Figure 5.12 | Visual feedback to locate tags

Figure 5.13 shows the representation of the service component of the system. In collaboration with thrift shops, GRAND.C offers an advanced service system with an extensive offer of old artefacts to enrich the grandparents' stories. From all products that are brought to thrift stores by customers, GRAND.C makes a selection of the most valuable items to enhance storytelling and manages the distribution to collaborating partners. Grandparents can lend specific objects via their online user account or they can wait for the GRAND.C bus that comes to the neighborhood every now and then. When the grandchildren's quest is completed, the objects can be returned to the nearest thrift shop.

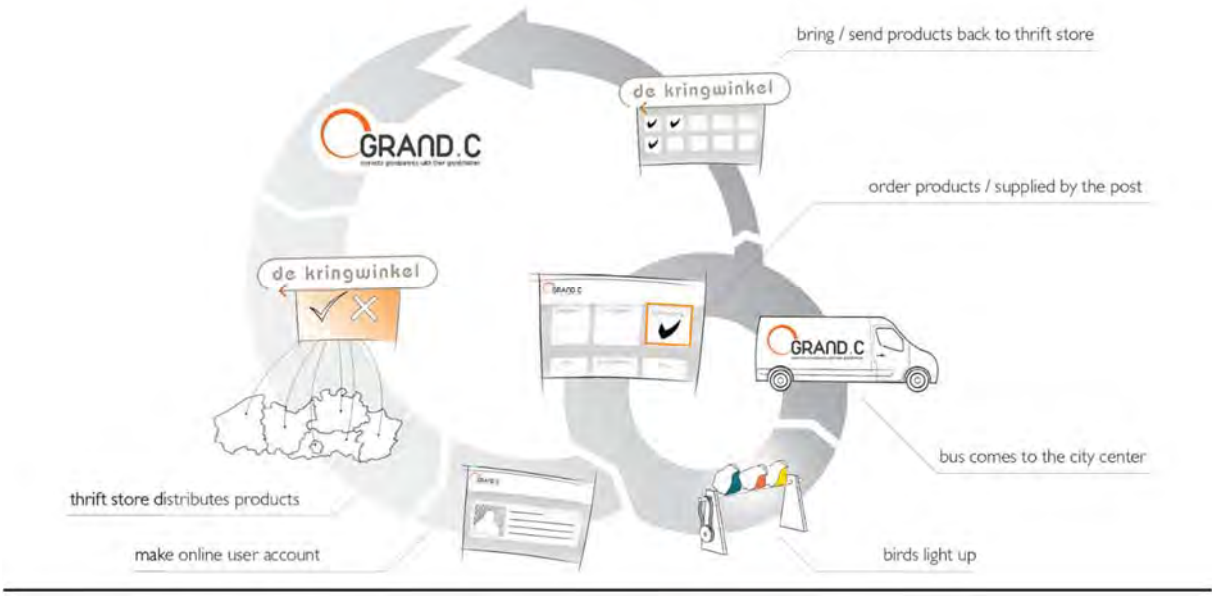


Figure 5.13 | Customer Journey of GRAND.C Advanced service system

Verification

In the final phase, the students address the end user again in order to verify the PSS concept. Prototypes and a photo novel are used to introduce the concept and demonstrate the interactions.

In each PSS design process, it is important to verify the concept with the end user. Therefore, it is necessary to have a clear representation. For the GRAND.C project, the team made a **visual prototype** of all the tangible components of the system. This makes it much more convenient to communicate with the end user. By introducing the PSS concept to the consumer, the prototype helps to demonstrate the interactions, which is much clearer than an abstract scheme.

Due to the prototype, they were able to put this front-end concept into a realistic context. Two grandchildren and their grandparents from the previous **user panel** were contacted and asked to re-enact all aspects of the scenario (Figure 5.14). By letting them interact with the prototype in a way that approaches reality as close as possible, the students could verify which elements of the PSS concept work well and which ones do not work as planned, before scaling up. The most important aspect to be tested is the value constellation: Do the children have fun during the game and is the game encouraging the grandparents to bring up personal stories that are fascinating the grandchildren?

The setting was the house of the grandparents, which is a familiar environment where the participants are at ease. The grandparents were asked to hide some tags with objects that they value. Because the prototype was not actually working, the team assisted the children to locate the tags by playing the classic hot and cold game combined with some other game mechanics. When a tag was found, the grandparents took some time to provide the children with several background stories.

In the next round some other game mechanics were included such as competing against each other, varieties in difficulty and other ways of searching, as these will also be present in the real GRAND.C game. In reality, the different colors of tags will represent different levels with evolving kinds of visual feedback that will get harder to interpret.

Figure 5.14 | Scenario re-enacting

This re-enacting of the scenario gave the student team the opportunity to capture every moment in the customer journey and make a detailed photo novel to communicate the total concept to the end user. By watching this novella, the user can easily empathize with the story, which makes it possible to gather feedback on all aspects of the product-service system.

This verification method confirmed of the capability of GRAND.C to turn a regular visit into a valuable moment of interaction between two generations. The game creates a pleasurable moment for the children but in the end it is just the medium to stimulate that special relationship between grandparents and grandchildren which they will value both significantly in the long term. Additionally, society will benefit from GRAND.C as well, since the preservation of an important aspect of cultural heritage is supported.

In order to further evaluate the game mechanics, a second prototype of the bird (Figure 5.15) was developed, providing real-time visual feedback to locate a tag. Here, the team aimed to implement electronics without losing the aesthetic qualities of the first prototype. By using two Bluetooth modules, coded in Arduino, they were able to put the received signals in different ranges and make it possible to distinguish distances. This input is converted into visual feedback; the closer the bird approaches a tag, the more lights will go on.

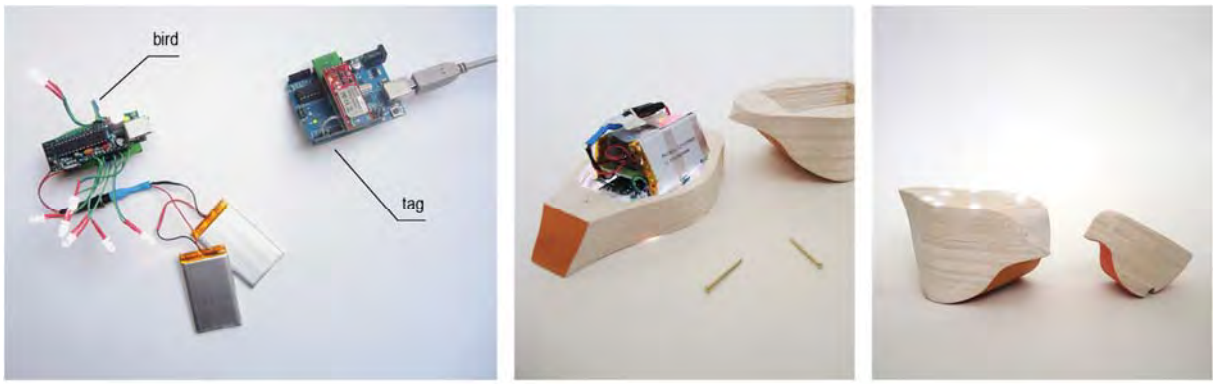


Figure 5.15 | Electronic prototype

With this prototype, the team could conduct another user test with less interference of the researchers. Figure 5.16 shows a participant using the bird to search a tag. Finally, the prototype was showcased at 'Buzzkruit' Expo in Antwerp[20], where visitors could try out the game and react to the concept (Figure 5.17). On this link below, a video can be found where the concept is explained (in Dutch) as well as a quick demonstration of the prototype.

Figure 5.16 | User test with electronic prototype

Figure 5.17 | GRAND.C exposed at Buzzkruit

[20] https://vimeo.com/135117515

The concept of GRAND.C can be assessed through the PSS strategy and typology. Tukker and Tischner (2006) distinguished eight different PSS categories, going from Product-Oriented to Result-Oriented (Figure 5.18). GRAND.C consists of two components with each a different focus. The basic product system can be situated in the category of a **Product-related service**. The bird readers, tags and birdhouses are sold as a product, but are combined with a product-related service. This advanced service system of GRAND.C concerns the collecting and lending of valuable artefacts through the GRAND.C bus and thrift stores. Therefore, it can be positioned in the category of **Product renting**, which is more Use-Oriented.

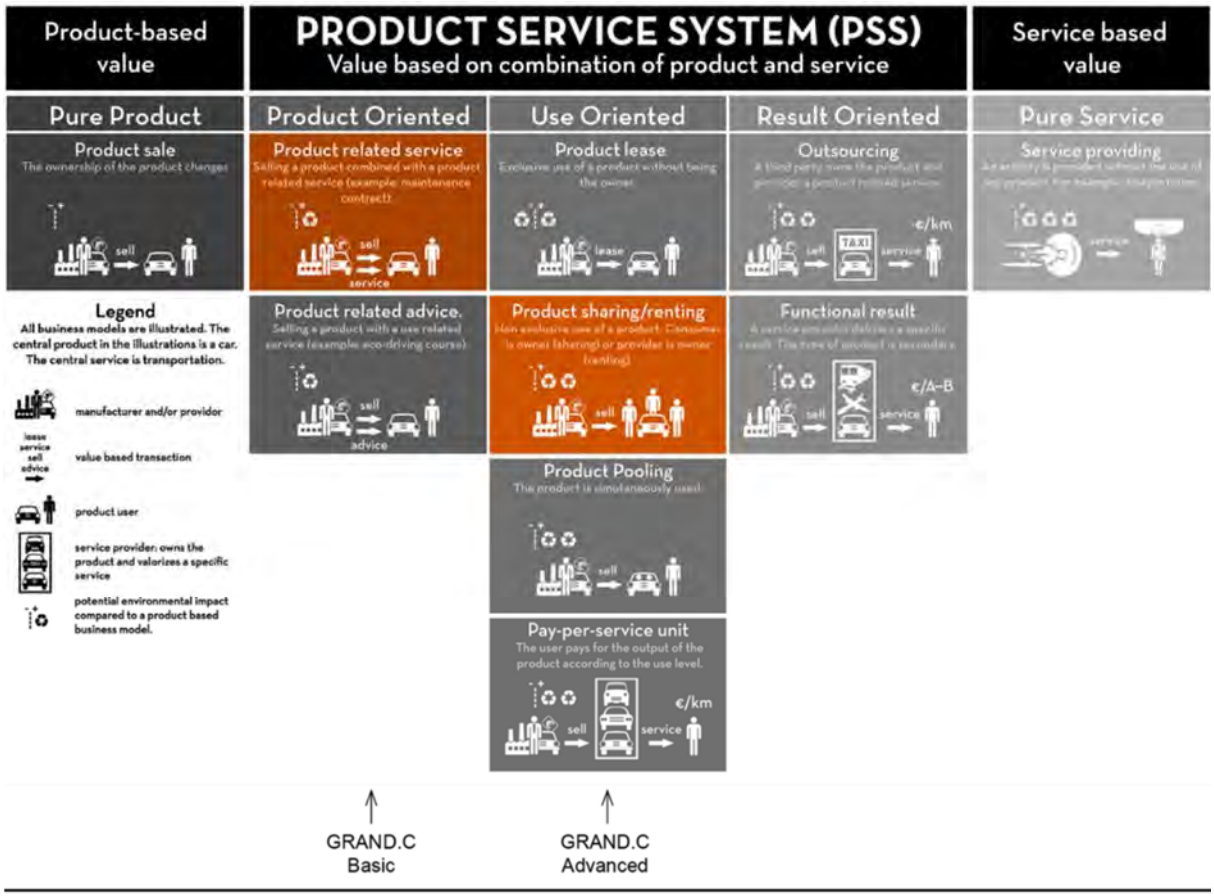


Figure 5.18 | Position of GRAND.C Basic & Advanced in the categories of PSS (Tukker & Tischner, 2006)

GRAND.C provides a pleasurable moment for both grandparents and grandchildren when the game is played. The game is a means to create a stronger connection on the long term that both parties will significantly benefit. Additionally GRAND.C supports the preservation of important cultural heritage. With all these ingredients, GRAND.C reconnects two generations digitally and physically in order to look beyond the temporality of this special node of life.

5.3.2 Case 2 | ChefKot

CHEFKOT, tackling obesity among students

A CASE-BASED REPRESENTATION OF THE PSS DESIGN TOOLKIT

This part describes a case visualization of an early stage product-service system design project in a first Master year for Product Developers. The main goal of the project was to address the growing obesity problem in our society, by means of an integrated PSS approach based on a dedicated toolkit. Many students are confronted with independence for the first time, when taking on higher education. Especially those who are settled in dorms, hence the choice of targeting this group of people as the main stakeholder. Usually this newfound independence is not accompanied with the best self-care in terms of nutrition. ChefKot tries to intervene during this period by making healthy food more accessible for the students through an optimal experience for the user, toward a self-sustaining ecosystem with its longer lasting effect on society.

Introduction

Product Service System (PSS) design toolkit

The challenge to deal with the complexity of the fast changing but crucial socio-economic issues of the near future requires a synthesis approach, focusing on the ecosystem as a whole and taking all interactions and relations between the various elements into account. These problems are often too complex to be solved by simple product solutions, hence a specific product-service system (PSS) approach is needed to deal with the required dynamics and support a valuable inclusion or transition. The focus on a synthesis approach (Drejer, 2004) offers a foundation to build new competitive advantages through a vast variety of tangible and intangible-based product-service combinations. Furthermore, besides the main challenge for the designer to manage the variety of underlying design processes, early representation and communication are key for the strategic rollout of the PSS concept (Maussang et al. 2007). Due to the lack of experience in developing integrated PSS offerings (Kowalkowski & Kindström, 2009), visualization techniques play a critical role in the Front-End of Innovation. Immaterial elements of the project need to be captured together with the storyboards that explain their relevance (Morelli & Tollestrup, 2007). The structure of PSS process visualization should give stakeholders a concrete view on the future solution, central in the PSS design process, because of its more holistic and integral nature (De Lille, Roscam Abbing, & Kleinsmann, 2012).

The design challenge

This case presents and evaluates the design efforts of first year master students in product development participating in the course, entitled ‘Integrated Product Development (IPD, 12 credits). The course is now running its fourth year, totaling 66 projects from 197 students. Each year with a different focus, the IPD project challenges students on topics such as 'milestones in life', 'physical and digital traces' and 'sharing concepts for a smart city'. In this paper, we illustrate one case in particular: ‘ChefKot’, which describes actual causes and effects that change the mindset with regard to food, activity levels and people’s behavior (Vandenbroeck, Goossens, & Clemens, 2007), ultimately 'tackling obesity'. To achieve the objectives for this project, student teams are expected to generate user insights, explore new opportunities, define and design a relevant concept for a product-service system. The innovative business model related to the PSS concept should fit the original goals to fulfil the final customer needs optimally, enable upscaling and sustainable growth.

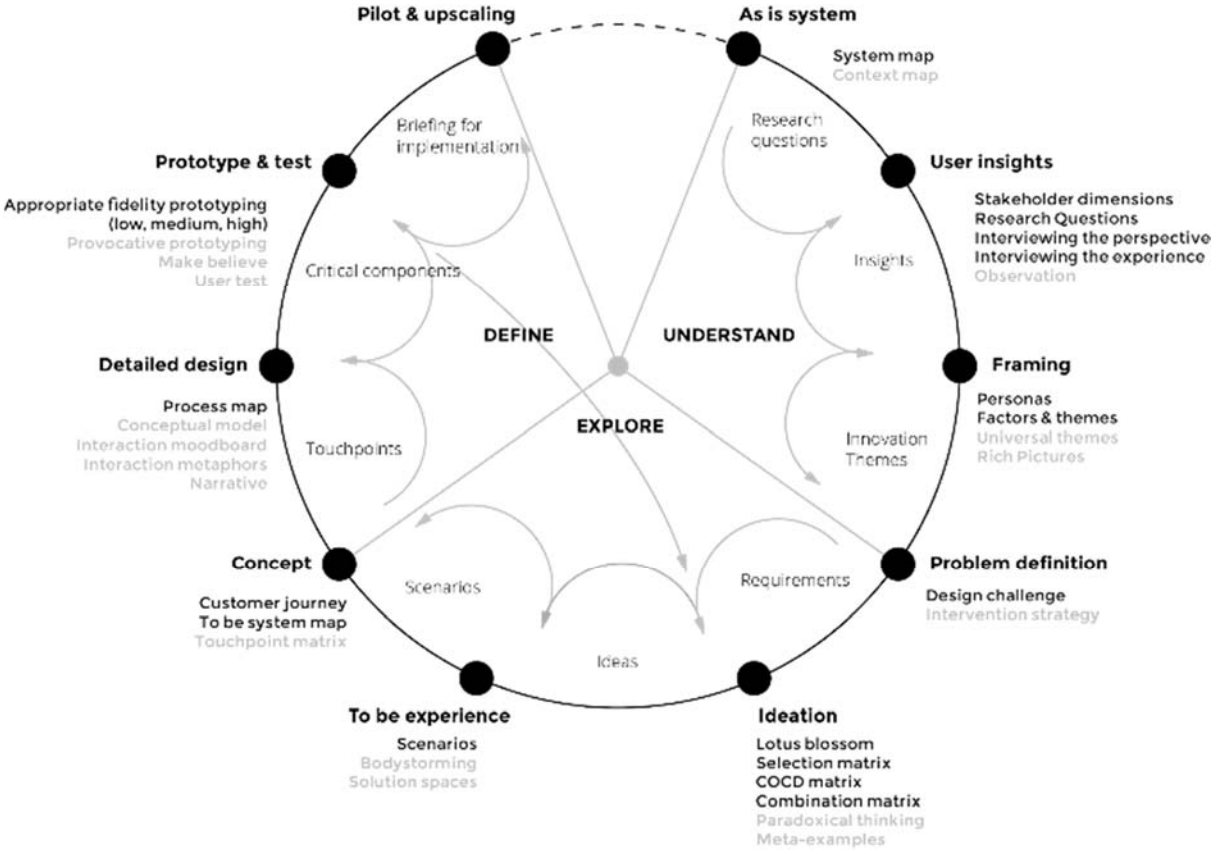


Figure 5.19 | PSS design toolkit overview (used tools in bold)

PSS process

Understand

Figure 5.19 presents the overview of three main phases in the Front-end of Innovation (FEI); understanding, exploring and defining. Each of these phases consists of different steps the designer can undertake to proceed. The designer is free to choose the number of tools (see Chapter 6 for detailed descriptions), depending on the gathered insights, the progress and the required output to serve as input for the next step. The tools marked in bold were actually executed. The design process of the case 'ChefKot' is presented by describing the way it was built up and visualized.

The **system map** (Figure 5.20) is an important tool in the understanding phase to determine the factors that play a major role in the case among the target group: students. This way a clear structure and overview of the importance and relationships between different elements involved in the obesity-story among students is obtained. The system map's purpose is to identify intervention points on which a PSS can anticipate. The core variables (in red rectangles) defined in this system map are: eating habits, awareness, independence and physical activity. After determining these core variables, the system map is expanded with variables (in green rectangles) that influence these core variables: people, emotions, nutrition, physical activity, physiology, artefacts, facilities, space, organizations and opportunities. Between these groups, positive (green lines) and negative (red lines) relationships are defined.

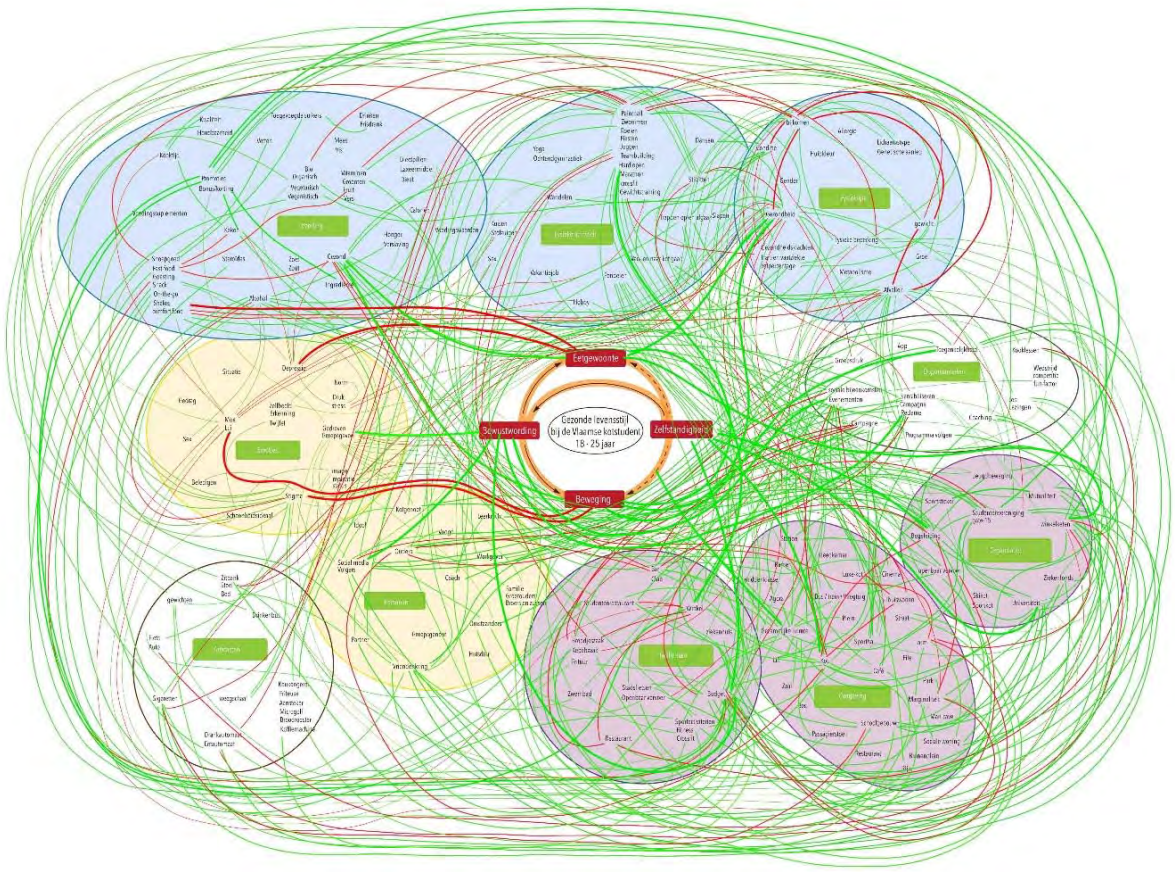


Figure 5.20 | System map

After this process, a clear overview enables to identify the most important factors: the intervention points. With these new insights, it is possible to confront the target group with more specific and direct questions. Based on the output of the system map, sub-questions are formulated on each of the intervention points. These questions are presented to a select group of students and stakeholders (a nutrition expert, a dietician, a supermarket manager and the communication department of a university). The aim of this qualitative research was to test the significance of the proposed influential factors in order to determine the six most important intervention points: nutrition, time, budget, awareness, group feeling and physical activity. After the qualitative research, **personas** were composed based on the gathered information in order to map and visualize the behavior, characteristics, needs and values of the target group.

- Nutrition: Most students know they should eat healthy, but these intentions are often obstructed by time, motivation or budget. Choosing for healthy products is not easy when take-away services and ready-made meals are an easier, faster and cheaper option.
- Time: Time is valuable for students. Most of their time goes to school assignments and social activities. With this (delusional) lack of time, students do not want to waste time going to the supermarket, searching for ingredients, cook, do the dishes, etc.
- Budget: Every student has a limited budget and therefore wants to keep the expenses as low as possible. This means when buying food, it is often cheaper choosing for unhealthy take-away food.
- Awareness: A good, effective intervention starts by spreading the correct information among people. The concept “Kcal” sounds familiar, but when asked what it stands for, many have no answer.

- Group feeling: The student is a social being. He likes to surround himself with friends and gladly participates in social life. Cooking together brings many advantages; the cost, work and clean up afterwards that come with every meal are shared among the participants.
- Physical activity: Lacking motivation to work out after a long and tiring day is the main reason why students do not sport very often. They would rather make money or go out with friends than sport in their time off.

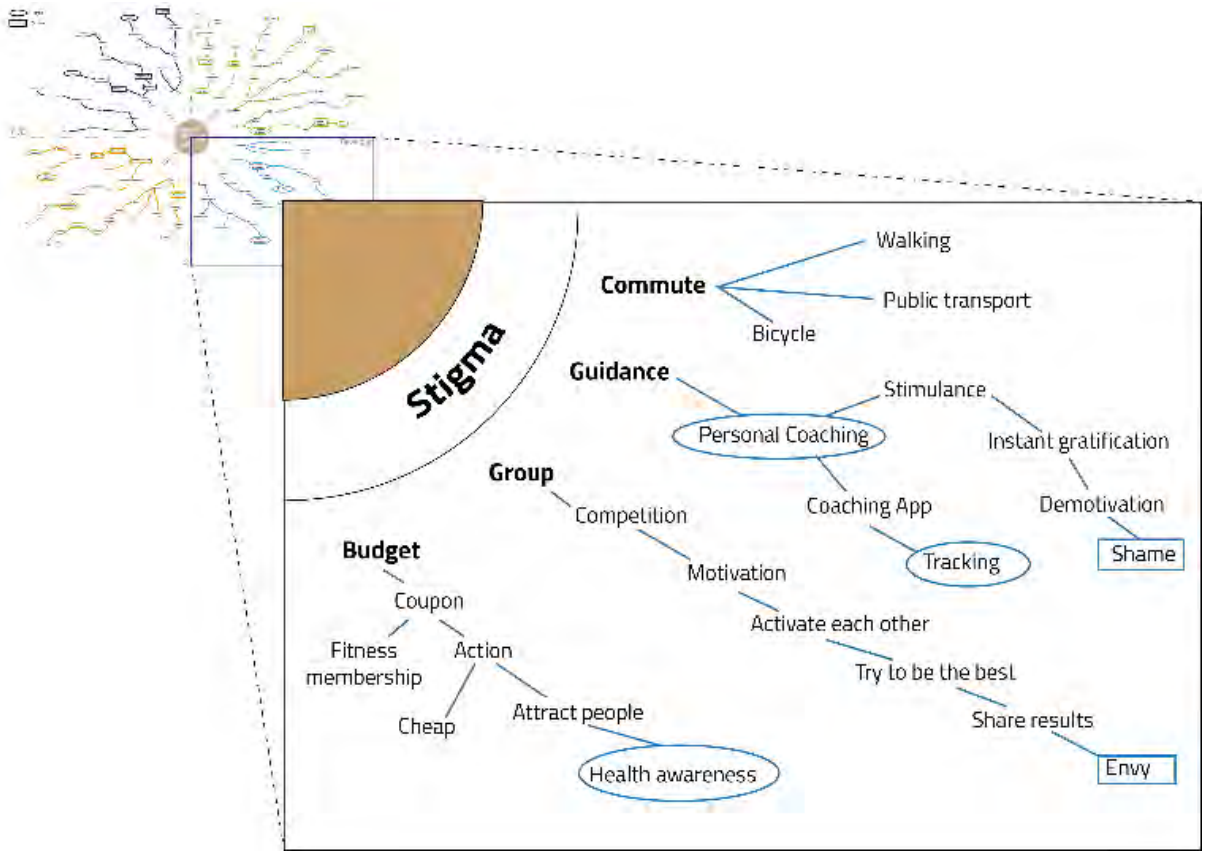


Figure 5.21 | Factors and themes tool (framing)

In a following step of the process, the underlying causes like emotions, fears and perspectives, combined with economic, societal and technological developments (trends) were identified. A hierarchy was found in the gathered insights **(factors) and themes** arose from the different clusters, enabling to better frame and finalize the understanding phase, see Figure 5.21.

With all previous described information at hand, the design challenge tool (Figure 5.22) was completed, formalizing the output of the 'understand' phase with the following research question: "How can a healthy lifestyle among Flemish students between 18 and 25 years old be implemented in a pre-emptive way, in order to achieve a successful, long-term intervention?"

Besides defining the main research question, the **design challenge** tool (Figure 5.22) enables to set out rational and emotional requirements; on the interaction between actors (how), the results of the PSS (what), the provided and received context (who) and finally the long term results (why). A major set of requirements closely related to the research question serves as input for the subsequent phase in the PSS design toolkit, 'exploration' (ideation, scenario writing and conceptualizing).

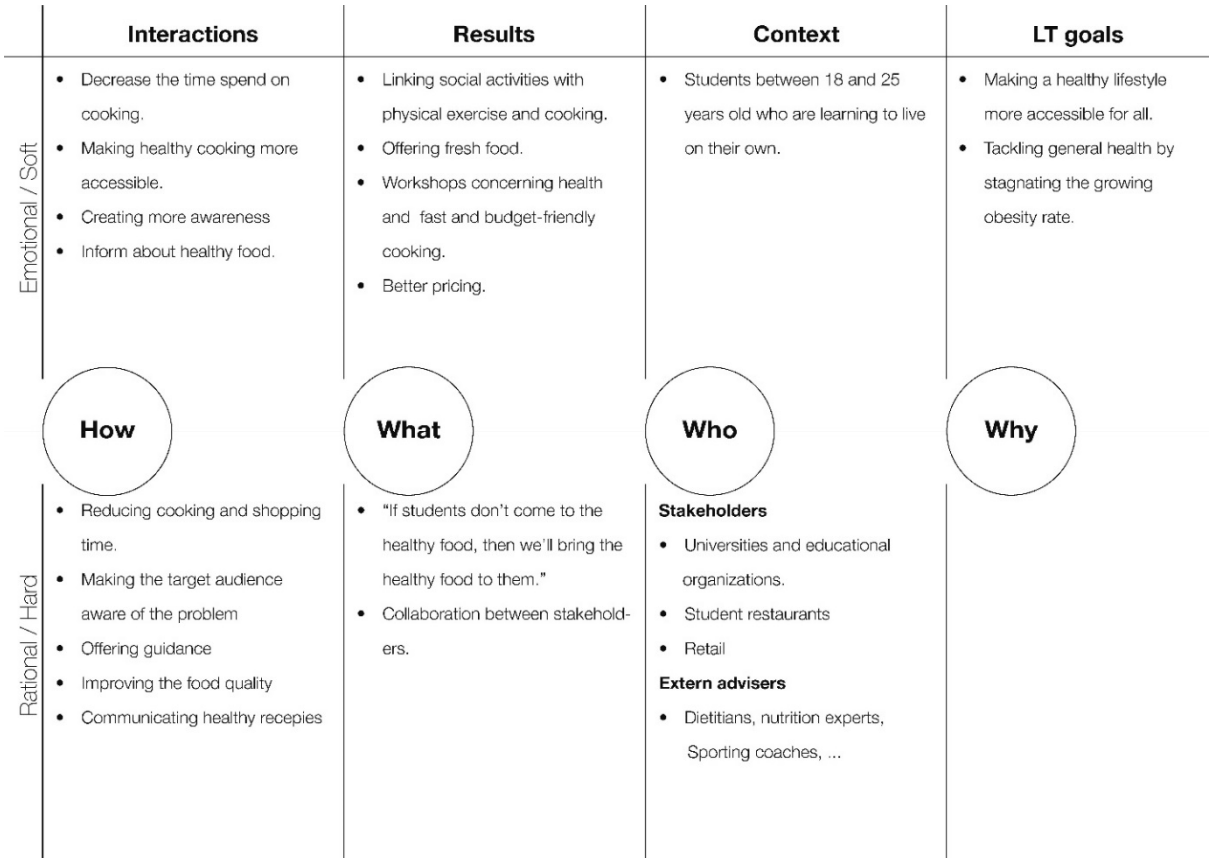


Figure 5.22 | Design challenge tool & requirements (problem definition)

Explore

In order to generate ideas to solve this problem, several techniques were used, one of them was the **lotus blossom** tool from Fig. 5.23. Based on the design challenge, eight requirements were put at the center of the lotus blossom, in order to make a difference (nutrition, time, environment, budget, group feeling, awareness, physical activity, guidance). For each of these requirements inspiring examples were gathered regardless of context or situation, analyzed and the most important characteristics for each example were defined.

- Nutrition: one person portions
- Time: food delivery
- Environment: ecologically responsible packaging
- Budget: Use of misshapen vegetables that were otherwise deemed unfit for sale.
- Group feeling: classes, lectures, after-school activities concerning healthy cooking.
- Awareness: campaign about nutrition value
- Physical activity: gamification of physical activity related to coupons for healthy food
- Guidance: free in-store advice from dietitian.

These properties served as input for creating ideas for solutions. With the characteristics for success in mind a total of 104 ideas were generated.

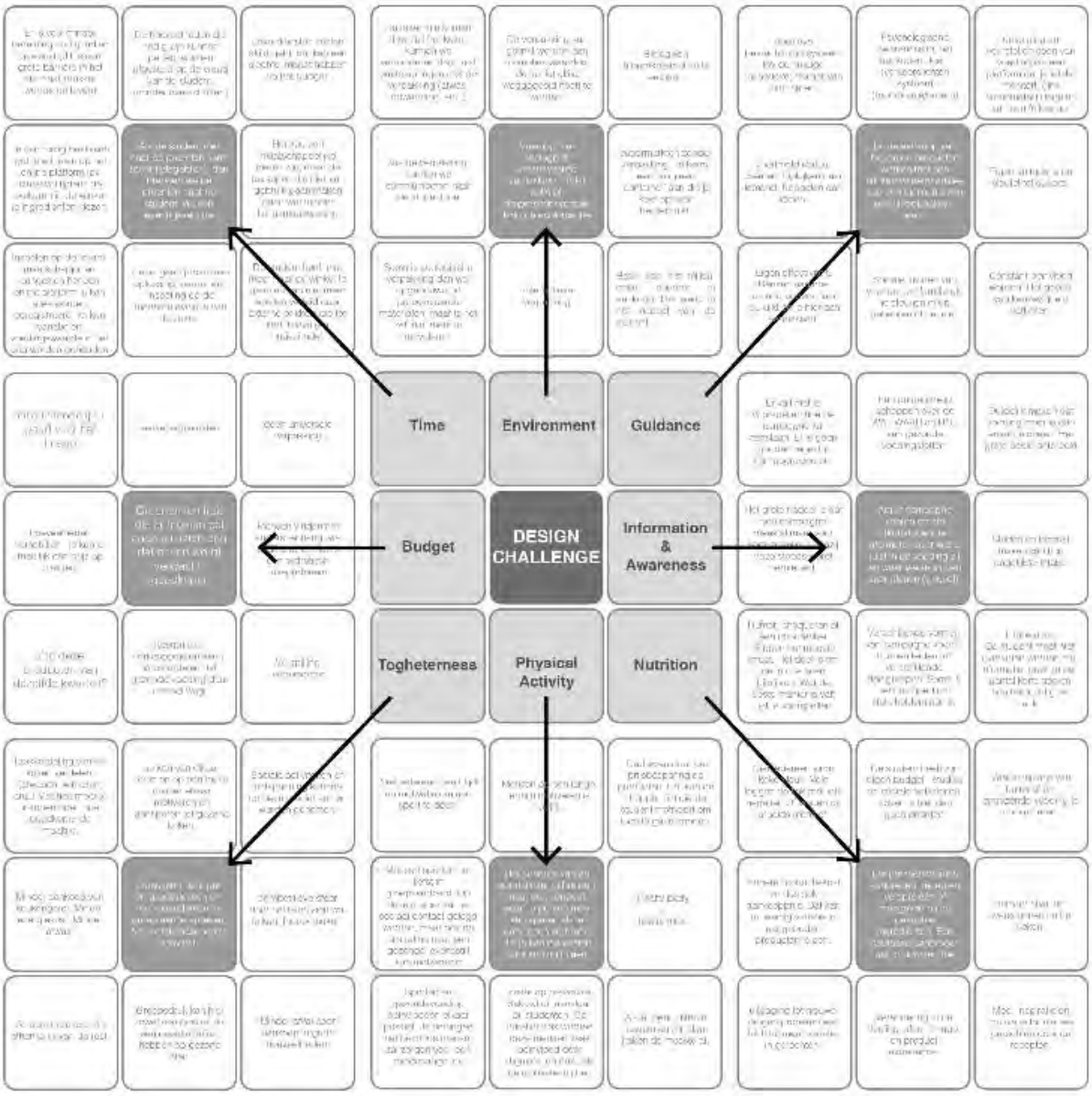


Figure 5.23 | Lotus blossom tool (ideation on (sub) requirements)

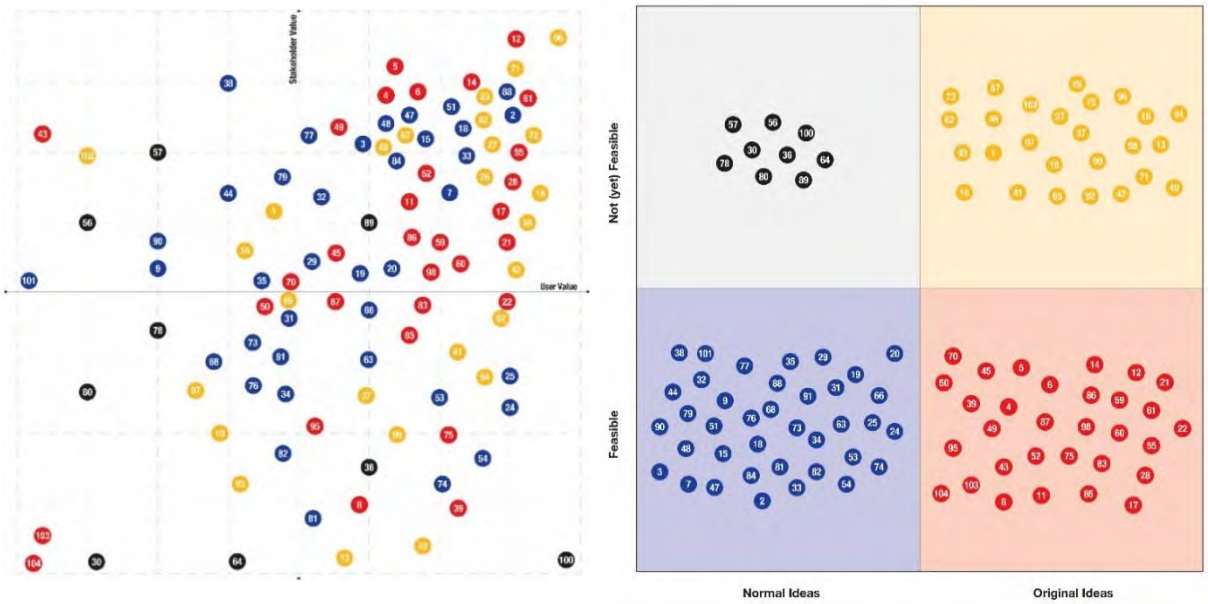


Figure 5.24 | (left) Selection matrix (user/stakeholder value) | (right) COCD matrix tool (feasibility/innovativeness)

In order to determine the value of the ideas, the participants (previously mentioned) had to rate each idea on 'stakeholder value' and 'user value'. Stakeholder being the specific provider (e.g., store, warehouse, dietitian, school, etc.) and the user being the student. Each idea was given a score between 0-10 on each factor, a time consuming exercise, but with a clear visual overview. The ideas that ranked high on both factors can be found in the upper right area of the **selection matrix** in Figure 5.24 (left). After identifying highly valued ideas, they were ranked (using four colors) on feasibility and innovation in the COCD Matrix (Figure 5.24 | right). Combining the selection matrix and the **COCD matrix** gave a visual overview of the most successful ideas as input for plausible scenarios. Highly visualized storyboarding and **customer journey mapping** (Figure 5.31) then served as input for evaluating the concepts with the stakeholders. After concept testing, it was decided to continue with the following PSS case: ChefKot (Figure 5.25).

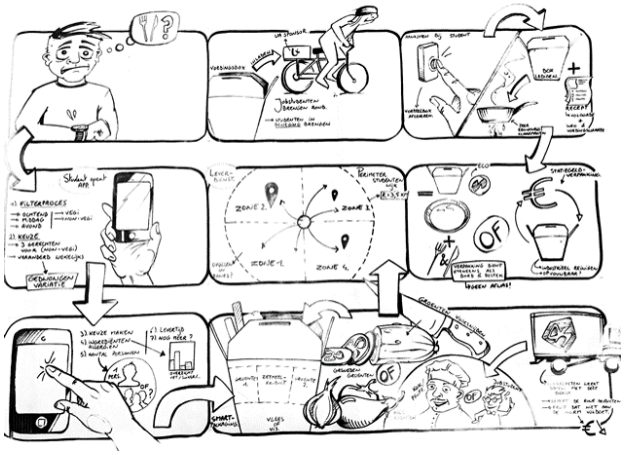


Figure 5.25 | Storyboarding

Define

ChefKot is a delivery service that provides healthy food for students, by students. It delivers fresh, precut ingredients for a healthy meal right up to the doorstep of student dorms in order to stimulate heathy cooking (Figure 5.26). *"If students don't come to the healthy food by themselves, we'll bring the healthy food to them!"* Students can take part in this back-stage activity, and earn something extra.

Figure 5.26 | ChefKot, after receiving student orders through the app

With this healthy food stimulus in combination with the satisfaction of students cooking their own meal and the smart materials to help them in this transition toward a more sustainable and circular society (Figure 5.27). With ChefKot, the design team hopes to show students that healthy cooking does not have to be time consuming or difficult. The opposite is true: it can now also be quite easy and most of all, affordable. In collaboration with stakeholders like the government, supermarkets and universities ChefKot can also run campaigns in order to spread more awareness in this matter.

Figure 5.27 | Choice of smart, sustainable and circular materials

Another touch point between students and ChefKot is the smartphone application. It provides a range of pre-made or customizable meals and takes into account various important factors like vegetarian and vegan options, allergies and current trends such as personal tracking and health awareness. Each box contains an integrated, programmable NFC-chip. When the meal is delivered, the student can unlock extra information about ChefKot and the specific meal. This includes health tips, recipes and a

cooking video (Figure 5.28). Receiving correct information about the nutritional aspects of food and the consequences of bad eating habits is after all the first step in this process of change.

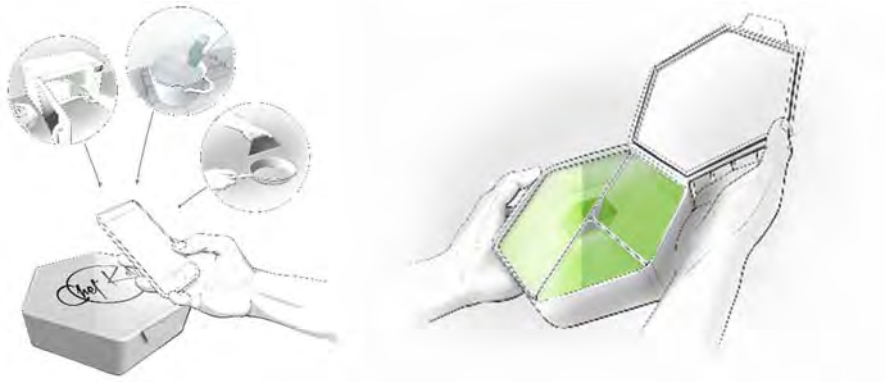


Figure 5.28 | Smartphone application and NFC integration

On the online platform, the customer can choose either to order pre-made meals or customizable meals. To save valuable time, both options have the possibility to have the ingredients precut. The student can order his or her dinner for that evening all day long. It is also possible to have your breakfast delivered the evening before. Hired students deliver the meals on cargo bikes between 5 and 8 o'clock inside a well-defined perimeter of the city. By doing this, it is possible to simultaneously promote the service as well as physical exercise among the target group (Figure 5.29).

Figure 5.29 | Online platform and type of student engagement (customization)

Another option is to pick up meals yourself, ChefKot works with students who rent the fridges in their dorms to stock ChefKot-meals (Figure 5.30). Alternatively, ChefKot provides the dorms with an eco-efficient fridge, specifically storing ChefKot meals. In this way, students can use the app to see where they can find the nearest pickup point to find the meal they want.

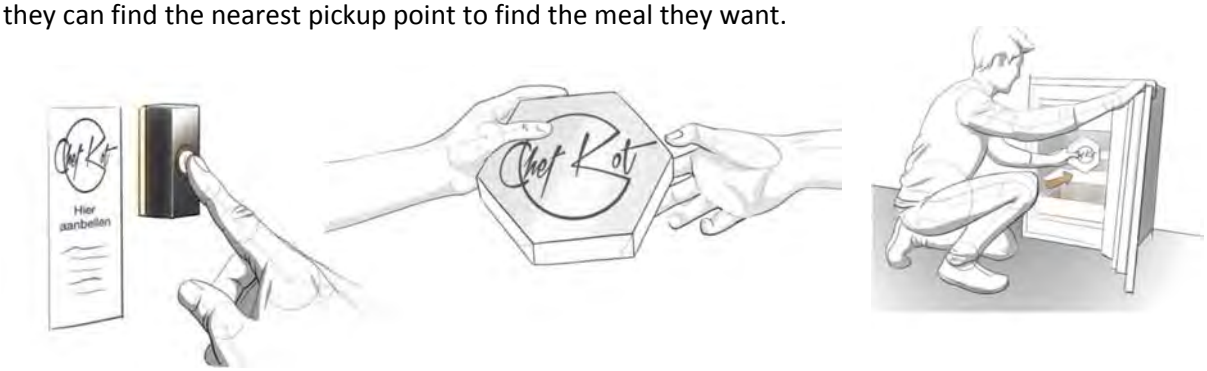


Figure 5.30 | Collaboration between ChefKot and students (pick-up point)

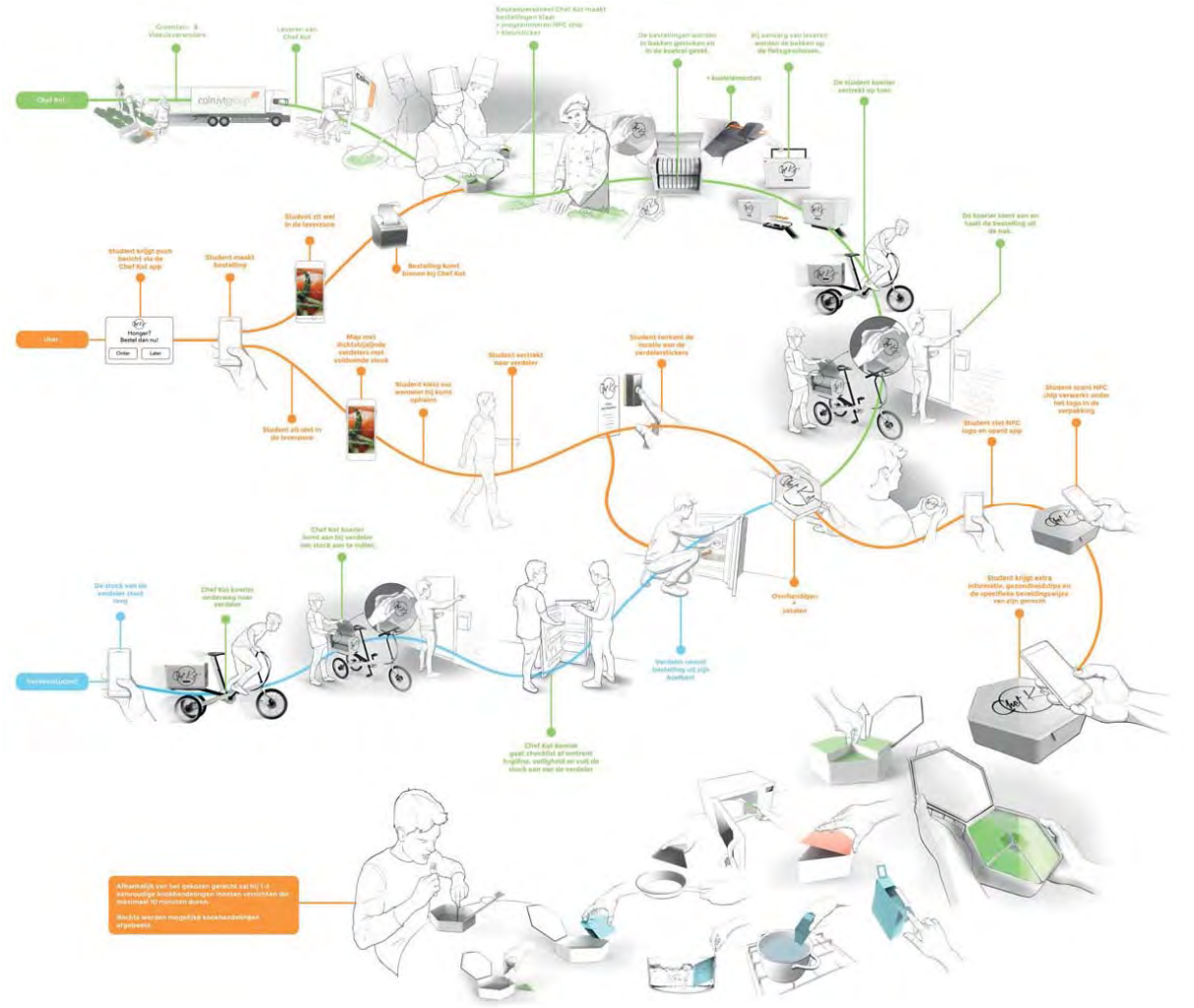


Figure 5.31 | Customer journey

To be successful, the cost of ordering and deliver healthy meals should be equally or less expensive than ordering fast food. To cut intermediates and obtain better value for less money, ChefKot works together with local stakeholders.

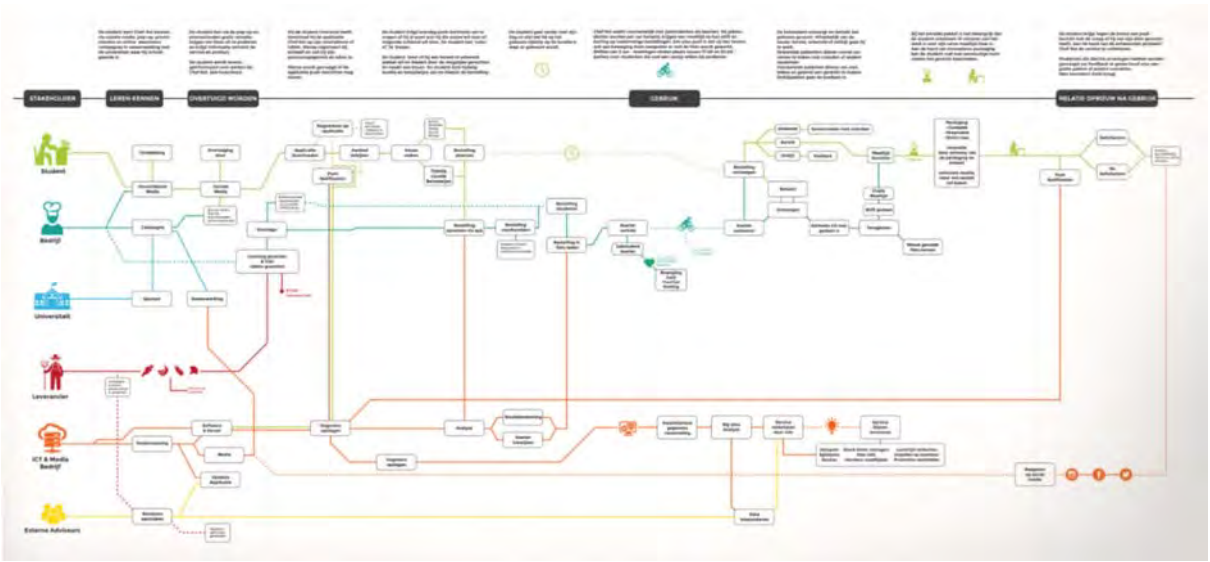


Figure 5.32 | Process mapping

The main goal of the project was to address the growing obesity problem in our society, by means of an integrated PSS approach based on a dedicated toolkit. Although there are already a lot of 'solutions' on the market, the majority of them seems to miss the main target by not focusing on the source of the problem and the necessary ecosystem to address it, avoiding rebound effects of the PSS (Demyttenaere, Dewit, & Jacoby, 2016). Therefore, the primary focus of ChefKot is the pre-emptive tackling of obesity among students. Vandenbroeck et al. (2007) prescribe that, in order to have a successful result, interventions best take place during periods of big change. Many students are confronted with independence for the first time, when taking on higher education. Especially those who are settled in dorms, hence the choice of targeting this group of people as the main stakeholder. Usually this newfound independence is not accompanied with the best self-care in terms of nutrition. ChefKot tries to intervene during this period by making healthy food more accessible for the students through an optimal experience for the user (customer journey in Figure 5.31) and a self-sustaining ecosystem (visualized by the process mapping in Figure 5.32) with its longer lasting effect on society.

5.4 Summary of case findings

Used as an extra confirmation method, we have presented two contextualized cases that describe and visualize the different steps the student teams have taken in the process of integrated PSS design.

5.4.1 GRAND.C

5.4.1.1 PSS design toolkit interpretation

The analysis of the case and personal communication with the student team brings the following most pertinent statements to the surfaces, regarding the usage of the PSS design toolkit:

(1) *The PSS design toolkit brings 'the service' much earlier to the attention of product developers and provides the necessary guideline in the product-service system design process. In general, the toolkit gives a good guidance, but the tools work too limitative or even directive in several occasions.*

(2) *The tools take some time to comprehend and we often have a tendency to see them as an end result, it's not always clear what to deliver. It would be advisable if multiple groups could sit together with one mentor and fill in or brainstorm on each of the tools, the groups would benefit more from such an approach.*

(3) *Tools should not feel like a snapshot and should allow room for enough own interpretation. Examples of filled in tools would help to clarify the expectations of the individual tools, the result or the deliverable.*

(4) *The PSS design toolkit should consider to revise the time spent on understanding, and put slightly more time and effort on (a) idea generation, visualization methods or support specifically on concept generation and interfacing, and (b) the design and prototyping, because the step from idea to an effective prototype came too late, therefore verification was hard.*

(5) *We have to repeatedly look back at the results of each tool and use in the later stages of the design process.*

5.4.1.2 Creativity Support Index (CSI)

Chapter 4 goes in detail on the way CSI was administered, and shows the results of the aggregated data for all four iterations of the PSS design toolkit. Table 5.1 describes the case-specific CSI results of GRAND.C, in relation with our findings it sheds light on the 'science of the particular', cases that deviate from the average but provide the knowledge as input for the consecutive iteration of the toolkit.

A higher factor-score (with a maximum of 20) on the left side indicates that the PSS design toolkit actually better supports that factor. The right side illustrates the expectancy level, enabling a comparison for each factor (with a maximum number of 5). 'Exploration' and 'Expressiveness' give the highest counts and have corresponding high importance. Respectively, this means that the PSS design toolkit supports creativity through different ideas, outcomes and possibilities; and that the students were able to be very creative with this toolkit. Noteworthy for this student team, Table 5.1 shows relatively low to moderate scores for all of the other factors. 'Enjoyment' scored low, however it was not deemed an important measure for the level of creativity support and perceived usefulness of the toolkit. Neither were 'Results Worth Effort' and 'Collaboration', it didn't feel necessary that the amount of effort required for the amount of work corresponds with the usage of the tool; not that it enables the participants to share ideas, designs and work easily in team.

Table 5.1 | CSI with PSS design toolkit as CST, case 'GRAND.C'

Creativity support factors	Statement Agreements (PSS design toolkit) /20 (based on two rating scales)	Priority Counts (relative importance) /5	
Collaboration	6	2	low to moderate importance
Enjoyment	7	0	low importance
Exploration	13	5	more important than any other factor
Expressiveness	11	4	moderate to high importance
Immersion	5	3	moderate importance
Results Worth Effort	8	1	low importance
Total score CSI	48		

Finally, 'Immersion' also depicted a low score, but, was considered as moderate important, suggesting that the toolkit has to get the students' attention fully absorbed in the activity, that they would forget about using it. When confronting the students with some of these remarkably lower scores, they provided a critical reflection on the PSS design toolkit that supported them in the design process of their specific case:

"However meaningful the tools were or were not, they ultimately served to reinforce the design brief and to communicate the concept to the end user." (student team)

5.4.1.3 Component distribution

In the post-inquiry (Table 4.7), the students have situated GRAND.C on the scale with an average score of 4.34 (1 being a pure product, and 10 being a pure service). Opposed to the total average (of 109 data entries) of 5.86 on the product-service continuum, the specific case study of GRAND.C can be situated in the PSS model as a rather product-focused concept (Figure 5.19). The tangible objects (bird and tags) have a significant role. *"Without a dedicated product the PSS cannot exist. The product carries specific aesthetic qualities and allows embedding emotion, personal meaning in the product"* (Dewit and De Roeck, 2014).

Figure 5.33 | Component distribution: product-focused (left) | balanced (right)

However, the service component allows the eco-system to be longer involved with the customer. The user experience does not end after playing the GRAND.C game, it can proceed much longer since the GRAND.C service constantly introduces new objects that evoke new stories every time. Thus combining both product and service components in one system results into a better user experience that lasts longer. We could argue that the concepts would be a balanced PSS, with an evenly important product and service component. However, when one of both would be removed, the PSS still makes sense. The product (bird and tags) can still be used as a game, and vice versa, the service (digital system, rental service and physical touchpoint) could be used on its own to tell stories.

5.4.2 ChefKot

5.4.2.1 PSS design toolkit interpretation

The analysis of the case and personal communication with the student team brings the following most pertinent statements to the surfaces, regarding the usage of the PSS design toolkit:

(1) *The PSS toolkit cannot be seen independent of the design process in order to achieve meaningful innovation. It enables us to comprehend the entire context and expectations of all possible stakeholders.*

(2) *The PSS design toolkit guided us in ways that are not limited to merely physical products, it strives to bring more to the story, comprehend the context and capture the bigger picture.*

(3) *The PSS design toolkit presents design tools in a way that does not limit, but rather guide and allow us to interpret the tools with a certain degree of freedom and encourage the exploration of the entire ecosystem around the case.*

5.4.2.2 Creativity Support Index (CSI)

Without a clear methodology for recognizing and evaluating creativity, the research makes use of the Creativity Support Index (CSI) survey (Carroll et al., 2009). This quantitative metric captures the perceived usefulness of a Creativity Support Tool (CST) and helps researchers and designers to evaluate the level of creativity support provided by a certain tool or method after applying a specific CST, in this case the PSS design toolkit. The CSI measures six factors: Collaboration, Enjoyment, Exploration, Expressiveness, Immersion, and Results Worth Effort. The results of the CSI (Table 5.2) bring forward insights, relevant for adaptations to the tested CST, the PSS design tool.

Table 5.2 | CSI with PSS design toolkit as CST, case 'ChefKot'

Creativity support factors	**Statement Agreements (PSS design toolkit) /20 (based on two rating scales)**	**Priority Counts (relative importance) /5**	
Collaboration	16	3	moderate importance
Enjoyment	14	0	low importance
Exploration	17	5	more important than any other factor
Expressiveness	9	2	low to moderate importance
Immersion	9	1	low importance
Results Worth Effort	19	4	moderate to high importance
Total score CSI	79		

A higher factor-score (with a maximum of 20) on the left side indicates that the PSS design toolkit actually better supports that factor. The right side illustrates the expectancy level, enabling a comparison for each factor (with a maximum number of 5). 'Exploration', 'Results Worth Effort' and 'Collaboration' give the highest counts and have corresponding moderate to high importance. Respectively, this means that the PSS design toolkit supports creativity through different ideas, outcomes and possibilities; that the amount of effort required for the same amount of work corresponds with the usage of the tool; and that it enables the participants to share ideas, designs and work easily in team. Furthermore, Table 5.3 shows a relatively high factor score for 'Enjoyment', however this was not deemed an important measure for the level of creativity support and perceived usefulness of the toolkit. Finally, 'Expressiveness' and 'Immersion' depict lower factor scores. However,

both were considered as low to moderate important, suggesting that the toolkit could still (but not necessary) improve on these creativity factors. When confronting the students with these remarkably lower scores, they do not interpret these as negative:

> *"Delaying the ideation phase actually stimulated thorough comprehension of the system through research. The PSS design toolkit forced us to do extensive research in the understand phase which resulted in a clear vision on the goals in the exploration phase" (student team).*

Optimistically, the way in which this case represents the progress of the PSS design toolkit, levers the general disposition of design students, practitioners and organizations toward creating new PSS.

5.4.2.3 Component distribution

In the post-inquiry (Table 4.7), the students have situated ChefKot on the scale with an average score of 7 (1 being a pure product, and 10 being a pure service). Opposed to the total average (of 109 data entries) of 5.86 on the product-service continuum, the specific case study of ChefKot can be situated in the PSS model as a rather service-focused concept (Figure 5.34). It is a delivery service that provides healthy food for students, by students. It delivers fresh, precut ingredients for a healthy meal right up to the doorstep of student dorms in order to stimulate heathy cooking. As stated by Dewit and De Roeck (2014): *"The PSS offers a specific functionality with a generic meaning that the user needs to assign"*, the tangible components (that could also be something completely different without changing the PSS) involved are a way to interact with the PSS. It is mostly important that users emotionally attach to, and the product supports that.

Figure 5.34 | Component distribution: service-focused

There are multiple possibilities in which the service provision can be modularly approached, that provides a way to balance the components out if necessary. The service component allows the ecosystem to be longer and more intense involvement of the customer in the process. The user experience can be increased by the product component's functionality when cooking, it's digitalized NFC tag for quality purposes, traceability and more information about cooking, and finally as an exchangeable artefact with the ecosystem.

5.5 Conclusion

The context of both cases is one almost everyone can relate to. Nevertheless the product-service system (PSS) tools, which combines a variety of existing perspectives and provides a structured approach to address the given prompt, i.e., 'nodes of life' and 'tackling obesity'. Especially the tools where interaction with the stakeholders was required, gave the students the opportunity to get inspired by the personal anecdotes of the test users. Each one of their unique experiences triggered out of the box thinking. The student teams noticed that the first PSS tools (during the understand phase) are rather focused on 'words' such as the Design Challenge. Yet, they reached a turning point with the Lotus Blossom tool. The design process suddenly became more visual and tangible using inspirational examples that could meet the requirements. It helped them to translate the needs and wishes to attributes and interactions. More opportunities for the PSS design toolkit lie in adding useful and diverse techniques supporting the definition and verification phase. PSS design is situated in the front-end of innovation and aims for a valid concept. Therefore, the outcome should be verified with the end consumer and communicated in an understandable manner.

At the start of the IPO Project: Integrated Systems, usually about ten users are involved throughout the design process, from introductive interviews to user testing. However, more participants would be advisable to generalize the obtained information and feedback. Nevertheless, it must be stated that even with this limited test group, similar information was gathered as designated by the preliminary literature research. In addition, this small group allowed the student team to elaborate on various aspects during the interviews and user testing, resulting in more qualitative information. It was interesting to explore the context of co-creation, which gives the opportunity to really involve test users during every stage of the design process and bringing them all together to discuss the conclusions and concepts. During the final phase, the students chose to develop a visual and low-tech prototype and experienced this as a meaningful and grateful way to communicate a complex system to stakeholders. In other words, the prototypes proved to be highly valuable for initial verification of the PSS concept. It allowed them to observe the rich interactions between the users and the different components of the PSS. Although a detailed system map where all interactions and touchpoints are described, and an 'appropriate' fidelity prototype of the product-service concept were validated, it remains uncertain how users respond to the new product-service throughout its entire life cycle. This is why the students recommended even more tools related to prototyping and user testing, as they should lead to more verified (fully functional) concepts. In addition, it would be Interesting to conduct research on the long-term effects, however not feasible within this course.

We claim to bridge or at least address the lack of formality with the PSS design toolkit, producing physical output, themes, and design ideas that are not arbitrary when compared to the research data. It should be rather immediately clear how one derived the one from the other, and besides representation, also formalization is necessary. The PSS design toolkit aims to provide a structured process, comprehensible output and is supported by understandable documentation.

We conclude this chapter and link back to the main research question.

The described case studies support the evidence that designers are able to use the PSS design toolkit with the desired performance. The formalized character of the toolkit affects the representational skills, furthermore its visual exploration (of products, services and people interacting with them) enables the designers to reflect on a more integrated design process, and results in a better communication and understanding of their design.

CHAPTER 6

PSS design toolkit | Overview

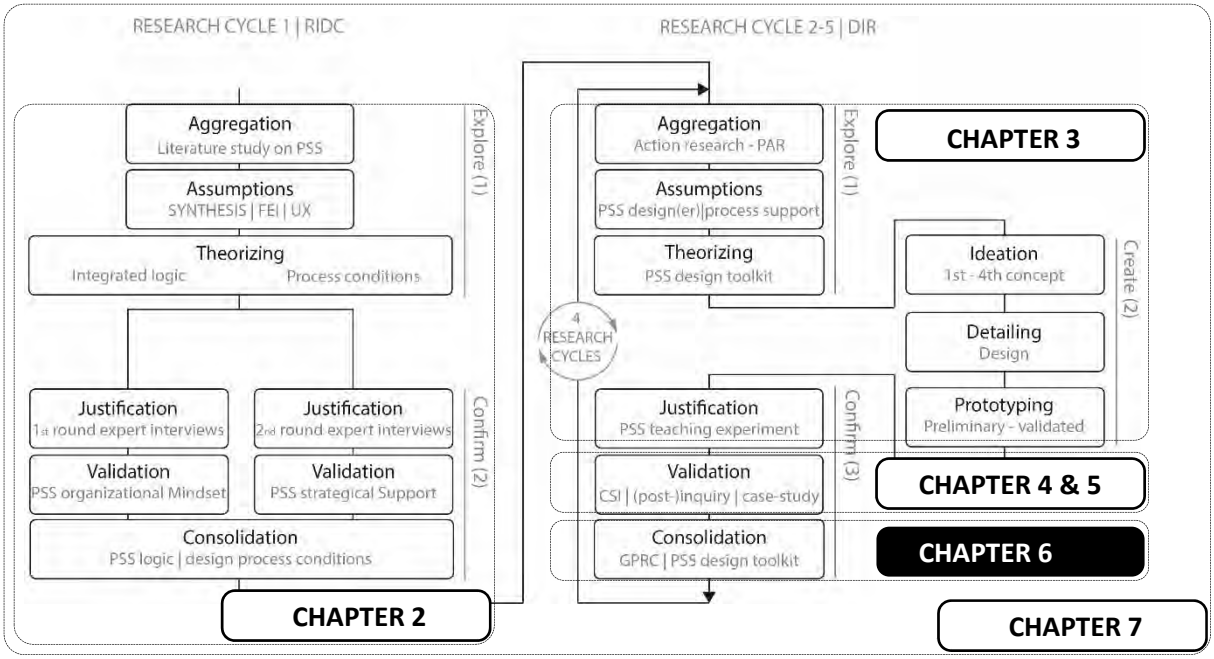


Figure 6.1 | Research design - chapters

6.1 Research methodology

Validation has been discussed in Chapter 4 through a triangulation of methods, i.e., creativity support index (CSI), post-inquiries, and two case studies in Chapter 5. In this way, we measure and interpret the extent to which the PSS design toolkit meets the objectives that it was intended to achieve.

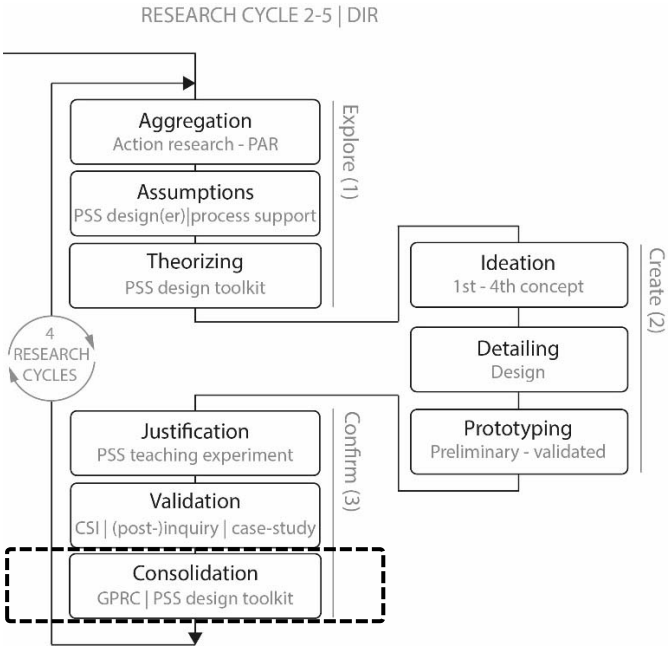


Figure 6.2 | Research Cycles 2-5 (comprehensive view)

Chapter 6 describes the consolidating phase of the third part (confirm) in the procedural approach of DIR. Our research intends to complement the existing knowledge on integrating product and services. Generalization is difficult because the correspondence of the conducted research with the real world situation could be seen as rather weak. Yet, to enhance applicability to real life situations outside of this specific research setting, our research was assisted and judged by the design agencies Namahn and Studio Dott, organizations such as Colruyt, DELA, Nokia Bell Labs, and governmental institutions like Stadslab 2050, and Antwerpen Aan ‘t woord. Already the instrument was used in other projects beyond the scope of this research (an IWT TETRA study, 250 sold copies of the PSS design toolkit internationally) and regularly decontextualized. This research would significantly benefit from retracting information and data from researchers and designers using the toolkit or repeating the same teaching experience elsewhere. Having received the GPRC label, we feel confident about the PSS design toolkit’s ***consolidation*** with the existing knowledge and practice on PSS (Horváth, 2008, 2013; Horváth & Du Bois, 2012).

* This chapter is derived from the ME1 Book as editor (2018), its four H1 Book chapters (2018) and one A3 Journal article (Journal of Service Design, 2018).

6.2 Research consolidation methods

We are interested in whether the PSS design toolkit complements the existing knowledge on PSS, and can be generalized to other contexts than design education alone. For consolidation purposes, we present the last in a series of the confirmative methods:

- the GPRC (guaranteed peer reviewed content) procedure, it challenged the validated toolkit from Research Cycle 5 to support the PSS design toolkit and its last adjustments in accordance with guaranteed academic standards.

Figure 6.3 below shows the consolidation stage at the end of Research Cycle 5.

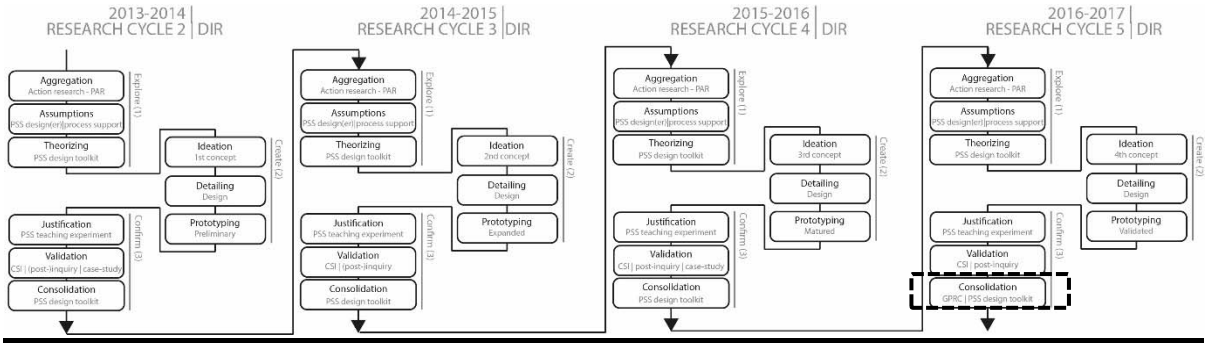


Figure 6.3 | Research Cycles 2-5 | DIR

This research ultimately consolidates the PSS design toolkit, and shows the result of Chapters 3-5. To enhance applicability to real life situations outside of this specific research setting in design education and still live up to academic standards, this chapter reveals the challenges and opportunities of the penultimate version of the PSS design toolkit from diverse angles. Approved by international academics and professionals in the field of PSS, we are happy to have published the final version of the PSS design toolkit in 2018 with GPRC label.

6.3 Confirm | Consolidation by guaranteed peer reviewed content

The GPRC label[21] (Guaranteed Peer Review Content) was developed by the Flemish organization Boek.be and is assigned to publications, which comply with the academic standards required by the VABB (Vlaams Academisch Bibliografisch Bestand) (Verleysen & Engels, 2013).

A GPRC label for our publication 'PSS design and strategic rollout, tools for product-service systems' is not an award, however it does mean that this publication is peer reviewed according to international academic standards. http://www.gprc.be/en/pss-design-and-strategic-rollout

What is GPRC exactly? GPRC stands for 'Guaranteed Peer Reviewed Content'. With this quality label the Group of Educational and Scientific publishers (GEWU) certifies that a peer review procedure which corresponds to the international academic standards, has positively evaluated the labeled publication.

What is the use of the GPRC label? With the explicit identification of high quality academic publications through the label, the Expert Group Academic Publishing of the Group of Educational and Scientific publishers (GEWU) aims to contribute to the realization of a qualitative Flemish Academic Bibliographical Database for the Social Sciences and the Humanities (VABB-SHW).

Which procedure is used to attribute the GPRC-quality label? The publishing house (University Press Antwerp, Aspeditions) which thus labels a specific publication, needs to be able to demonstrate the successful evaluation of that publication through a peer review procedure according to internationally accepted standards. In close consultation with the academic authorities (the Flemish Interuniversity Council (VLIR), this demonstrability is defined by the availability of a peer review dossier which contains at least the following components: (1) Table of Content of the publication in question; (2) Affiliation of the Reviewers; (3) Chronological overview of the main phases in the review procedure; (4) Minimum two Review Reports; and (5) Format confirmation that the Reviewer authorizes publication with the quality label.

Below, we go more in detail on the third component of the review procedure, and give a rough description of the chronological overview of the main phases in the review procedure and how they contributed to this publication. The quotes - in blue font color and highlighted in citation style - come from the reviewers. However, in GPRC procedures all information remains anonymous.

6.3.1.1 Originality

To assist the PSS design toolkit, the theory addressed in chapters one, two and three of this dissertation aim to provide a broader and more thorough introduction that explains what PSS is, where it comes from and what kind of design challenges the tools help (re)framing. The intention of the PSS design tools is to reach out to any type of design project, and be able to approach it differently, with a very broad set of tools applicable for PSS.

> *PSS has no borders, so that tools are relevant in any context. (reviewer)*

For the compilation of the tools, we use the metaphor of the board game, something that engages its users to get dedicated to PSS all along the way (1). The three phases - understand, explore and define

[21] https://www.gprc.be/en/content/what-gprc

- that the process goes through, are built-up without any dominant push (on product and/or service) up-front. When you are working toward a solution, you cannot design with an outcome 'up-front' in your mind. Nonetheless, the PSS design tools would as much be able to guide you through a design process with a focus on *servitization* or its counterpart *productization*.

It covers a spectrum of tools and methodologies that successfully provide a 360-degree approach to a systematic design process. Works well for deep exploration as well as for using the results of one tool to fuel another and increase impact. (reviewer)

The user's background and knowledge enables possibilities to integrate product and service where necessary, and without a force-fit, s/he can go through **Part 1 - PSS Design** and explore a more long-term beneficial outcome. In this case, one starts to use the rationale of the method to get inspired (2). However, short-term solutions might not profit from a PSS push, and maybe a service addition, a touchpoint makeover or a simple packaging would suffice or be more interesting to begin with. For these examples one is more likely to plug and play with the multiplicity of tools and techniques offered throughout the systemic design process in general, in any particular phase or with a specific kind of focus (3), and ultimately go faster to **Part 2 - PSS Strategic Rollout**. The actual aim is to give the user the potential to grow with and through the use of the toolkit.

6.3.1.2 Scientific and international relevance

Referring back to the research methods, the entire PSS design methodology and its tools are based on scientific research and have been iteratively tested, following a design inclusive research (framing) methodology. During four years of participatory action research on the PSS design toolkit in the educational field, but in close collaboration with industry and design agencies from both service and product design side, we frequently reported - subject to peer review - in the scientific field on our advances and applications.

Although it does include tools mentioned in other sources, the compilation of the tools into a systemic process is original and reflects a reality of practice that grounds the theoretical content of the tools. (reviewer)

By now we have around three-hundred design students, design agencies and organizations (including government and non-for-profit) working together with us. After a number of conference and journal papers, workshops and more, we have now sold over two-hundred and fifty copies nationally and internationally. It is nice to *finally* have the very first reference with GPRC label in the field of PSS, rather than only talking about the use of the so-called 'PSS design toolkit'. We hope that with this peer-reviewed effort, this publication can be an original basis and a first for PSS design, scientifically relevant and internationally spread.

Curation of the tools is evident, as well as the buildup and handover between different actors in the PSS system. It is applicable in international contexts as well as companies with international affiliates and multi-disciplinary fields of application. (reviewer)

With this international character, we (now) hope to receive more insights from elsewhere on how others use our PSS design tools and how they work in their specific context of use, whereas now a big part of the examples and concepts are presented in Flemish/Dutch. Outside our country borders, Architecture students have been applying it in Riga, Latvia; it's part of a course at the University of Sao Paolo in Brazil; it has been used in the Technical university of Denmark in Copenhagen; and at the Linköping University in Sweden two researchers are about to implement it at the Department of

Management and Engineering. We claim that this can produce valuable additional information on pragmatic validity and practical relevance (van Aken et al., 2016). We also applied parts of the knowledge - PSS strategic rollout - in collaboration with Antwerp Management School as part of a Technology Transfer (IWT TETRA) project, the eight companies involved provided their insights with mostly PSS exploitation purposes.

6.3.1.3 Accuracy of data, sources, reasoning and research methodology

To increase the validity of the work and to show that our choice of tools is somehow grounded, we do an effort to provide a clear explanation of why and how we selected the set of tools described. Our scientific papers and **Chapters 2-5** refer to these explanations, on the selection of the tools, that after four years eventually add up to the overview model presented in **Chapter 6** and connected into the Integrated PSS Design Framework in **Chapter 7**. The shape of the overview model comes from the original service design toolkit, whereon we based our earlier versions of the PSS design toolkit, (and had a circular approach too). It works visual, clockwise and opposes to Cartesian linear thinking. This toolkit and the systemic lens actually needs something recurring, the building up of knowledge and feedback loops, and especially a design process and an ecosystem that evolves around the user. Besides that, it gives the user an alternative to a traditional index at the front of a book.

It is well documented, all sources are clearly stated, and references are provided to allow the reader to investigate further any specific tool they might find interesting. (reviewer)

A year after the design course, we see the students internalizing the knowledge and using the toolkit for their master thesis to ultimately taking this into their professional career. During the design course, people from all over have been asked to be part (participated, interviewed, testing prototypes) in the discussion and exploration on complex topics. Companies like Colruyt (FMCG) followed our progress on 'obesity', DELA (insurance for the deceased) participated on 'digital and physical traces', the City of Antwerp and NOKIA BELL LABS engaged when we designed for 'Sharing concepts for a smart city'. Product and service design agencies actively engaged throughout the twelve weeks, together with a PhD researcher on this topic (myself) and teaching staff trained in product design, but each with a slightly different angle (e.g., strategic, interaction, technology-driven) on the discipline.

It is evident that the tools selected have been tested with a user group and have been selected to navigate the wicked problems that companies face in their daily challenges in the PSS ecosystem. (reviewer)

Nowadays more people and agencies are asking whether they can use the tools, so we hope this GPRC label will pinpoint and acknowledge the PSS design toolkit's scientific merit and relevance as a first reference in the field!

6.3.1.4 The manuscript's conclusions provide a clear answer to the research question

Several improvements made sure that the way in which the tools are presented, fits their goal. We made sure that the descriptions are PSS specific and that unique aspects of PSS design are addressed and explained for every tool. However, we will try to explain why we do not explicit the use of product and service too much. It is necessary to postpone judgement of designing product and/or service when you are designing a (new) system that offers a solution to the design challenge. E.g. 'appropriate prototyping' makes you feel whether a product, service or software (app, web based interface, etc.) is necessary or supports the user better and keeping regard of the (costs, resources, platforms, etc.) constraints put forward by the possible client / organization(s) you are doing this for.

So ‘where necessary’ because in the first stage, you are just understanding (framing) the current system and its context causing an interplay of products, services, people and the interactions between them. Up to the point where a new design challenge is put forward, no clear suggestion of product or service has been made. Even during the exploration level, you are still looking for ways to reframe and intervene with the new product-service system, and in its turn, it sets high-level ‘rational, emotional, context, interaction, etc.’ requirements for the start of ideation. When the first ideas - addressing these requirements - are formed, the first signs of (in)tangibility show, later they are combined into scenarios and concepts that form a solution to the earlier stated design challenge. So gradually, we begin to detail the touchpoints and their necessary design / critical (product and/or service) components that can be tested, prototyped and integrated into the final PSS.

To avoid the descriptions of the steps to be too complex and vague, we included examples and systematic concrete applications of the methods to really understand how to use the tools. Otherwise, a designer would have difficulties in taking one of the descriptions and use it straight away. Thus, besides the presentation of a sketched description of the steps, we try to do that with a concrete example where possible. To supplement the descriptions with some additional, short paragraphs, we added introductory chapter pages that already show the user a specific direction for a final deliverable of the tools, before starting the next level and its respective tools set.

Conclusions and takeaways help structure outcomes and enable readers to implement the tools in their specific context, hence answering the research question of how to overcome barriers for incorporation and implementation. (reviewer)

We have put an effort in iteratively testing the way that fits best the user of this PSS design toolkit. The complexity is quite understandable because of its nature, but we can confirm from our yearly evaluations that the support is sufficient to get the job done (see **Chapters 2-5**). When dealing with students or newbies, professional guidance is still advised. The (trained) designer would be capable of interpreting its functional use, and generally ‘hates’ it to be held by the hand and being taken the freedom for acting autonomously. There is not one direction. As a metaphor we refer to a board game, usually one person reads it, while the others are bored and eager to play. So usually they just play it for a first time ‘cards open’ and gradually see what happens. After playing on multiple occasions, the real fun starts because everyone knows the rules and reaches a level of complexity, each with their own set of goals and capabilities to master the game. After some time, they start bending the rules to make it more interesting.

6.3.1.5 Structure, coherency, clarity and accuracy

We worked toward a clear structure that serves the reader immediately and works as a reference to the overview model to remind the user where s/he is in the process. The book is divided in three parts, (re)using the overview graph and an introductory description. Furthermore, the tools were provided with the same graph, showing in which phase the user is using a particular tool and in what sequence, related to the other tools in that phase.

Easy to navigate by practitioners as well as beginners. Well structured, with instructions of use, and proposed time to deliver the activity and number of participants, as well as diagrams and examples of use. Visual, intuitive and well organized. (reviewer)

We made an effort to do a more consistent description for each tool, however, sometimes it’s more a technique rather than a tool or method and needs less description, where it serves inspirational purpose when slowed down in the process, or when looking for a way to find alternatives.

The examples that are used in the toolkit (and related pictures) regularly have a visually guiding recommendation on how to use the tools. Visual because otherwise the students' work shows signs of dominant design, literally using or referring to these examples, rather than using it as a reference point. It is all about trial and error with the tools, with a freedom to use and elaborate on them. Students, similarly to organizations have a tendency to overly focus on creating deliverables, rather than enacting change. This kind of behavior brings catchy taglines like, e.g., *"Think About The Journey, Forget About The Map."* (Kerry Bodine). https://kerrybodine.com/how-to-scale-service-design-coaching/. We actually see fantastic things happening through this experimentation, different ways of using a tool and the striking effects on the outcome. The *results worth effort* is higher when the tools are 'rather freely' explored, rather than a following a systematic approach. We also see new approaches, people are looking for ways in which they really like to use the tools, and this was one of the reasons why we provided vector drawings of the tools for download and personalization purposes. Most of our direct users are not new to using tools in general, however they still remain *newbies* to the PSS design process. The more advanced they get through multiple use, the more they can read on it, using its references, plug and play with the tools, using the rationale and eventually going dedicated on PSS.

The content and focus of the book is clear and overall complete. (reviewer)

The conclusion will also embed an explanation of the 'holistic' process of constant diverging and converging, which sets the 'systemic' angle more central and stress more on the synthesis approach (of product and service) we have toward an integrated logic for designing PSS, beyond the dichotomy.

6.3.1.6 Comparison with publications covering the same subject

Ultimately, PSS is more a research term and probably only used the academic scenery, but it is the designer's primary focus when following an integrated logic. The user or end-consumer is interested in the solution, regardless of it being a product and/or a service. The reason why we do not stress PSS too much in the tools is that the tools serve to 'automate' and 'formalize' the design process. It is a way to build up a repertoire of tools and terminology that contributes to insight in the systemic perspective and discuss the matter more easily with a vast array of stakeholders.

There are different toolkits that include a variety of tools, but this book has curated the content to cover gaps in the PSS System and offers relevant tools to enable companies to grow and be more competitive. It also dedicates effort to integrating non-designers into a design process and the tone of voice is approachable and professional. (reviewer)

A second danger is to claiming PSS specifics and equally important however, this toolkit sets less focus on the economic and ecological value. With the user experience, exploration and synthesis central throughout the entire process, we hope on the necessary spillover effects and moral of the designer to make a PSS as sustainable as possible. Originally intended, the transition from products to services foremost implied 'less products'. We also state that a good design will have to be checked on economic viability. Therefore, a series of adjustments were made in Part I. First, we added two extra tools 'Value Proposition', 'Business Ideation Canvas' and the notion of using Lean Canvas and/or Business Model Canvas in the define phase. Specifically Part II addresses and complements the first part on indicators for a more typical business-oriented exploitation.

There are different books that collect design tools for services or products, but a book on PSS design tools is missing. Stressing the PSS uniqueness of the tools and their usage makes the value of the book really come through. (reviewer)

Toolkit

PRODUCT SERVICE SYSTEM DESIGN

Product Development
University of Antwerp

namahn studiodott. UPA

6.4 PSS design toolkit (peer-reviewed)

This toolkit is an ongoing effort to develop a methodology, with tools and techniques, for designing meaningful product-service systems. It mixes state-of-the-art insights from the domains of systems and systemic thinking, service design, human-centered design, interaction design, product design and design thinking. Furthermore, the toolkit can also be used to solve societal and Internet of Things challenges. Systems thinking is a new addition to this design approach and fundamental to solving complex and connected issues. The biggest difference between systems thinking and conventional design thinking is the way it looks at the whole instead of the parts. Figure 6.4 below represents the PSS design process (enlarged in **Appendix VIII**). Clockwise it shows the three FEI-levels (understand, explore and define), its respective set of tools (in greyscale) resulting from the four iterations in Research Cycles 2 to 5.

The **PSS design toolkit** brings forward an iterative support in the design process with a threefold focus; a synthesis approach, the user experience and the front-end of innovation (FEI). The toolkit aims to revise, adapt and add to the current PSS design tools and to better support future generation designers for deep *exploration*.

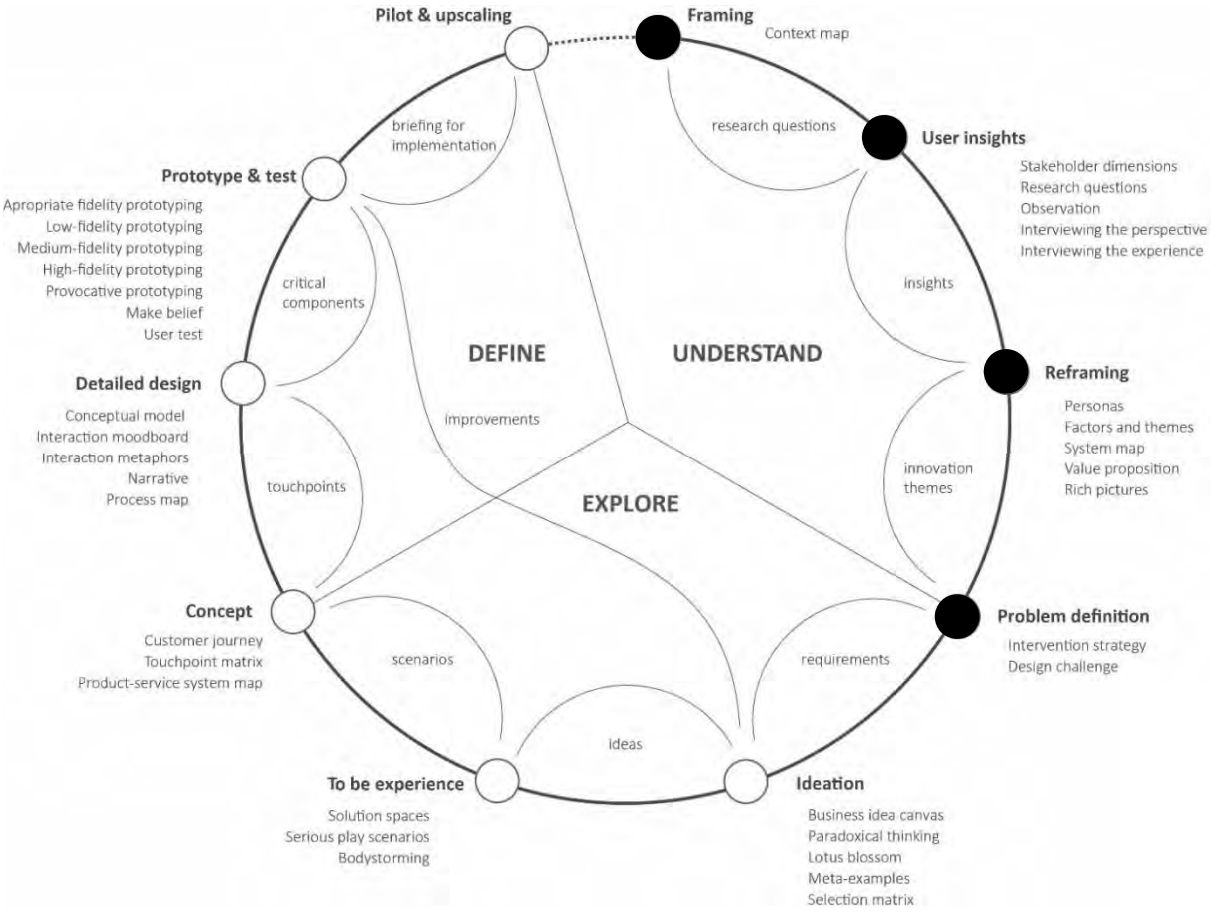


Figure 6.4 | PSS design process - level Understand

UNDERSTAND

The project brief gives you a starting point (your issue-at-hand) in your PSS design process. Insights in the context and the underlying human drives helps you to understand and reveal all possible interactions between those affecting the context and others affected by it. Intertwined desk and field research supports a profound understanding of different perspectives, needs and expectations of all stakeholders, a set of characteristics that will influence your future PSS. Pre-shooting (up-front sense making as preparation of the fieldwork) helps you to get a deeper understanding of the user's current experience, enables you to apprehend the more interesting motivations, emotions, and triggers behind changes in their experience (activity) curves. These insights can be obtained with a variety of methods, but it remains central that you are able to identify patterns in behavior and interactions (even if unintended). Each tool offers an interpretative lens to enable sense making of the context, in order to reframe the perspectives or to change them.

Stepwise you come to an understanding of the system's structure, stakeholders, elements and their relations, you will discover the leverage points that are relevant to rethink the whole system when reframing its purpose. Clustering the promising patterns will support you to capture the bigger themes and ultimately address the underlying phenomenon of the situation. A representation of all (re)framed insights should encourage stakeholders to discuss, interact and attain a holistic understanding of the issue.

6.4.1 UNDERSTAND // FRAMING

6.4.1.1 CONTEXTMAP

What | Context mapping is exactly what it says it is: making a map of the context (of use) of the (future) product-service.

Why | Context mapping is especially useful in the understanding phase of a project. It gives you insights into the context of your issue and the underlying needs of your customers.

How | Make large labels of general categories. These are typically the five Ws+H: Who, Where, What, When, Why + How or the stakeholders (users, employees, organizations, etc.), the places, the products, services, the moments of use, the goals and the activities involved. *www.kumo.io*

Identify the key stakeholders and define for each of them why and how they actually use or offer the product or service. You can use the *human drive cards* (Namahn) to find the underlying drives and needs. Draw lines between the elements that exchange values. Describe the values the elements bring each other. (Visser, Stappers, van der Lugt, & Sanders, 2005)

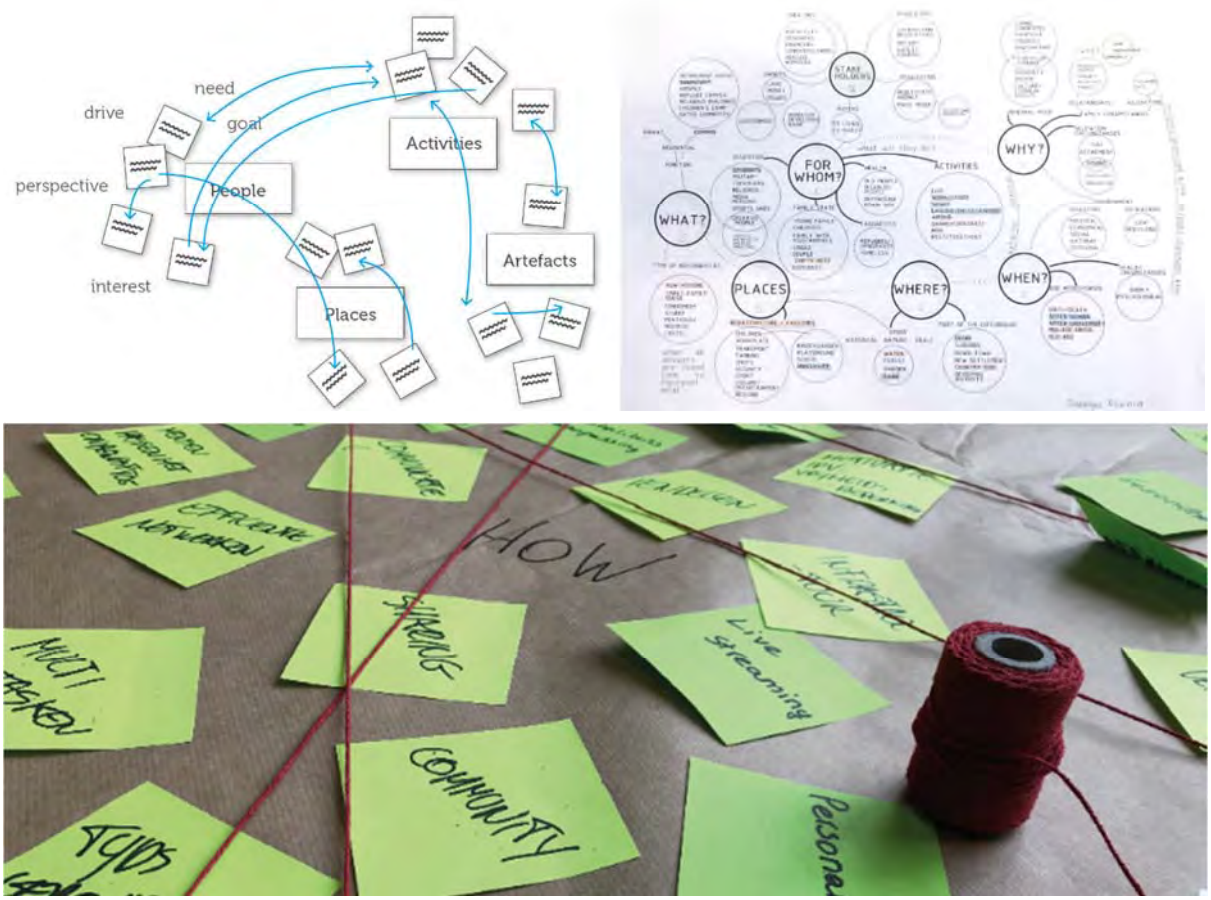


Figure 6.5 | (upper left and lower) Context mapping adopted from PSS Design and Strategic Rollout (Dewit et al., 2018) | (upper right) context map used by students Architecture in Riga, Latvia (picture courtesy: Bart Melort)

6.4.2 UNDERSTAND // USER INSIGHTS

6.4.2.1 STAKEHOLDER DIMENSIONS (TEMPLATE)

What | Stakeholder dimensions are the set of characteristics that will influence your future product-service system.

Why | During the field study - in the next step - you want to understand the different perspectives, needs and expectations of the stakeholders. You have to identify these first.

How | You do this exercise several times, once for each stakeholder group you want to interview (users, service providers, decision makers, etc.).

Look at your *context map* and identify the stakeholders that you want to interview. Include at least the people who are most affected by the system, and who are most influencing other stakeholders (look at relations that are substantially reinforcing). Decide on the most important opposing characteristics that are relevant for your project (get inspired by *paradoxical thinking*). Examples are differences in character traits, motivation, knowledge, experience, attitude, standards, context, etc. Make sure to consider differences in perspective (or worldview). Select the differences that have the most influence on the experience and set them out horizontally. Determine realistic combinations of characteristics that together could constitute a stakeholder and link these vertically. Repeat this until you end up with ± six profiles. Find people who match the profiles as closely as possible and make an appointment to interview them.

Figure 6.6 | Stakeholder dimensions adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

Originally adopted from the Service Design Toolkit. 2014 www.servicedesigntoolkit.org

6.4.2.2 RESEARCH QUESTIONS (TEMPLATE)

What | Research questions are clear and concise questions to guide your interviews. There are two categories of questions: hypotheses for verifying your assumptions and open questions about what you do not know.

Why | Thinking about your questions upfront helps you to better understand what you are looking for.

How | Start from the *stakeholder dimensions*.

Deepen your understanding of the experience for each of the stakeholder types you identified by googling video testimonials, psychological and sociological studies on the topic. For each interviewee, set out what you currently understand about the experience. This can be about the experience during a whole lifetime or during a particular event. First, list the phases or activities your stakeholder goes through (before, during and after). Then draw the experience curve. Now look at the highs and lows and think about the reasons behind them. Look back at your *context map* to find your hypotheses. Look at relations between the variables - you assume that they influence each other - and pay special attention to potential intervention points. Formulate questions to verify your assumptions based on the influencing elements and the relations on the map. As the next step, write down additional questions about what you do not know yet. These questions typically involve motivations, emotions and triggers behind the changes in the curve. Use the *human drives* map to help you with this.

Figure 6.7 | Research questions adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

Originally adopted from the Service Design Toolkit: www.servicedesigntoolkit.org

For more information, read on Human Drives at www.namahn.com/share/human-drives-card-deck.

6.4.2.3 OBSERVATION

What | Observation is a technique that helps you to understand the people involved in your product-service system by observing their behavior, interactions and body language.

Why | The purpose of observation is to find opportunities for improvement by identifying the patterns of use. You are especially interested in the moments of flow, the hurdles and the unintended behaviors.

How | Select a number of places where you can observe people in the context of use. Choose places that are as different as possible from each other (e.g., a waiting room in a regular doctor's cabinet and a waiting room in a hospital emergency unit. Also consider various observation times if this makes a difference (e.g., in the day-time/at night).

The use of the AEIOU framework (by Rick Robinson et al.) can help interpret observations gathered by ethnographic practice. During field observation, use the AEIOU framework as a lens to observe the surrounding environment. AEIOU stands for the five elements to be coded: Activity, Environment, Interaction, Object, and User. *www.doblin.com*

Figure 6.8 | Observation adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

Originally adopted from the Human Centered Design Toolkit: www.ideo.com/post/design-kit

6.4.2.4 INTERVIEWING THE PERSPECTIVE

What | A perspective or worldview can be defined as how one sees life and the world at large. People make sense of life and comprehend the world around them through the interpretive lens. Sometimes the lens brings clarity, on other occasions it distorts reality.

Why | You want to capture the perspective of your stakeholder toward the problematic situation in order to design upon these perspectives or to change them.

How | This is a face-to-face interview with one interviewee at a time. Try to conduct it in the context of your system. After the interview, you can use the model of universal human values *(by Schwartz)* to interpret the answers (Schwartz, 2013). People tend to pick corresponding colors, shapes and materials if they agree with the value (behind your problem, issue or solution) and name the opposites when they disagree.

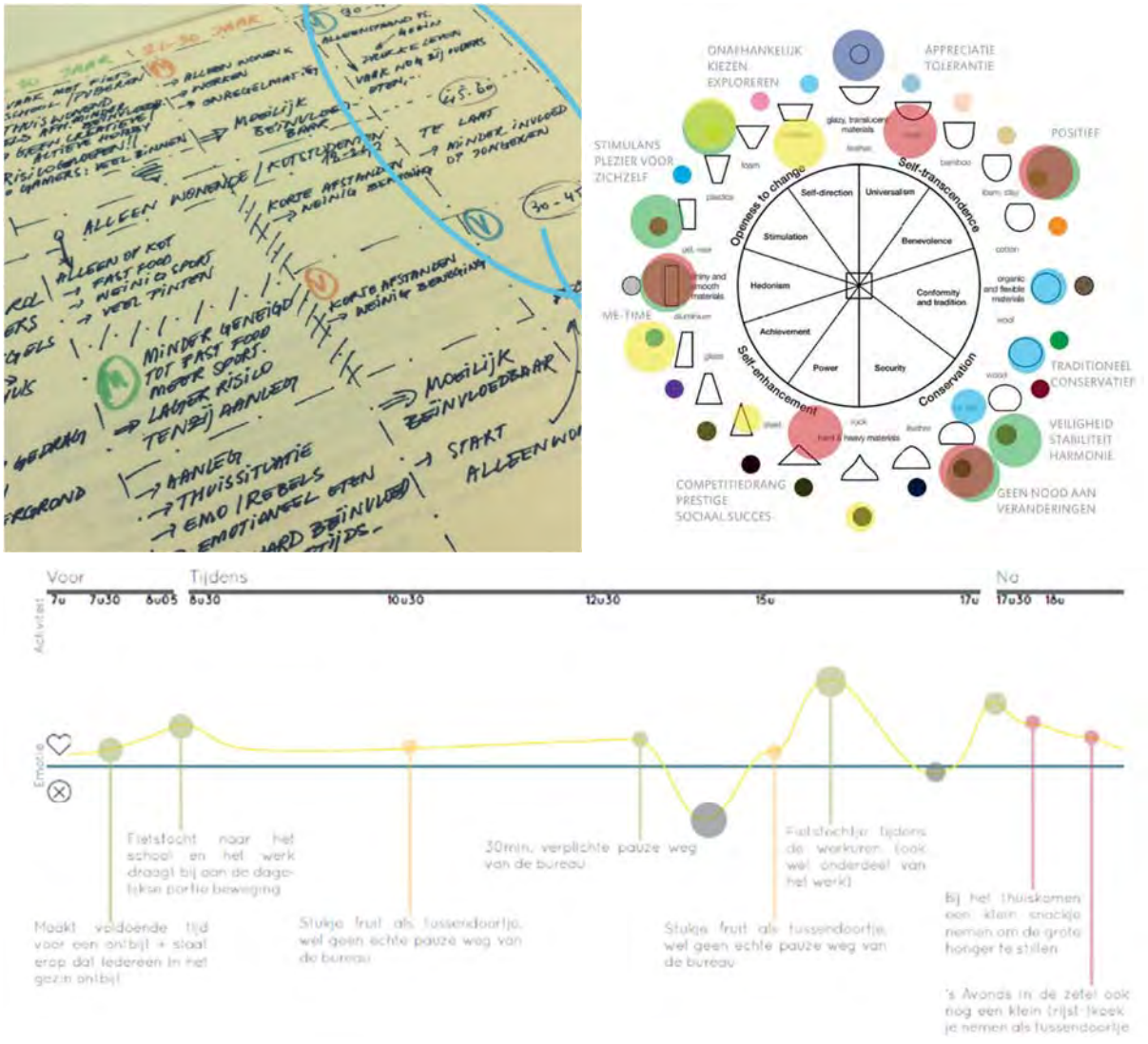


Figure 6.9 | (upper left) interview analysis adopted from PSS Design and Strategic Rollout (Dewit et al., 2018) | (upper right and lower) interview analyses from the IPO Course: Integrated Systems at UAntwerpen

6.4.2.5 INTERVIEWING THE EXPERIENCE (TEMPLATE)

What | Experience interviews are a way to understand the current experience of the stakeholders within the actual system. You want to find out about current experiences, the different steps in the experience, needs, motives, feelings, underlying drives and fears.

Why | Ultimately, you want to find patterns and underlying drives. Based on these, you can draw a framework for the further development. You gather insights by talking with your target users about the current context of your future product-service experience. You also want to check if your assumptions (hypotheses) are correct.

How | Use the same technique as for preparing the interview questions. Ask the interviewee to tell you about their experience (in the context of your PSS), from start to finish. This can be about the experience during a whole lifetime or during a particular event. Write down for each step which touchpoint is used (website, other person, building, object, etc.). Specify the user experience at every moment together with the interviewee: Which activities were conducted? What was the trigger? What was the objective? How positive or negative was the experience? What was the main feeling at each step? Let the stakeholder draw the experience by means of a curve. Once you have detailed the experience, look at the most extreme moments (positive or negative). Ask why this was such a positive or negative experience. Ask several times (why), this is how you reach the heart of the matter. Write the underlying reasons on the template so that your interviewee can read and react on them.

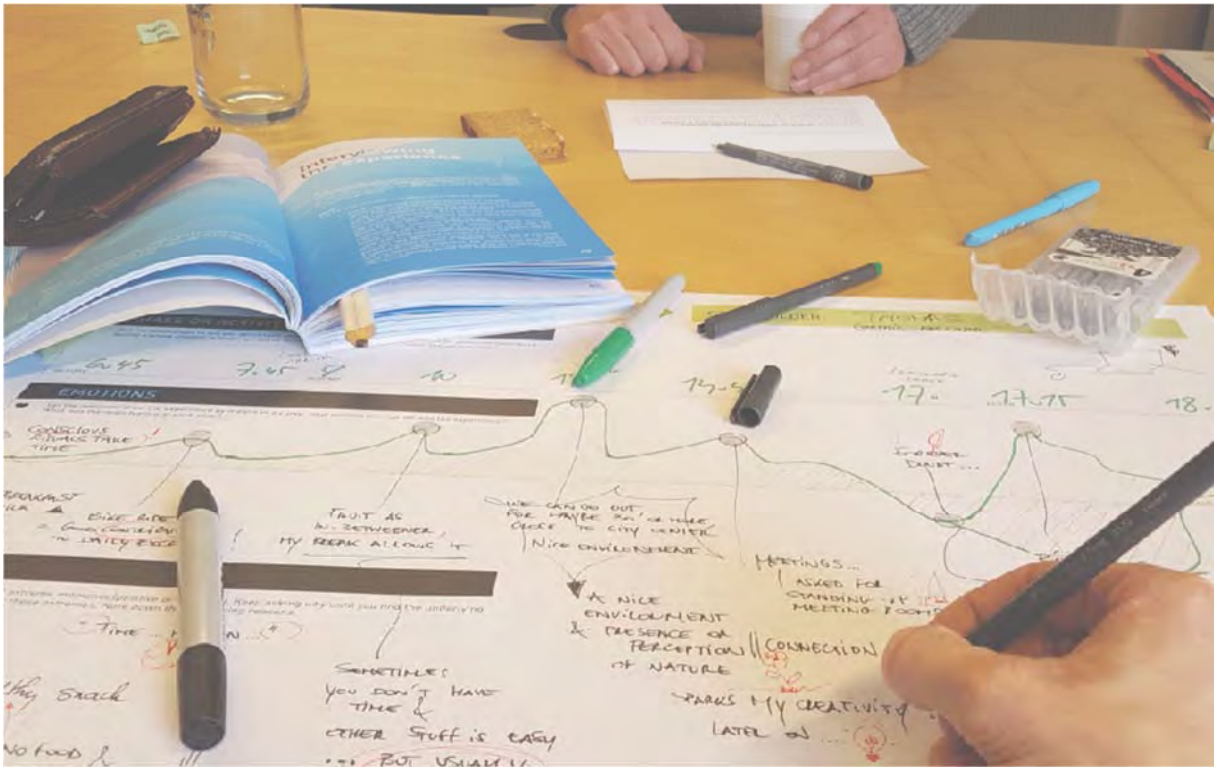


Figure 6.10 | Interview (example) from the IPO Course: Integrated Systems at UAntwerpen

Originally adopted from the Service Design Toolkit: www.servicedesigntoolkit.org

6.4.3 UNDERSTAND // REFRAMING

6.4.3.1 PERSONAS (TEMPLATE)

What | Personas are fictitious stakeholders in the system, your paper users.

Why | Personas help you get under the skin of your stakeholders and, in the later phases, to design the solutions from the various perspectives. They are especially useful to communicate your user insights to team members that were not involved in the field study or to clients and stakeholders that you want to involve in future workshops.

How | Start from the *stakeholder dimensions* and select the most diverse profiles.

Make a portrait for each of the profiles by giving them a face, a name and a context. Limit yourself to information that is relevant to the project. List the characteristics you indicated with the *stakeholder dimensions* tool. Refine with additional insights from the interviews. Describe the experience of your persona in the context of the product-service system. What are their immediate and long-term objectives, both rational as well as emotional? What is their attitude toward the issue? Build on the insights you have captured during the interviews and the themes you defined. Add a quote that summarizes the attitude and feeling of your persona toward the system. Do not make too many personas: it is most important to capture the different attitudes toward the issue.

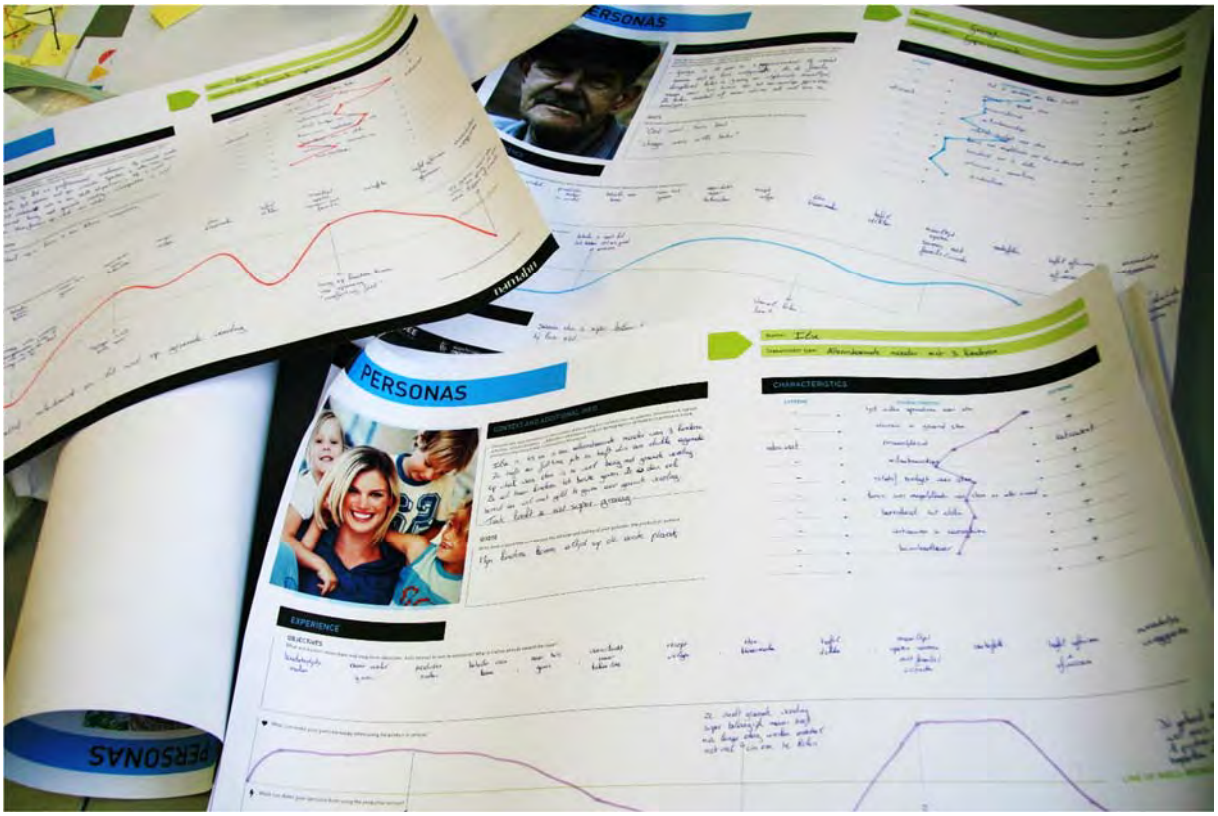


Figure 6.11 | Personas from the IPO Course: Integrated Systems at UAntwerpen

Originally adopted from the Service Design Toolkit: www.servicedesigntoolkit.org

6.4.3.2 FACTORS AND THEMES

What | Factors are the elements contributing to a particular result or situation. Themes are the drivers of the patterns of human behavior.

Why | You want to explore the contributing factors and find patterns and themes behind them. This will help you to create a response to the problematic situation.

How | Look back at your interview notes and spot the main tasks and activities and the needs, motivations and drives associated with them. Continue by looking at the problems and identifying underlying causes. Conclude with feelings, fears and perspectives. Write everything on post-it notes.

Complement your *interview* findings with economic, societal and technological developments (e.g., aging population, personal robots) and trends (e.g., self-monitoring) in the context of your topic. Cluster all factors on a wall and try to find the hierarchy within each of the clusters (something can be a sub-factor of something else). Look at all the factors and draw the relations between them. Identify the most influencing factors and relationships and give them a theme name. Use the *value proposition* tool to find the deeper themes behind them.

For more inspiration, read Frame Innovation: Create New Thinking by Design (by Kees Dorst) (Dorst, 2015).

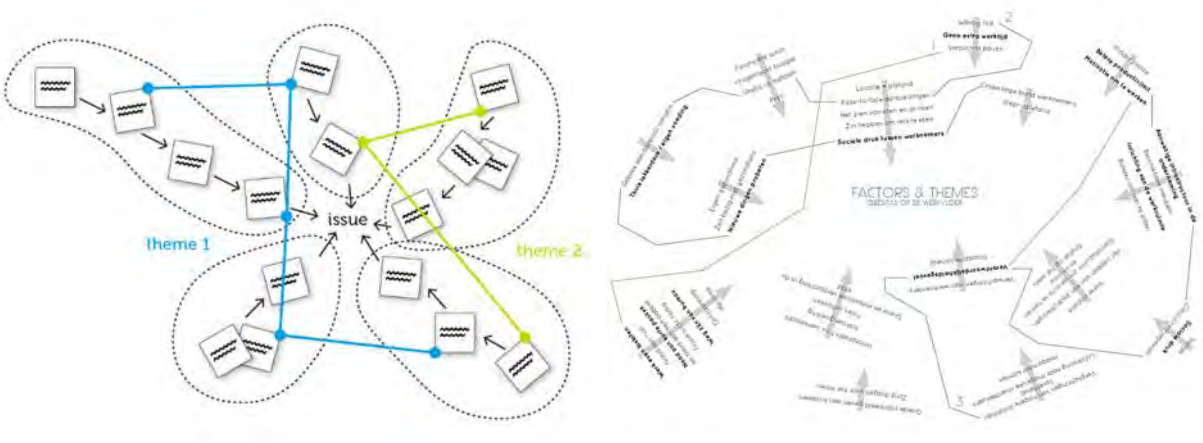


Figure 6.12 | (left) Factors and themes adopted from PSS Design and Strategic Rollout (Dewit et al., 2018) | (right) factors and themes from the IPO Course: Integrated Systems at UAntwerpen

6.4.3.3 SYSTEM MAP (TEMPLATE)

What | A system map is a tool for understanding the system, its structure, the interrelations between the elements of the system and the things that flow in the system.

Why | You make a system map to discover the leverage points in the system. Besides this, a system map is also a useful tool for developing a shared understanding between the stakeholders about the complexity of the system and the interdependences and causal relationships between the variables.

How | First decide if you want to solve the issue (or unwanted result) of the current system or instead rethink the whole system by rephrasing its purpose.

Start drawing your map by defining the core of the system. Identify the core activities or the raison d'être of your ideal system if you work with the purpose. It helps to use a metaphor to define them. Define what variables influence the core. They are typically related to the five capitals: natural capital (energy and resources), human capital (health, skills, motivation, etc.), social capital (relations, collaboration), manufactured capital (goods and infrastructure), financial capital (currency, shares, etc.), and the rules that govern them. Draw the relations between all elements on the map. Mark relations that are substantially reinforcing and indicate if they reinforce each other in the same (S) or opposite (O) direction. If applicable, indicate delays in the system. Identifying the leverage points - these are the nodes with the most arrows leading to or from them and most connected to the core. If you can change them, you will most probably have an impact on the system.

For more inspiration, read Frame Innovation: Create New Thinking by Design (by Kees Dorst) (Dorst, 2015).

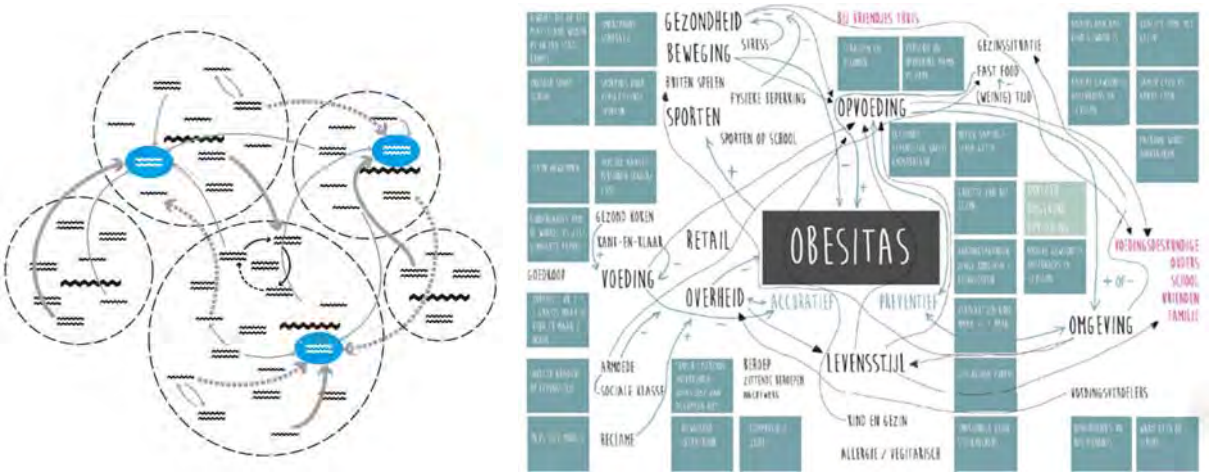


Figure 6.13 | (left) System mapping adopted from PSS Design and Strategic Rollout (Dewit et al., 2018) | (right) system mapping from the IPO Course: Integrated Systems at UAntwerpen

6.4.3.4 VALUE PROPOSITION (TEMPLATE)

What | The value proposition is a tool to make your value proposition explicit and to agree on how to make value for people, organizations and society at the same time, as well as from the perspectives of economics, psychology, sociology and ecology.

Why | You want your innovations to be as meaningful as possible, by preparing your workshop participants to generate ideas that bring benefits to all the involved stakeholders.

How | The tool can intervene in different moments of the design process. Once the values (potential benefits) for the target users are clear, you want your stakeholders to understand the benefits for the other levels: organization, ecosystem and society (e.g., core values of the organization, shared values of the business ecosystem and value for society as a whole).

You generally use the tool after *factors and themes*, where you understood the factors that underlie the needs, motivations and experiences of the 'players' in the context. Thus, this tool enables you to deepen the themes and capture the underlying phenomenon of the situation, seeking meaning in the realm of universal values. The Value Framework by Elke den Ouden (Innovation design, 2011) offers a great deal of insight on the terminology (definitions, models and concepts) on value(s), we suggest further reading is necessary for an understanding the deeper layers of meaning that underlie human behavior (den Ouden, 2012).

This tool also enables the connection between the *system map* and the future *intervention strategy*, to make sure the stakeholders embrace collective benefits when formulating the *design challenge* to start ideation. Stick the template to the wall and look at the themes/leverage areas from the previous phase. Identify the values for the user in the four dimensions (economic, psychological...), write them on post-its and stick them in the center of the poster. Now look at the other levels, and identify the potential benefits that you want to achieve for the single organizations, the ecosystem and society as a whole.

For more inspiration, read Innovation design: Creating value for people, organizations and society (by Elke den Ouden) (den Ouden, 2012).

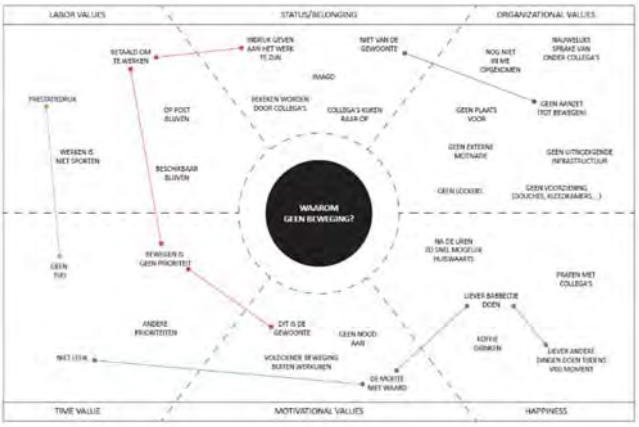


Figure 6.14 | (left) Value proposition adopted from PSS Design and Strategic Rollout (Dewit et al., 2018) | (right) value proposition from the IPO Course: Integrated Systems at UAntwerpen

6.4.3.5 RICH PICTURES

What | A rich picture is a pictorial, cartoon-like representation of everything you discovered up to now.

Why | You want to present your analysis to the client or you want to inspire the design team that will work on the solution. You can also make the picture in a workshop with your client and stakeholders to encourage discussion, interaction, and to attain a holistic understanding of the issue. Note: It can also be useful to update your *system map* at this stage.

How | There is no one particular way to make rich pictures but if you do not know where to begin, the following sequence may help to get you started:

Look for the elements of structure in the situation (these are the parts of the situation that change relatively slowly over time and that are relatively stable; the main stakeholders, the places, the hierarchy and the dependencies). Next, you look for elements of process within the situation (these are the things that are in a state of change: the activities that are going on). Then look for the ways in which the structure and the processes interact. Doing this will give you an idea of the climate of the situation. That is, the ways in which the structure and the processes relate to each other. Within the situation, look at the social roles that are regarded as meaningful by those involved, and look at the kinds of behavior expected from people in those roles. If you see any conflicts, indicate them.

Based on the guidelines of www.Sysweb.open.ac.uk

For more inspiration, read Soft Systems Methodology (by Peter Checkland) (Checkland & Poulter, 2010).

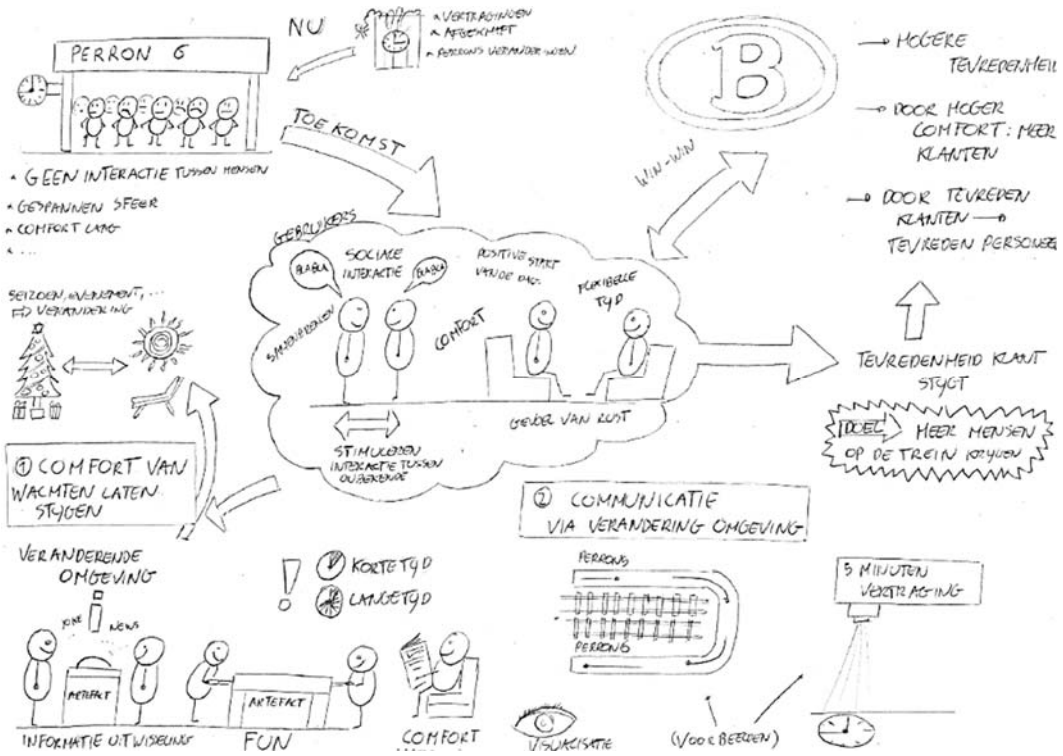


Figure 6.15 | Rich picture adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.4.4 UNDERSTAND // PROBLEM DEFINITION

6.4.4.1 INTERVENTION STRATEGY (TEMPLATE)

What | The intervention strategy is a method to help you to understand how (on which levels) you can intervene in the system.

Why | There are multiple ways to intervene in a system and a solution should always be a combination of interventions. The intervention strategy template helps you to see the spectrum of possibilities in a workshop together with your client and stakeholders.

How | Start to familiarize yourself with the intervention levels (12 categories of leverage points, in ascending order of effectiveness).

For more information, read: Leverage Points: places to Intervene in a System (by Donella Meadows) (Meadows, 1999).

Look back at the issues and leverage points you defined in the *system map* and discovered during the *observations* and *interviews*. Answer the questions under each intervention level category from the perspective of your *personas* (use post-its). Ideate on ways to modify the current approaches, they should lead to an adequate outcome or benefit for all stakeholders/personas. Decide which interventions you take along based on feasibility, impact and momentum. Input for *design challenge*.

12. **Numbers**: Constants and parameters such as subsidies, taxes, and standards.
    E.g., Water flow can be blocked, drops or with the force of a fire hose.
11. **Buffers**: The sizes of stabilizing stocks relative to their flows.
    E.g., Keeping money in the bank rather than living from the flow of change through your pocket.
10. **Stock-and-Flow Structures**: Physical systems and their nodes of intersection.
    E.g., Physical arrangement of roads, traffic lights, speed limits and its effects on pollution.
9. **Delays**: The lengths of time relative to the rates of system changes.
    E.g., How long it takes between the birth of a child and the time when that child is ready to have a child.
8. **Balancing Feedback Loops**: The strength of the feedbacks relative to the impacts they are trying to correct.
    E.g., Self-correcting nature of the human body to maintain temperature, the ability to sweat or shiver.
7. **Reinforcing Feedback Loops**: The strength of the gain of driving loops.
    E.g., Rich people give their kids inheritances (more money, more interest) and good education (on and on).
6. **Information Flows**: The structure of who does and does not have access to information.
    E.g., Companies drop their emissions because of a 'corporate shame' list and they want to get off it ASAP.
5. **Rules**: Incentives, punishments, constraints.
    E.g., Suppose the students graded the teachers, suppose there were no degrees … leave when learned.
4. **Self-Organization**: The power to add, change, or evolve system structure.
    E.g., Technical advance or social revolution, adding wings or computers, testing with DNA …
3. **Goals**: The purpose or function of the system.
    E.g., "Ask not what your government can do for you, ask what you can do for your government".
2. **Paradigms**: The mindset out of which the system - its goals, structure, rules, delays, parameters - arises.
    E.g., Nature is a stock of resources to be converted to human purposes. One can "own" land?!
1. **Transcending Paradigms**: The power to go beyond the paradigm of the system.
    E.g., Stay flexible, no paradigm is "true", and if so … choose whatever to help achieve your purpose.

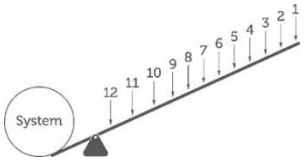


Figure 6.16 | intervention strategy adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.4.4.2 DESIGN CHALLENGE & REQUIREMENTS (TEMPLATE 1 & TEMPLATE 2)

What | A design challenge is a (re-)formulation of your problem based on all the insights that you have gathered. You decide where you want to focus on, and you formulate what you wish to design in a single, clear sentence.

Why | You want to define and explore the problem(s) or challenge(s) to solve in the next phases.

How | Formulate the objectives of your PSS based on all the insights that you have acquired in the previous steps. Phrase this as a design challenge. Usually it is in this order: How can we, for these users, do this (verb), with what and who, to achieve what.

Write the "who", "does what", "with what" and/or "with who", "to achieve" in the boxes in the middle of your design requirements tool template. Think about how specific requirements (context, interaction, product, service, rational and emotional) in the boxes above and below will address this challenge. List the eight most important requirements, which would make the most difference if you offered a good answer to them. Use *paradoxical thinking* in the next step to find and sharpen the requirements.

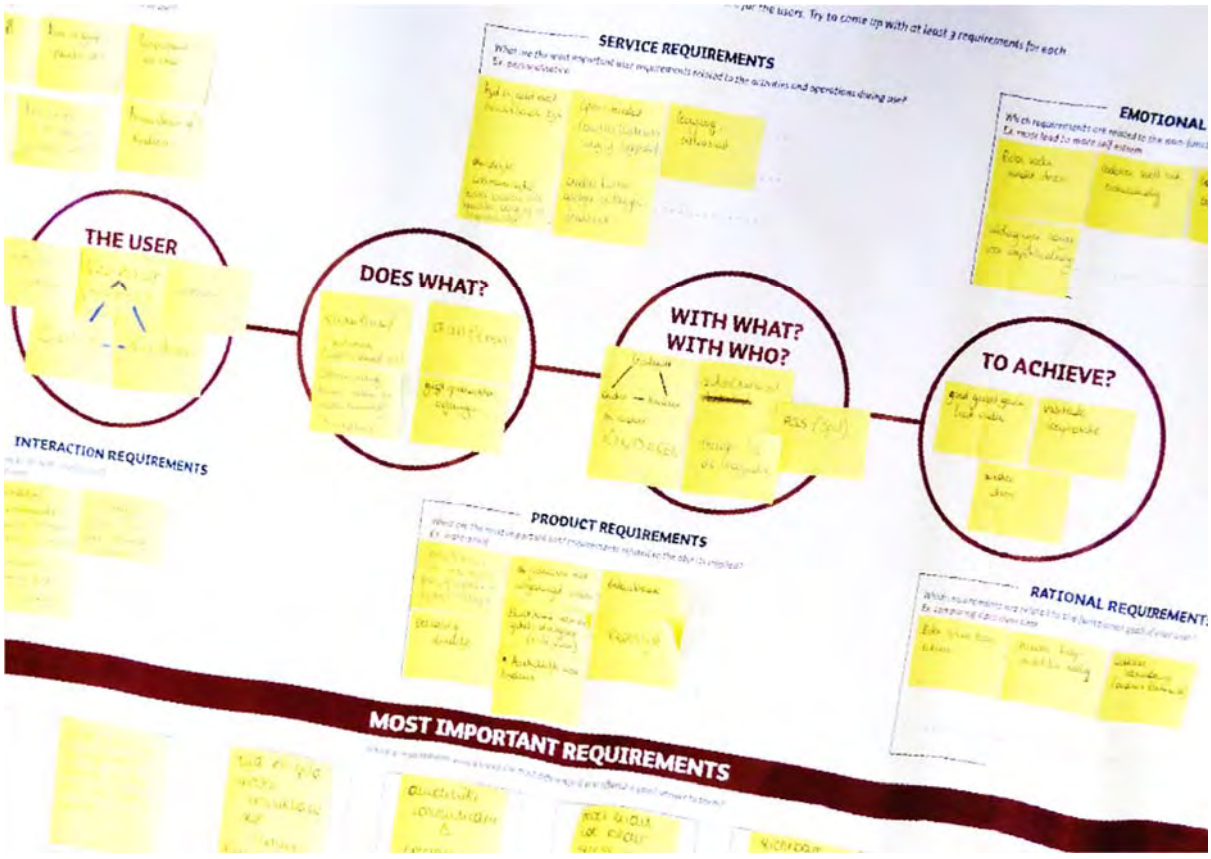


Figure 6.17 | Design challenge & requirements adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

Originally adopted from the Service Design Toolkit: www.servicedesigntoolkit.org.

6.4.5 OUTRO UNDERSTAND

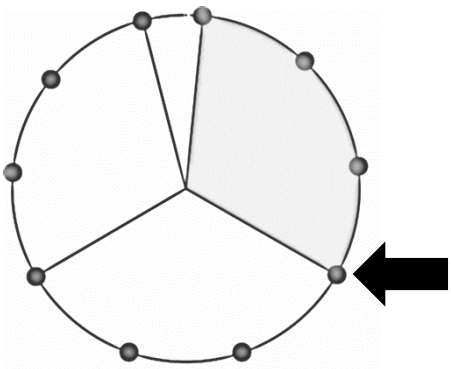


Figure 6.18 | PSS design process - level Understand | Explore

When arriving at the end of this PSS design process stage, the prior information should be apt, to identify (together with stakeholders) the multiple ways (levers) on how to intervene in the system. If agreed upon, this sets the start to a (re)formulation of a clear design challenge (of the problem/opportunity) - a first convergence - based on all gathered insights and focus on “who does what, with what/who to achieve …”. Because of the deep understanding of the system, context, interaction, rational, emotional and (non-) technical requirements should come out easy, the perfect starting point for exploration.

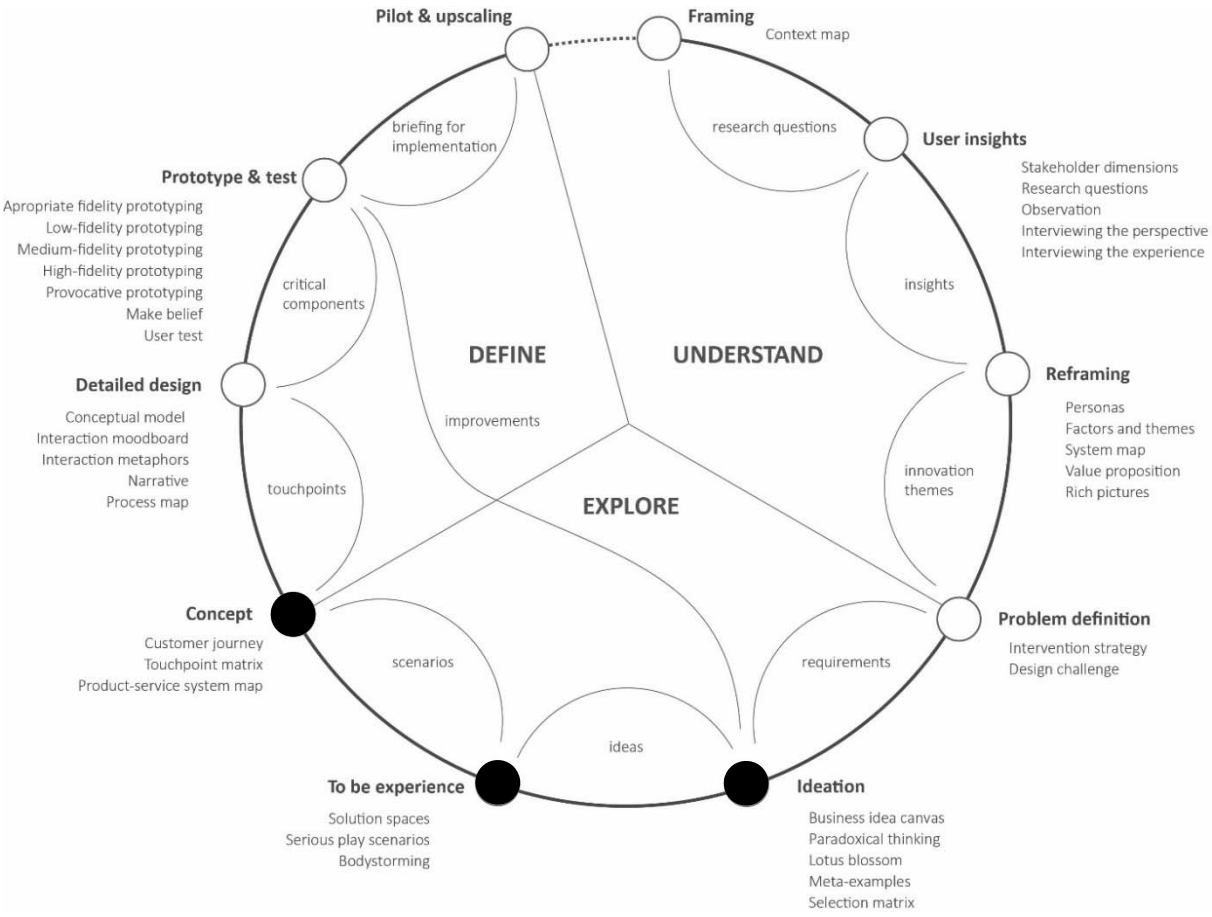


Figure 6.19 | PSS design process - level Explore

EXPLORE

The design challenge and its requirements set ground for explorative purposes. Different (stimuli) techniques are provided to generate a large amount of opposites, alternatives and inspirational input in order to achieve solutions for the whole and its sub-challenges (functionalities it should offer to respond to user and client goals). It is about AND thinking instead of OR thinking, consciously generating unusual viewpoints enables you to ideate on the extremes (the opposite of one truth may very well be another profound truth). Sometimes metaphors help to understand unfamiliar design problems and find a large quantity of solution ideas by juxtaposing them with known situations from other domains, cultures or systems. Simple questions can even bring you to finalizing the ideation, e.g., Who else - besides your users and client - could benefit from your solution? Can you build new products/services around your basic offering that enhances the experience or creates value for the whole eco-system? What can you do with the generated data?

The requirements of the first phase have built-up evaluation criteria for discussion, a second convergence on the relative importance of each idea, bringing those ideas to the surface that have the most impact on the user and value for the client to proceed. Narrowing down opens up a refined exploration of the playground of your future solution, different scenarios and their underlying business model will emerge. This will enable you to understand the consequences of your choices on the (front- and backstage) interaction with product, service and resulting overall experience. By creating the future user and stakeholder environment, you can easily see them (re)acting to the events as if they were real. As you stage the choreography, you might need to adapt situations, with better ideas derived through thinkering and immersing in the relationships between people, their physical location and the things they use in that environment. Seriously, play with Lego, body storm or whatever is needed to give you the necessary input for the elaboration and third convergence into your one future concept.

6.4.6 EXPLORE // IDEATION

6.4.6.1 BUSINESS IDEATION CANVAS (TEMPLATE)

What | The PSS business ideation canvas is a tool to incorporate business model thinking in the ideation phase, with possible extension into IoT.

Why | In the ideation phase you should not only look at the user experience but also at ways to create value for your client. The purpose of the PSS business ideation canvas is to make sure the business value emerges from your concept instead of added afterward.

How | Start by mapping out your opportunity space (the drives, needs and goals of your users and client; list the key capacities of your client's organization, its ecosystems, the context of use; external opportunities and limitations; technological possibilities).

Combine the above into ideas, start from your product component, what functionalities should it offer to respond to your users' and client's needs, drives and goals? Who else, besides your users and client, could benefit from your solution? Do they need extra functionalities? Can you build services around your basic offering that enhance the experience, and create value for the whole ecosystem? What can you do with the (meta)data generated and co-created by the users and the 'things'?

Figure 6.20 | Business ideation canvas adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.4.6.2 PARADOXICAL THINKING

What | *Paradoxical thinking* is the process of consciously bringing together the paradoxical sides of a problematic situation to achieve solutions for the whole. It is about AND thinking instead of OR thinking.

Why | *Paradoxical thinking* generates unusual viewpoints, leading to a better and broader understanding of the true nature of a particular problematic situation or opportunity.

How | Look back at the *system map*, the themes, the *design challenge* and the *requirements* and spot the paradoxes: the situations that seem contradictory or conflicting. Ideate on the extremes—separately or combined and combine the solutions for both extremes into your concept.

For more information, read: Design Problems and Design Paradoxes (by Kees Dorst) (Dorst, 2006).

Figure 6.21 | (left) Paradoxical thinking from the IPO Course: Integrated Systems at UAntwerpen | (right) paradox cards (by Namahn) adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

For more information, read: Paradox cards at www.namahn.com/share/paradox-cards.

6.4.6.3 LOTUS BLOSSOM (TEMPLATE 1 & TEMPLATE 2)

What | The lotus blossom is a creativity technique for finding ideas by means of lateral thinking (original version of this brainstorming technique by *Yasuo Matsumura*).

Why | This technique stimulates the participants to find inspiration by looking at how others fulfil the requirements. It is especially useful when you brainstorm with people that are not used to thinking out-of-the-box.

How | Gather inspiration from state-of-the-art examples from other domains or from your domain.

Write the *design challenge* in the center of the poster. Look at the *design requirements* you defined earlier. Pick the eight requirements that will make a difference if you solve them right (they are most problematic or differentiating from existing offerings). Place them around the design challenge. Find an inspiring example for each requirement. Write the inspiring examples in the boxes further away from the cluster in the center. For each of the examples, think about what makes it perform so well. Combine the characteristics into solution ideas. An alternative way of using this technique (the 8x8 Solution Grid) is to split up your challenge into sub-challenges or sub-functions and to look for solutions in existing systems and other disciplines (see templates).

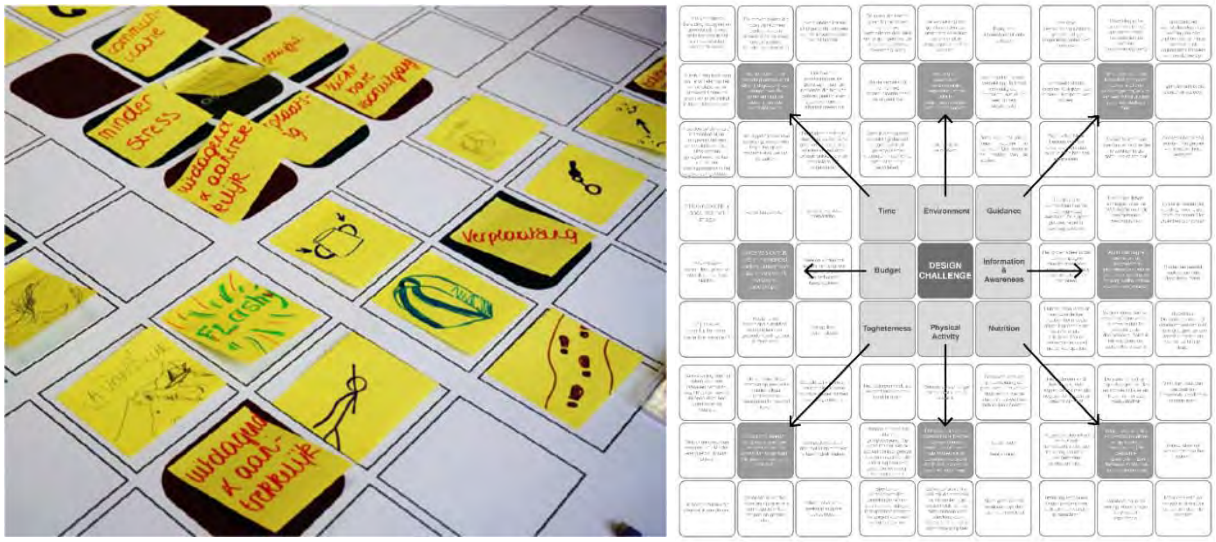


Figure 6.22 | (left) Lotus blossom adopted from PSS Design and Strategic Rollout (Dewit et al., 2018) | (right) lotus blossom from the IPO Course: Integrated Systems at UAntwerpen

Originally adopted from the Service Design Toolkit: www.servicedesigntoolkit.org

6.4.6.4 META-EXAMPLES

What | Meta-examples or metaphors in design are inspiring examples from other domains, cultures and systems (e.g., nature).

Why | Metaphors help designers to understand unfamiliar design problems and to find solution ideas by juxtaposing them with known situations.

How | Look back at to your *factors and themes* and find an inspiring example of a system that addresses this well. For example, if your theme is about creating a better community feeling in a nightlife district of a city you could take the music festival Tomorrowland as a meta-example.

Now look at your *design challenge and requirements* and investigate how your example deals with each requirement. For example, if your requirement is “exchanging contact information” you could find inspiration from the Smart Bracelets, which allow festivalgoers to trade Facebook contact information with the tap of a button. You can also make a mood board of all the ways your requirements are addressed by the example system and use it as a visual reminder during the following steps. Combine visuals with words that describe the values.

For more information, read: Frame Innovation: Create New Thinking by Design (by Kees Dorst) (Dorst, 2015).

6.4.6.5 SELECTION MATRIX

What | The selection matrix is a way to select your ideas. The matrix is especially useful for looking at large numbers of ideas and assessing each idea's relative importance.

Why | To select ideas based on their value for the users and for your client.

How | Draw the matrix and decide on the axes. Typically, it is "value for the user" versus "value for the client" but you can make this more specific: for example, "impact on the user's lives" versus "feasibility for the client", or "impact on all stakeholders" versus "economic value for the client".

Make a list of selection criteria based on your *themes*, *design challenge and requirements*. Make sure everyone has a clear and common understanding of what the criteria stand for. If some decision criteria are more important than others, review and agree on appropriate weights to assign (e.g., 1, 2, and 3 or 0, 1, 3, and 9). Write all your ideas on post-its (one idea per post-it). Determine the number of votes to give by each participant based on the number of ideas and participants (number of votes equals number of ideas divided by number of participants). Let your team members vote on both axes. First let the team members vote individually, otherwise they will influence each other. Bring the votes together on the post-its, sort, and cluster them on the matrix. You can use colored round stickers to mark the different vote types.

The ideas that score best on both axes are of course the most important ones. These should be retained. Ideas that are ordinary for the user but very important to the client should be renewed (can we make this idea more interesting for the user?) Ideas that have a high impact on the user but are of lesser value to the client are to be revised (can we achieve the same goal differently? For example, by involving external parties) or to be put aside for later. COCD *(by Mark Raison)* can assist selection: *www.cocd.org*

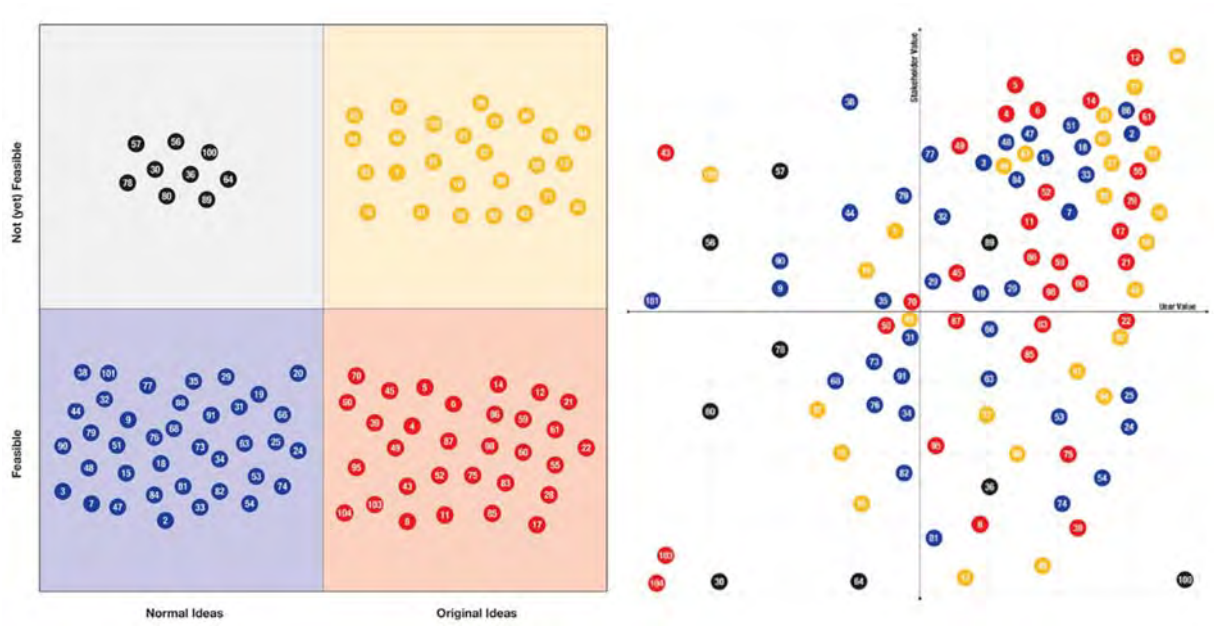


Figure 6.23 | Selection matrices from the IPO Course: Integrated Systems at UAntwerpen

Originally adopted from the Service Design Toolkit: www.servicedesigntoolkit.org

6.4.7 EXPLORE // TO BE EXPERIENCE

6.4.7.1 SOLUTION SPACES (TEMPLATE)

What | Solution spaces is an exploration of the "playground" of your future solution. You do this by playing around with the specific characteristics regarding the PSS and its related business concept.

Why | Before you decide on your final solution, you want to create a range of different PSS scenarios and underlying business concept in a more structured way to and understand the consequence/influence of your choices on the interaction with product, service and resulting overall experience.

How | Look back at your defined *themes* and their *value propositions.*

Explore the potential for both your users as for your client by playing around with the PSS dimensions. Start with the predefined ones on the top of the template and add your own. Decide on three sets of solution approaches by connecting them vertically. Make the sets as distinct as possible. Describe and visualize each approach. Evaluate each approach. Now combine the best ideas of each approach into one final approach.

More inspiration on the template has been derived from research on product-service spaces, PSS characteristics, strategies, pathways and component distribution (Deckmyn, Leyssens, Stouthuysen, & Verhulst, 2014; den Ouden, 2012; Dewit & De Roeck, 2014; Kim, Kim, & Roh, 2015; A. R. Tan & McAloone, 2006; Tukker & Tischner, 2004; Valencia et al., 2015),

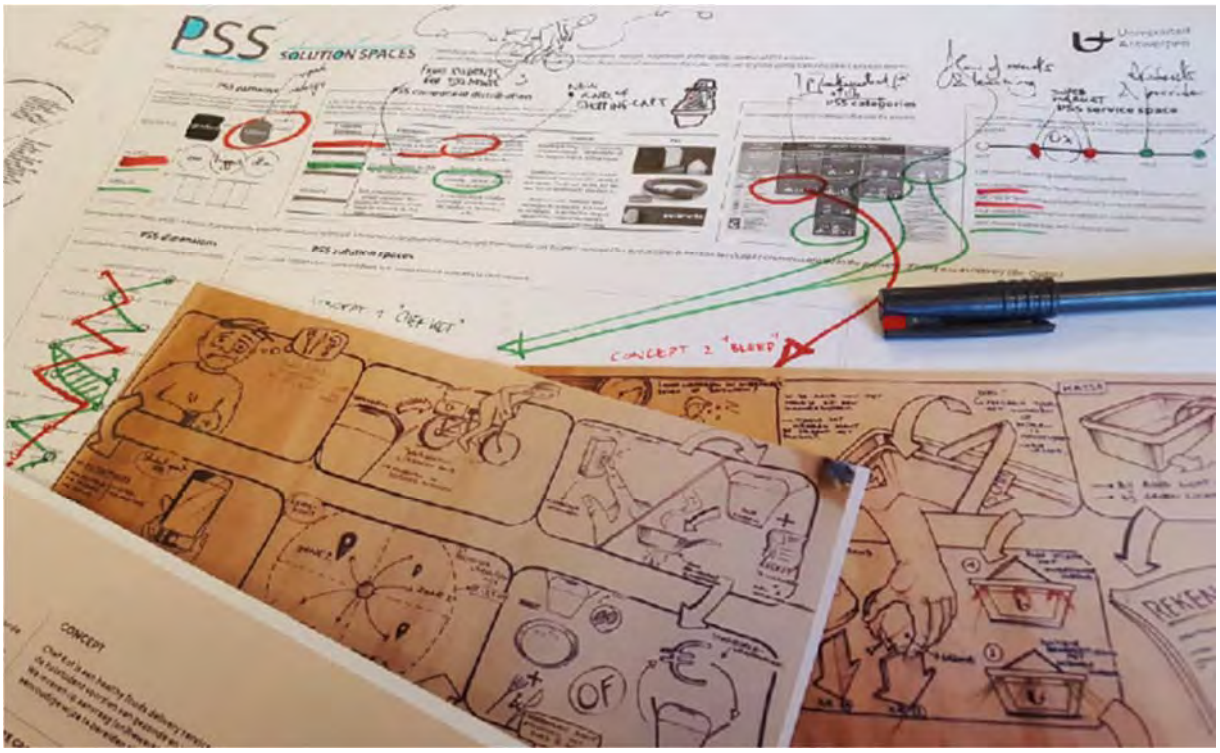


Figure 6.24 | Solution spaces adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.4.7.2 SERIOUS PLAY SCENARIOS

What | Serious play scenarios is a technique to connect your ideas into scenarios for the future user experience. You do this by thinkering (thinking and tinkering) and role-playing.

Why | By role playing you'll find ideas that you hadn't thought of because the technique encourages you to think from a user's standpoint and to go through all the steps.

How | Look at all your ideas and create the future users' and other stakeholders' environment and artefacts from Lego, Play-doh, paper, etc.

Look back at the user types you defined with the *stakeholder dimensions* tool and choose Lego or Playmobil figures for each user type. Add figures for the other stakeholders involved. List major steps the user or other stakeholders goes through. Start with the activity before the main action (e.g., noticing your offering) and stop with an activity after the PSS usage (e.g., receiving a mail with upcoming offerings). Role-play the whole product-service from start to end. How would the characters act and react to the events if they were real users? As you play, adapt the product-service system as soon as you run into problematic situations or get new, better ideas. A nice way to do this is to let the person who addresses the situation or has the new idea take over the Lego piece and play until someone else has a better idea. Role-play the whole journey the user goes through when they use the product-service system, repeatedly. Document the best parts of the scenario by taking pictures and notes (on post-its) or by drawing a storyboard.

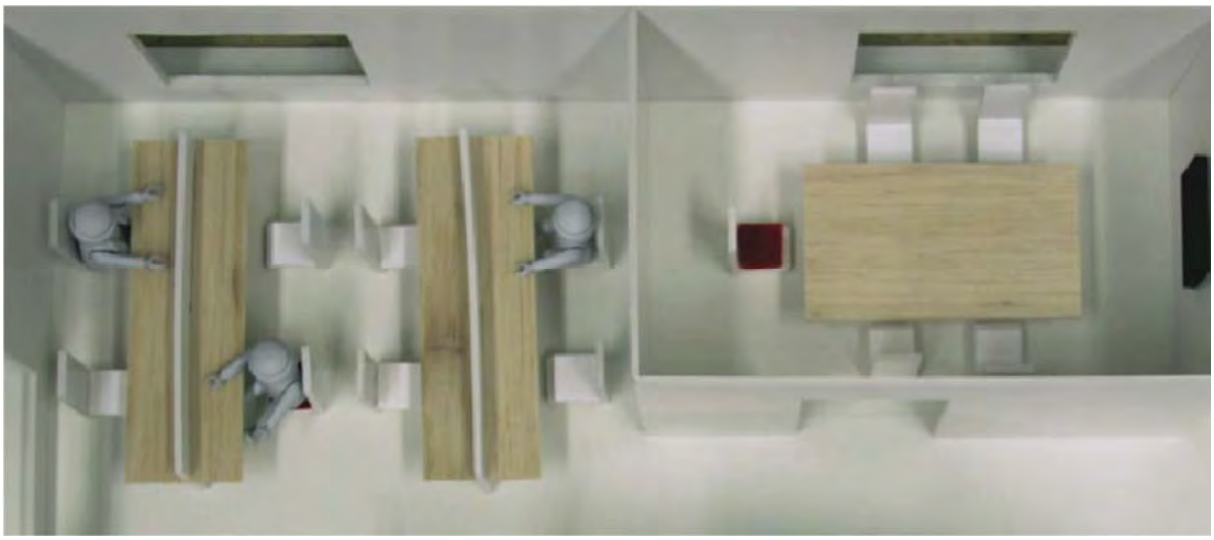


Figure 6.25 | Serious play scenario (screenshot) adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

Originally adopted from the Service Design Toolkit: www.servicedesigntoolkit.org

6.4.7.3 BODY STORMING

What | Body storming is an immersive ideation method for exploring scenarios through roleplay and physical interaction with props, prototypes, actual products and physical spaces.

Why | The overall goal of body storming is to understand the relationships between people, their physical location, and the things (e.g., tools, devices, materials) they use in that environment.

How | Get a small group together for the body storming.

Define the locations where a product or service will be used. Visit those locations and observe how people interact. Watch how people interact with each other and the artefacts in their environment. Develop the prototypes and props that you need to explore an idea. You can do this cheap with cardboard, sketches, existing furniture, and whatever else you can find nearby. Identify the roles that are important for understanding your product, service, or environment. Keep in mind that people may play the role of hardware or software as well as the roles of customer, user, or troubleshooter. Role-play different scenarios. Feel free to improvise and role-play new situations and scenarios that emerge from your initial round of body storming. Reflect on the body storming experience. What did you learn? What new questions emerged? You are likely to find new possibilities as well as new challenging problems.

Source: http://dux.typepad.com/dux/2011/04/uxd-method-11-of-100-bodystorming.html

For more information, read: Body storming as embodied designing by Schleicher et al. (Jylkäs & Kuure, 2018; Schleicher, Jones, & Kachur, 2010).

Figure 6.26 | Body storming adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.4.8 EXPLORE // CONCEPT

6.4.8.1 CUSTOMER JOURNEY (TEMPLATE)

What | A customer journey is an overview of the future product-service both from the viewpoint of your end-users and from the service providers. The journeys are looked at in time and through all the various touchpoints. You now combine the scenarios.

Why | You want to bring everything together into one complete product-service concept and eventually, present the solution to your client and to the stakeholders to discuss, improve and validate them. You can also make the customer journey in a workshop together with them.

How | Start from your scenarios and touchpoint ideas.

Take a big sheet of paper and draw four lanes: users' actions, touchpoints, front-of-stage interactions, back-of-stage interactions, and support processes. Horizontally write or visualize the steps of the users and the goals in each step (e.g. finding information). Start before the main action (e.g., the reason to use your PSS) and stop after the main action (e.g., relationship building). Draw all the touchpoints that are involved in that step and write or visualize exchanges between the user and the system (e.g. registration, payment, etc.). Also think about the activities that should happen behind the scenes to make the front-end activities happen (e.g., control identity).

Optional: list the supporting processes in an additional bottom lane (e.g., manage the registration database) thus transforming the customer journey into a blueprint: *www.bridgeable.com*

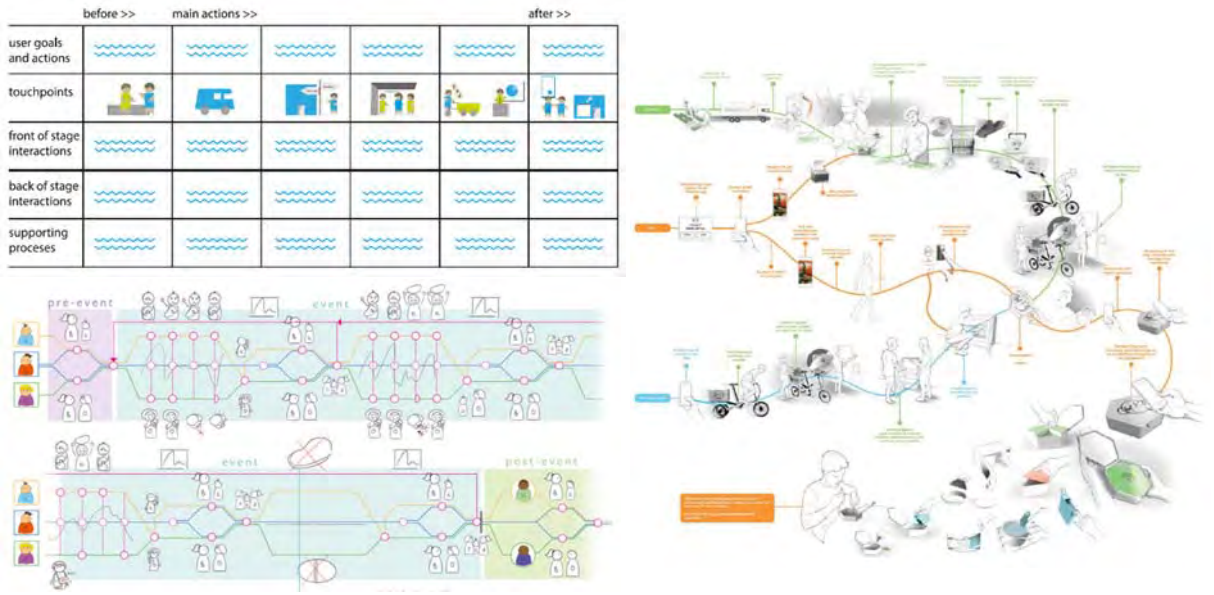


Figure 6.27 | (upper left and right) Customer journey adopted from PSS Design and Strategic Rollout (Dewit et al., 2018) | (lower left) customer journey from the IPO Course: Integrated Systems at UAntwerpen

Originally adopted from the Service Design Toolkit: www.servicedesigntoolkit.org

6.4.8.2 TOUCHPOINT MATRIX (TEMPLATE)

What | A touchpoint matrix is a design tool for analyzing and designing the user experience.

For more information, read: Connecting the Dots of User Experience by Gianluca Brugnoli (Brugnoli, 2009).

Why | The purpose of the touchpoint matrix is to verify and refine your PSS concepts by visualizing the connections between the system and the user.

How | Vertically list the different touchpoints within the *scenarios* you played in the previous step: artefacts (e.g., smart thermometer), digital services (e.g., diagnosis app), physical service (people - e.g., consultation) and contexts (e.g., the doctor's office) that are part of the system. Horizontally list the actions, intentions and values that are supported by the system itself. To find them, look back at the themes and the *design challenge* (objectives, goals, intentions, values). Indicate these intentions with dots in the matrix. Once this structure has been composed, verify it by putting a *persona* or stakeholder inside and imagining their journey through the different touchpoints, connecting the related dots. Use a different color for each *persona journey*. Finally, look at the whole and examine improvements that contribute to more goals? Look at the blanks, do you need more touchpoints? Can you make the system simpler by reducing the touchpoints?

For more information, read: Service innovation through touch-points (by Simon Clatworthy) (Clatworthy, 2011).

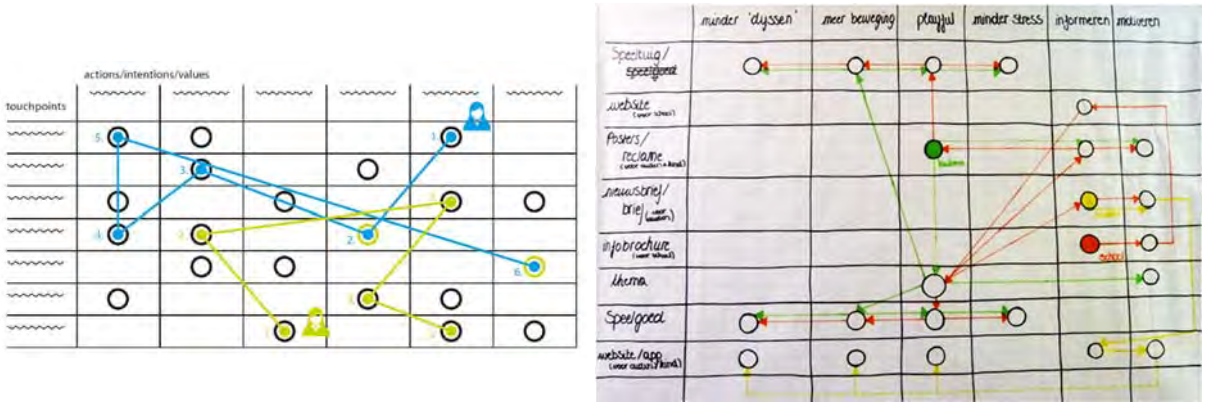


Figure 6.28 | Touchpoint matrices adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.4.8.3 PRODUCT-SERVICE SYSTEM MAP

What | A PSS map is a visual presentation of your future system.

Why | You want to present the system solution to your client and stakeholders to discuss or to validate them. You can also make the drawing in a workshop together with the client and stakeholders.

How | Similar to the *rich picture*, there is not one way to create a (to be) PSS map. Start by mapping out the 'to be' what, who, why, how and where. Indicate, by arrows, the relations between them and specify which values are exchanged (emotional, rational and financial). Point out the new goals of the system. Show which leverage points should change to make the future system solution work.

Establish visual hierarchy—the context of the map should be seen from across the room, the most important from two meters, and the details do not need be readable before you stand close to the map. Visualize, visualize, visualize—this makes it easier to remember both the details and the whole as you are working. It will also help others grasp what you are doing.

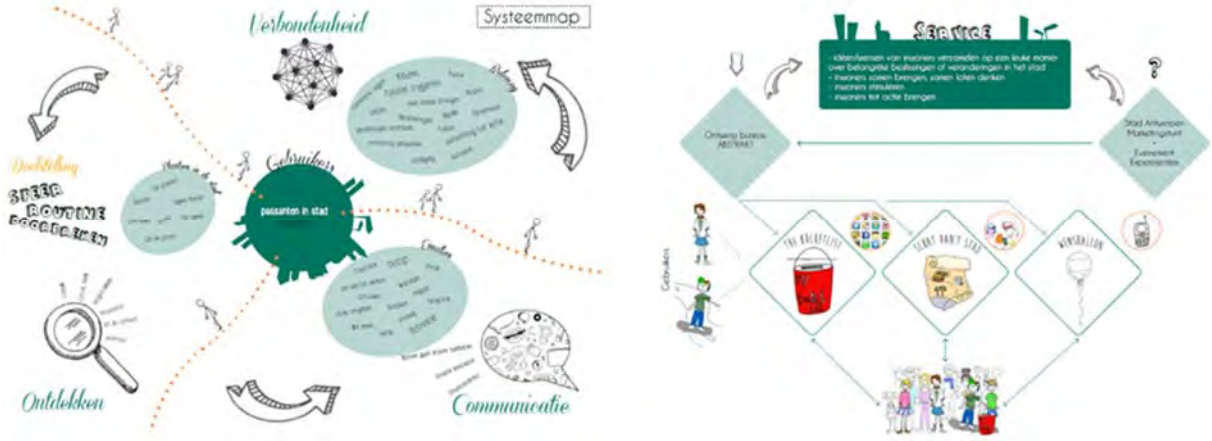


Figure 6.29 | Product-service system map from the IPO Course: Integrated Systems at UAntwerpen

6.4.8.4 OPERATIONAL VALIDATION MATRIX (TEMPLATE)

What | Use the operational validation matrix to assess your solution concept.

Why | You want to verify if you future system is flexible enough to cope with changes in capacity and demand.

How | Start by reflecting on what will influence the demand of the users/customers and the capacity of your solution.

Typical cause of demand variations are: seasonal climate changes; working periods/holidays; moments in the day; accidents, crime and disasters; etc. Typical cause of capacity variations are: stock capacity; manufacturing and delivery capacity; number of employees; breakdowns; etc. For each of the quadrants think about 'what if' scenarios related to your activity model. Identify the process elements that are at stake. Brainstorm to find solutions to the problems. Use the best solution ideas to improve your activity model.

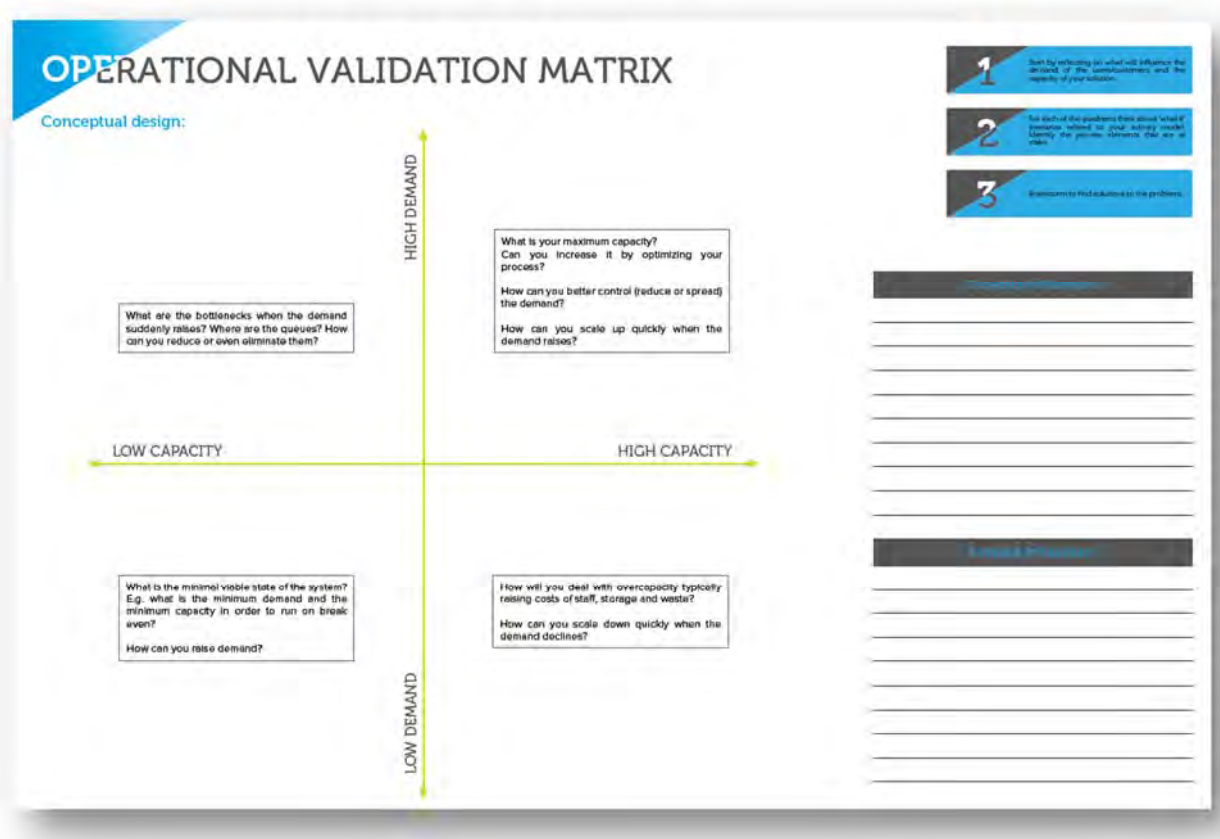


Figure 6.30 | Operational validation matrix adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

Figure 6.30 is the template of the operational validation matrix, this is one out of twenty tools that have been formatted is this manner to create the consistency throughout the toolkit, enable collaboration and communication with all stakeholders.

6.4.9 OUTRO EXPLORE

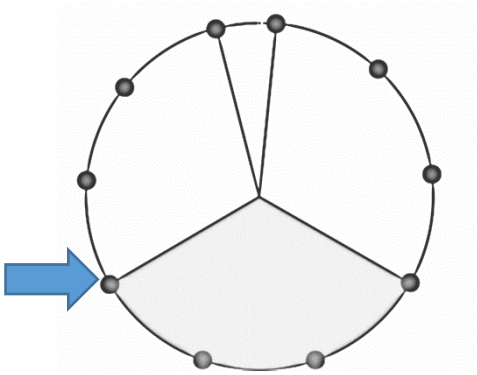


Figure 6.31 | PSS design process - level Explore | Define

Coming up to this point in the PSS design process, the input of your exploration turns into a clear concept and is the beginning for the customer journey, the future viewpoint of (fragmented) interactions between users and the providers of your (PSS) solution. Running alongside each possible / necessary touchpoint enables a matchmaking of actions, intentions and values with different technical and non-technical system-user connections and ultimately their design. A visual representation of your future PSS helps to discuss on operational validity with all stakeholders, a fourth convergence.

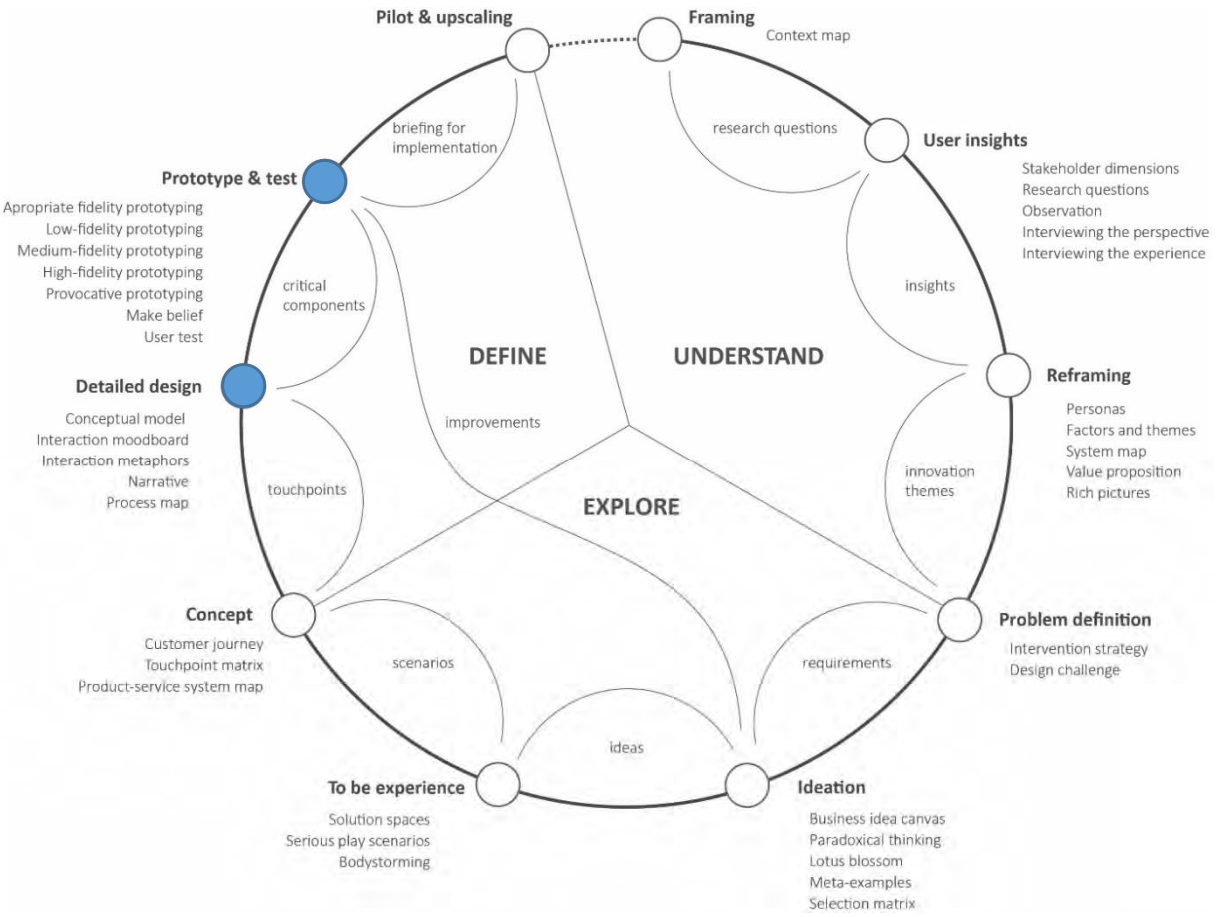


Figure 6.32 | PSS design process - level Define

DEFINE

We now bridge the gap between the current knowledge and the target knowledge of the user (what one has in mind about the product/service, which parts should be understood by whom) through actual design/interaction representation. Visual compositions convey the look and feel of your system, ensuring coherence and consistency over all touchpoints. It gives an identity to novel or unfamiliar system functionalities and a possible entrance point and inspiration for prototyping the products and services in the system. A report of the connected events makes it easier to present the final concept to all stakeholders. Detailed (systematic) level, showing the front- and backstage activities and their related consequences, needed to deliver the product-service.

The goal of designing the critical components with an increasing level of fidelity is to focus on getting a good understanding of a concept's core functionality before moving on to the bells and whistles that might be required. Therefore, appropriate fidelity prototyping is used to question the level of fidelity at every iteration of the concept (some parts can be more detailed than others). Unfinished prototypes make it more clearly to stakeholders that it is work in progress, enabling people to react more freely. Another way is to deliberately prototype products/services to trigger emotions or reactions among the stakeholder group, facilitating conversation about less straightforward topics. Prototypes are learning material, later on they become the showcase of the end-result. If time is not on your side, less intensive methods might be useful (e.g., acting out, service rehearsal, wizard of Oz, role-playing). There is nothing wrong with tricking them to believe it is real. User testing should be to test the PSS with real stakeholders in a context, as real as possible.

6.4.10 DEFINE // DETAILED DESIGN

6.4.10.1 CONCEPTUAL MODEL

What | A conceptual (or design) model is an abstraction of the system, a schematic representation of the concepts a user should understand in order to be able to interact with the system (Weinschenk, 2011).

Why | As a designer you want to give clues to the users about how the system works and how they can interact with it. In other words, you want to help the user in building their own mental model. The touchpoints are evidences of this model.

How | The conceptual model tries to bridge the gap between the current knowledge and the target knowledge of the user, so first, you should get insight into the current knowledge of the user:

What are they used to? How do they see the current system? What will be different? This information is obtained during the previous phases e.g., *user insights, personas, scenarios*, etc. List the main parts and functions of the new system and indicate who should understand which parts. Structure and cluster the concepts the user needs to know and specify links between them so you capture which concepts need to be presented together (e.g., used at the same time, choice between two options, next step, …). Indicate the main interactions and think about how you can build affordance into them. Investigate whether and how the concepts and interactions will evolve over time and adapt your model accordingly.

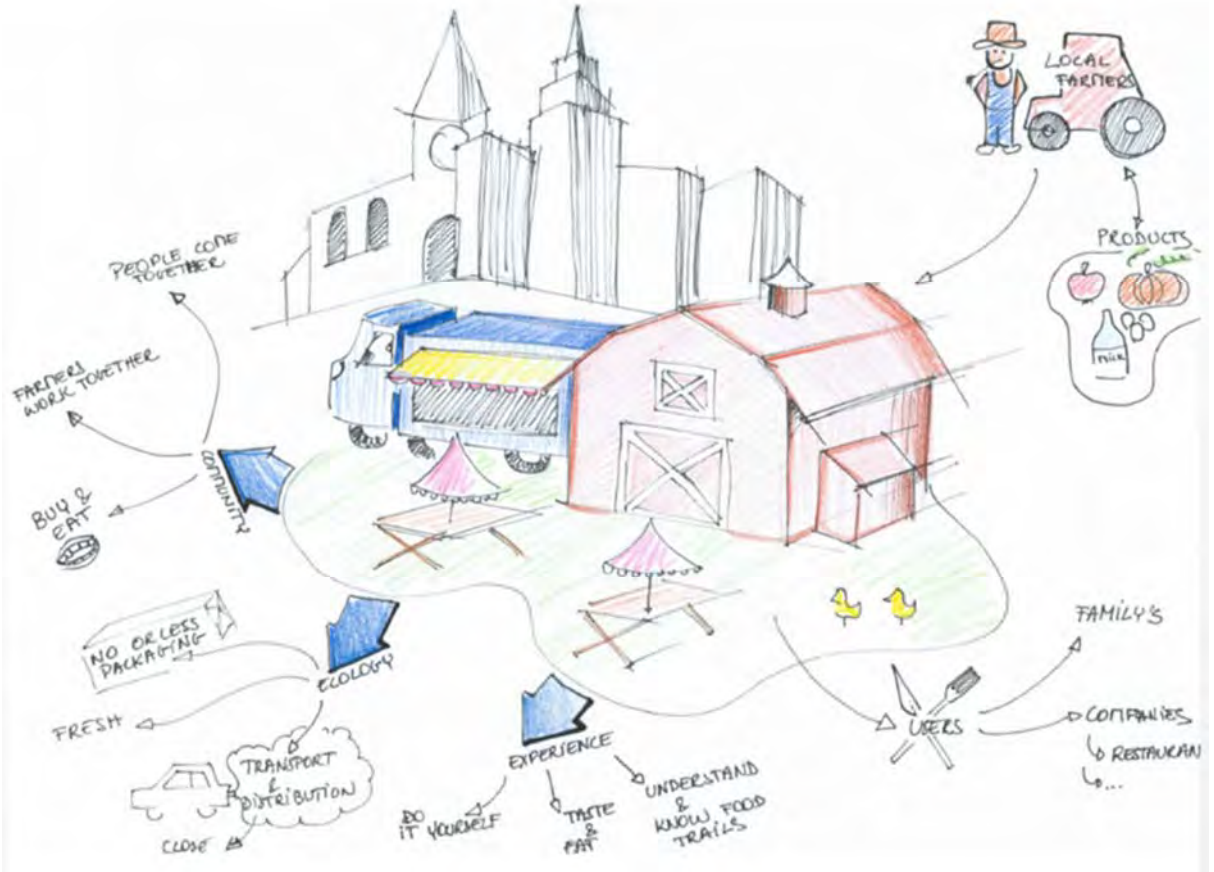


Figure 6.33 | Conceptual model from the IPO Course: Integrated Systems at UAntwerpen

6.4.10.2 INTERACTION MOODBOARD

What | Interaction mood boards are visual compositions of colors, materials, expressions, etc. that together convey the look and feel of your system.

Why | To ensure a coherent and consistent look and feel over all touchpoints, and to challenge your solution to the goal. The interaction mood board inspires your prototyping and the design of your services and products.

How | Look for colors, materials, sounds, light, textures and expressions.

Start by collecting material to describe the Vision of your system.

For more information, read: Vision in Design: A Guidebook for Innovators by Hekkert and van Dijk (Hekkert & van Dijk, 2014).

Myth, Philosophy and Ritual are common for all touchpoints. Every touchpoint serves a different Purpose. Start with images that describe the Vision of your system across touchpoints. Bring everything together in one board. Compare with your *design challenge and requirements* for consistency. Compare with your *rich picture* of the as-is system for deviations. The bigger the contrast, the harder to implement your solution, the further the implementation could move in the future.

Describe the staged context (social, organizational, technical or physical) or setting and the course of action: before, during and after the interaction. Think about the way the following should be represented:

- Function: Practical use or purpose by design
- Affordance: Relation between actors that affords the opportunity to perform an action
- Structure: Arrangement of and relation between the parts
- Form: Particular way in which the touchpoint exists or appears
- Material: Matter and characteristics

Figure 6.34 | Interaction mood boards adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.4.10.3 INTERACTION METAPHORS

What | Interaction metaphors is a technique to explore meaningful interaction models by tapping into the knowledge that users already have of other domains.

Why | Humans use metaphors to understand one concept in terms of another. In design, you use metaphors to provide clues to the users about unfamiliar product-service use, thereby turning a novel interaction into an intuitive and comprehensible one.

How | Make a list of all the system functionalities. Next, identify which are novel and thus unfamiliar to your users.

Generate possible metaphors for each of the unfamiliar functionalities. A useful way to generate metaphor ideas is to ask others (users) what each functionality is like. Make sketches or prototypes of each metaphor and identify what the attributes are that call for interaction. Analyze your metaphor ideas by running task-based and goal-oriented scenarios. Use the interaction metaphor attributes to build affordance into your design.

- *E.g., you want to design a smart wearable by which you can transfer hugging on a distance.*
- *E.g., a door handle is an interaction clue to enter a house (metaphor).*
- *E.g., make the squeezing interaction explicit by using soft materials and textures.*

Figure 6.35 | (upper left and right) Interaction metaphors adopted from PSS Design and Strategic Rollout (Dewit et al., 2018) | (lower left) interaction metaphor from the IPO Course: Integrated Systems at UAntwerpen

6.4.10.4 NARRATIVE

What | A narrative or story is a report of connected events, actual or imaginary, presented in a sequence of written or spoken word and still or moving images.

Why | You want to present your final concept to your client and to the stakeholders.

How | First think about what you want your story to convey:

What do you want your viewers to take away from the presentation? Which part of our solution do we want to emphasize? Make a storyboard. Be aware of the story's beginning, middle and end. Use your *personas* in the story, and make new characters if necessary. Work on your dramaturgy. Dramaturgy is the amount of intensity (excitement or tension) through the story. Remember that all the characters in your story have skills, needs and personal goals. Include a few small but effective details in the way your characters act or look, to help the viewer's relate to the characters and feel that they know the person. Play on stereotypes. If it fits, add some elements of surprise the story to make it all more interesting.

Make a video (stop motion, video sketch, short movie) to present the concept.

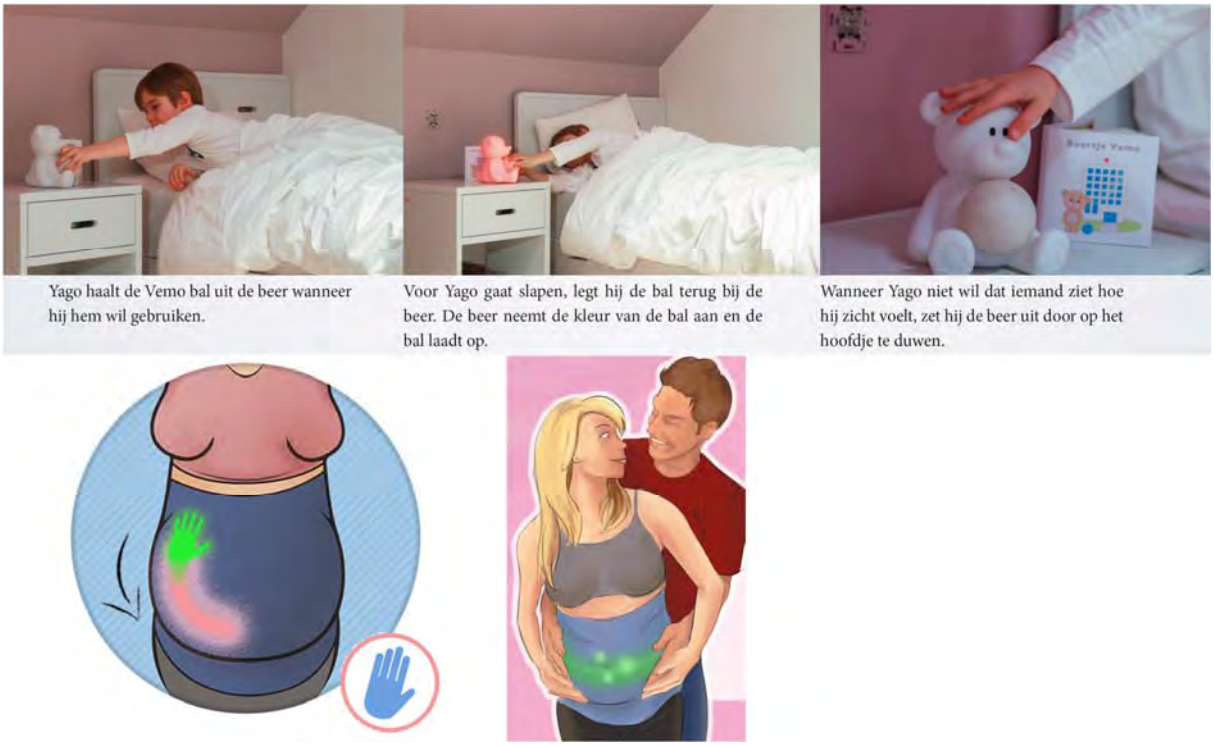


Figure 6.36 | Narratives from the IPO Course: Integrated Systems at UAntwerpen

6.4.10.5 PROCESS MAP

What | A process map (also called process flowchart) is a systematic diagram that shows the activities needed to deliver the product-service.

Why | You want to define in detail what is needed to deliver the product-service, from the business point of view. Once you map out a process, it is much easier to explore the capacity and the limitations of the service and where there might be a problem. Identify the steps that are most time-consuming and that require a recurring investment of resources. This will allow you to clearly define the required investments and the strategy for growth of the PSS. Identify each step that your process needs to function well.

How | Start from your *scenario* or *touchpoint matrix* and write the main steps of the process(es) on post-its. Flowchart them in sequence as they are performed. Use connecting arrows between boxes to represent the direction of the sequence. Estimate for each step what is needed to actually perform the task: Who will carry out the task (e.g., person(s)/role(s), computer, system, etc.)? How much time will this take? What is needed to perform the task (e.g., inputs, tools, environment, etc.)? Identify the bottlenecks, typically caused by capacity and timing issues and improve your process to solve them.

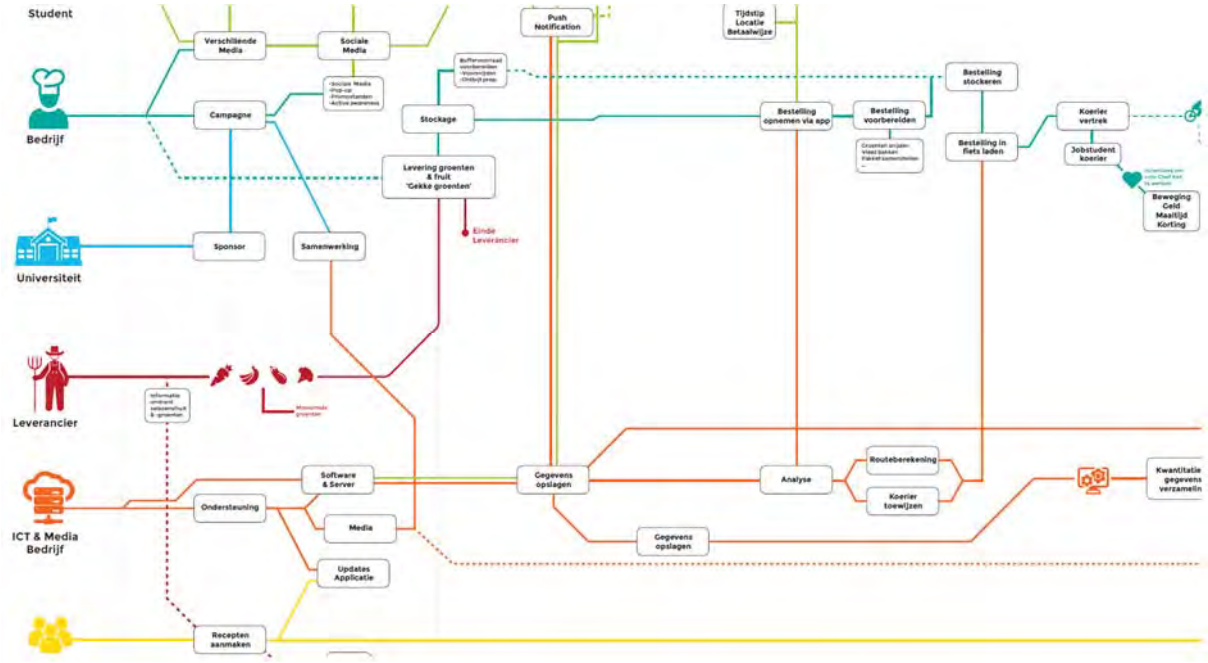


Figure 6.37 | Process map adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.4.11 DEFINE // PROTOTYPING & TESTING

6.4.11.1 APPROPRIATE FIDELITY PROTOTYPING

What | Prototyping does not happen in a linear way. Although an increasing level of prototype fidelity seems like a logical thing to do, it makes more sense to question the level of fidelity at every iteration of a product-service concept. In his book 'sketching user experiences' Bill Buxton states "There is no such thing as high or low-fidelity, only appropriate fidelity" (Buxton, 2007). This statement hints that prototype fidelity can and should be questioned throughout the design process. A design team should be aware of what the goal of a prototype is at every stage in the design process. When you know which part of a prototype to focus on, you can make some parts more detailed than others.

Why | When prototyping a concept, it is often suggested to start with a low-fidelity prototype and move to a high-fidelity prototype later. The goal of designing with an increasing level of fidelity is to first focus on getting a good understanding of a concept's core functionality before moving on to the bells and whistles that might be required. A prototype should allow stakeholders to envision what a product or service can be like.

How | Do not spend time reinventing the wheel nor the hot water. When you can simulate parts of your concept or idea using existing techniques, build something that incorporates these. For example: sticking a tablet behind a picture frame suddenly makes that picture frame appear as an interactive photo frame. There is nothing wrong with revisiting an idea by others, as long as you are clear and open about it. When you are still early on in a design process, do not make your prototypes look finished. Unfinished prototypes (on paper or cardboard for example) make it clear that they are a work in progress, which enables people to react on them more freely.

For more inspiration, read: Fake it or make it - tools and toys for prototyping connected products (by Paauwe and De Roeck) CRISP magazine.

Figure 6.38 | Appropriate fidelity prototyping adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)
Picture courtesy: The DIOTTO project consortium, Studio Dott, Waylay and Sensolus.

6.4.11.2 LOW-FIDELITY PROTOTYPING

What | Low-fidelity prototypes are rough models of your touchpoints.

Why| You make low-fidelity prototypes to test your solutions fast and at low cost.

How | Decide on the touchpoints or solution that you want to test (critical, entirely new experience, etc.)

Make a mini (tabletop) or real-size prototype with low-cost materials. Emphasize the interaction elements. Use paper and marker to prototype your interfaces. Pop-up menus, messages, and dialogue boxes can be simulated with post-it stickers. For 3D prototypes, many options are available. You can use cardboard, foam, wood, plastic, clay and building blocks. Consider intangible touchpoints such as guidelines for employees on how they should address people or what body language they should adopt or avoid.

For more information, read: The Design with Intent Method: A design tool for influencing user behavior (by Dan Lockton) (Lockton, Harrison, & Stanton, 2010).

Figure 6.39 | Low-fidelity prototyping adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.4.11.3 MEDIUM-FIDELITY PROTOTYPING

What | Medium-fidelity prototypes are models of your touchpoints with enough detail to enable the testing of the main functionalities and interactions. In a medium-fidelity prototype, at least one or a few elements are functioning.

Why | You make medium-fidelity prototypes when you know what you want to build (i.e., your system is defined) but you are still searching for the most optimal interaction design.

How | Make your prototype appear as if it works 'for real'. The key is to 'trick' people into thinking everything works.

Augment your prototype with some interactivity using an electronic or digital prototyping platform. The tools you use will greatly depend on your concept. Test the main functionalities and interactions with users. During testing, you are ideally present to observe interactions and stakeholder reflections in detail. After a medium-fidelity testing session, you typically engage in a dialogue with your respondent to reflect upon the designed service and/or product.

Where relevant, medium-fidelity prototypes could be changed on the fly. For example, elements can be removed, added or changed based on stakeholder feedback or observation.

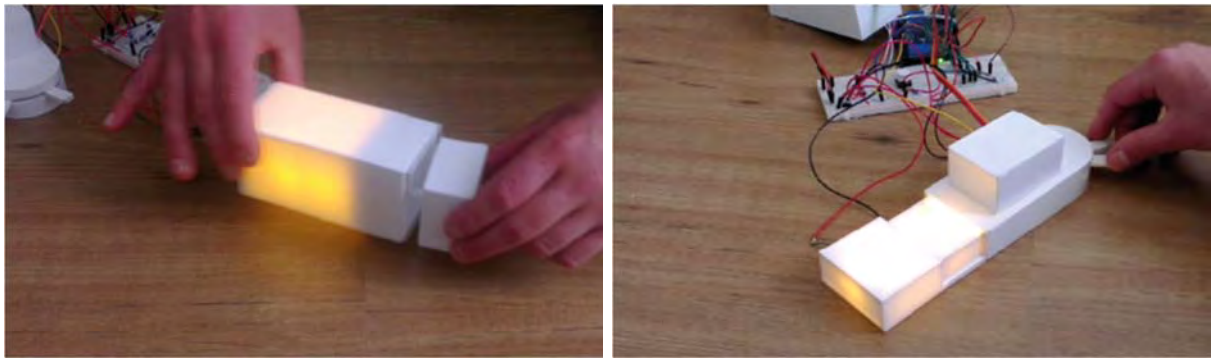


Figure 6.40 | Medium-fidelity prototyping adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.4.11.4 HIGH-FIDELITY PROTOTYPING

What | High-fidelity prototypes are detailed models of your touchpoints, with lots of detail and functionality.

Why | From a user testing point of view, a high-fidelity prototype is close enough to a final product and/or service to be able to examine usability questions in detail and make strong conclusions about how behavior will relate to use of the final product and/or service.

How | Consolidate findings during low and medium-fidelity testing and define all aspects of a final prototype.

You create a list of specifications, which allows you to outsource any components (soft or hardware) which you are not able to create yourself.

For more inspiration on this prototype: https://www.youtube.com/watch?v=xDpyuy7DoeU

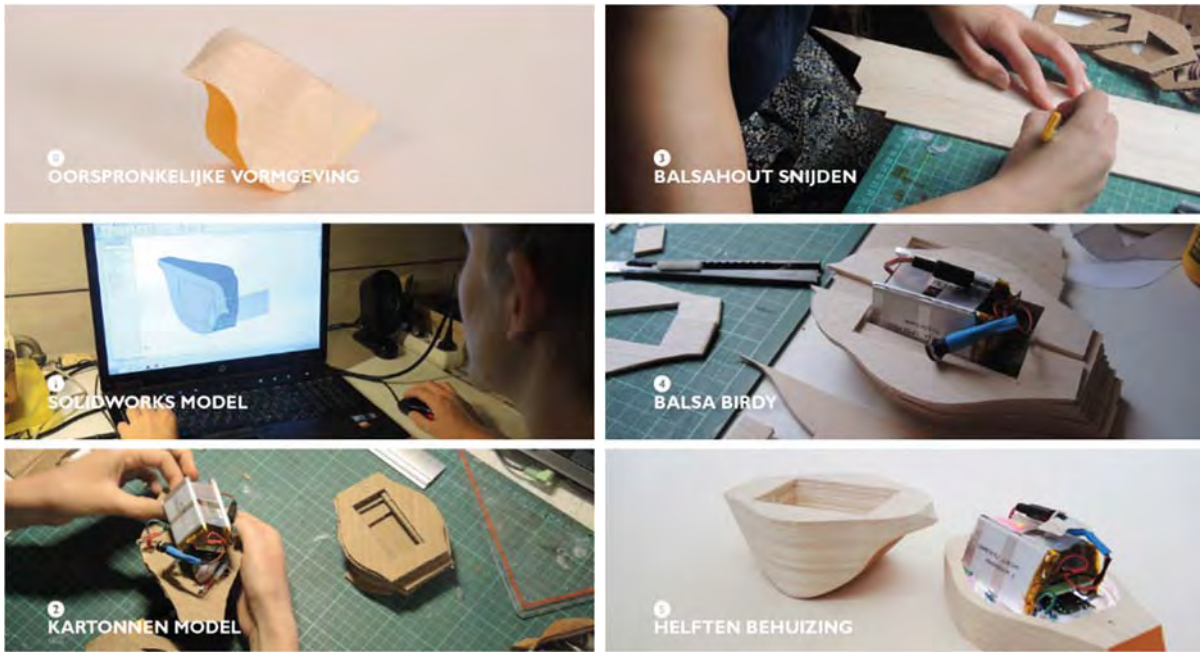


Figure 6.41 | High-fidelity prototyping from the IPO Course: Integrated Systems at UAntwerpen

6.4.11.5 PROVOCATIVE PROTOTYPING

What | The goal of provocative prototyping is to deliberately make prototypes of products and/or services to trigger emotions or reactions amongst your stakeholder group.

Why | People tend to be better at reacting on something that is given to them instead of constructing something themselves. Provocative prototyping abuses this humane 'quality' by eliciting reactions, which facilitates conversations about less straightforward topics.

How | There is not one specific take on this. The way a provocative prototype is made often depends on the question you want to tackle or the discussions you want to trigger. Nevertheless, there are some guidelines:

Make more than one prototype. When stakeholders react on a prototype, it is easier to compare between multiple options. Provide multiple points of entry to your prototypes. When something is only printed on paper, be aware that not all people will be able to make the translation of a drawing or render to a 'real' product. Therefore, it makes sense to create a low or medium-fidelity prototype, this allows people to envision what something looks like better.

Never assume that a provocative prototype will be an end result. When doing this type of prototyping, you know that all things you are making at this phase are temporal. The things you are making are basically 'throw away' concepts which allow you to understand the vision of your stakeholders better.

Ask your stakeholders how the prototype could be improved to serve their purpose better instead of what they like or do not like about it. Your prototype(s) should provide enough building blocks for people to construct their own design proposals.

Figure 6.42 | (left) Provocative prototyping from the IPO Course: Integrated Systems at UAntwerpen | (right) provocative prototyping from 'solitude aspirationals' (by Lore Zoons) at UAntwerpen

6.4.11.6 MAKE BELIEVE

What | Prototypes as learning material.

When creating prototypes, the primary goal should be to get feedback from 'real' stakeholders at specific points throughout the design process. Very often, the mistake is made to only create prototypes as an end result of a process. Prototypes should be used to learn and change first, and can later on become 'showcases' of the end result.

Why | Time is not on your side.

Prototypes take time to build, and to test. Therefore, it is useful to be able to build and test prototypes using less time-intensive methods. 'Make believe' is a crucial strategy in doing so. By pretending that something is real, you can trick stakeholders into believing that a prototype actually works. In addition, you can pretend that a service is real in order to experience what it would be like to have a specific service in place.

How | Relations with other methods.

Acting out is not just one method, but it can be a strategy. Methods that use this strategy include *body storming*, service rehearsal, Wizard of Oz testing, roleplaying and acting out. Stay in character. When you go through a 'make believe' style method, take it seriously and learn as much as you can. It might seem very entertaining afterward, but when you do not take it seriously from the start chances are low you will actually get something out of it. Know what you want to get out if. Do not just do a roleplaying exercise for the fun of it, but also set some learning goals upfront. Never lie. When you are asked, be very clear that you are testing something and what your motivation is.

Figure 6.43 | Make believe from the IPO Course: Integrated Systems at UAntwerpen

6.4.11.7 USER TEST (TEMPLATE)

What | In a user test, the future PSS is tested with real stakeholders using prototypes in a context as real as possible.

Why | The intention of the test is to efficiently learn in practice what works and what doesn't work before actually building the system.

How | First decide what you want to test with whom. Make sure to look back at your *design requirements* and *stakeholders dimensions* to define this.

Setup the prototype in a realistic test setting and recruit the stakeholders (users, service providers, third parties, etc.). Give several test subjects the same assignment. Let them conduct the test and think aloud while doing so. The project team observes the test. Collect the test results and improve your concept by adapting what fails and strengthening what works well. With the test, you want to figure out if: the stakeholder understands your solution, the solution is an answer to the problem or need of the stakeholder, the solution motivates the stakeholder (drives), and if the solution is user-friendly.

Take time after the test to talk through the experience, you can use the *interview* tools for this. Let the test subject talk and regularly ask how and why. Avoid pushing your own viewpoint. Take notes of these conversations.

Figure 6.44 | User test from the IPO Course: Integrated Systems at UAntwerpen

6.4.12 OUTRO DEFINE

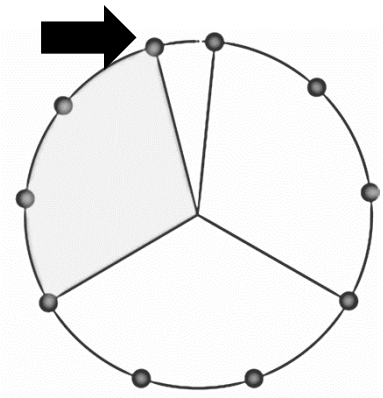


Figure 6.45 | PSS design process - level Define

Essentially, you want to efficiently learn in practice what does (not) work before actually building, piloting and upscaling the system.

The purpose of this toolkit is threefold:

1. ***It offers designers a structured approach to tackle product-service systems related challenges, thus helping to grasp the complexity and find meaning in the whole.***

2. ***It creates a common vocabulary and grammar in the design community, on which can be built upon.***

3. ***It offers tools as artefacts for dialogue and co-creation between and with stakeholders, allowing them to become active participants in the design process***

However, a toolkit remains just a bunch of tools. Too literally applied, a toolkit can lead to an oversimplified, rigid and hollow design process. We encourage all designers to look at this toolkit as an entry point for jamming. Make it your own, improvise on it, adapt it to your project and finally yet importantly, use it to let the creative energy flow. Moreover, we hope you will end up with a very different kind of briefing for implementation. The final solution defines the tasks, responsibilities and benefits for all possible stakeholders, they will have a better understanding and verified interest of your PSS.

Toolkit

PRODUCT SERVICE SYSTEM STRATEGIC ROLLOUT

Product Development
University of Antwerp

antwerp management school

UPA

6.5 PSS strategic rollout toolkit

Besides the main challenge for the designer - managing the variety of underlying design processes - early representation and communication are key for buy-in and strategic rollout of the PSS concept. Companies and design practitioners can also use the toolkit to add services as by-product or vice versa, using products as a means to provide services and focus on *exploitation* of their current and derived business model. In this case, we strongly advise you to plug and play the PSS design tools in combination with part two of the toolkit on **PSS strategic rollout**.

6.5.1 Introduction

The reason why manufacturers are unable to turn services into growth is still considered a black box. We took a holistic perspective of the firm and examined the internal barriers that companies encounter when upscaling product-service systems (PSS). Over the course of eighteen months, we conducted an exploratory study consisting of both multiple case and participatory action research methods with eight local manufacturers that have taken concrete steps towards services. Our goal was to develop insight into the internal levers for upscaling PSS, and apply a new tool to support companies in generating and prioritizing PSS-enhancing projects. Based on our observations, we distinguish three barriers that prevent companies from upscaling PSS. First, while companies may show ambition for further growth by improving current PSS offerings, thus unlocking their current PSS potential, they have insufficient knowledge to roll out current PSS. Secondly, manufacturers often put emphasis on innovating either products or technologies, and treat service as an add-on; they have insufficient experience in an integrated design approach to create new PSS. Thirdly, in companies that are having trouble upscaling PSS, the root of the problem often lies in an unsupportive organizational logic, which prevents the company from successfully creating and implementing integrated PSS.

6.5.2 Project outcome

By experimenting with a new set of tools at companies that are currently dealing with issues related to rolling out and/or designing PSS, we developed a toolkit focusing on three key aspects of potential PSS upscaling.

First, companies are introduced to the concepts of ‘exploring’ vs. ‘exploiting’ PSS opportunities, which is in line with our distinction between developing new PSS and rolling out current PSS. During the workshops, teams are advised in making a distinction between PSS exploration and exploitation projects, emphasizing how they may differ in terms of both investments and benefits.

Second, by involving employees from different backgrounds within the firm, teams can easily map the bottlenecks for PSS improvement projects since each member can offer a different perspective. By addressing these bottlenecks and discussing ways to bypass them in teams, companies may also start to leverage a shared organizational logic for supporting PSS.

Third, by clearing out any lack of clarity on the co-creation effort and support needed from employees and/or external stakeholders at the beginning of the PSS-orientated project and setting out the best possible team formation, a strong collaborative team set-up is created that can deal with the complexity of PSS development.

6.5.3 STEP 1 // STRATEGY SPRINT 1 (TEMPLATE)

What | A strategy sprint is a tool for activating the involvement of employees in the early stages of an innovation project by setting up a discussion on the current strategy and future trends and changes necessary to make the strategy a success, prior to determining the project scope. It acts as a mirror, reflecting the current status of the strategy and how employees translate this into practice. It is a 'sprint' for performing a quick check; it is not intended as a tool for creating a new strategy.

Why | To create a shared understanding between actively involved internal stakeholders (future project team-members) and senior management on what their organization stands for, what the current strategy is and which projects could strengthen the current value on offer or create new value. It encourages individual stakeholders to share opinions while taking decisions as a team by quickly linking knowledge from the work field with strategic knowledge.

How | The strategy sprint combines a Values - Mission - Vision exercise with an ideation brainstorm and consists of several questions that participants have to go through step by step. Every question has to be answered individually, after which the results are analyzed in groups and final answers are chosen by the group. A facilitator is needed to guide the participants through the sprint, using a presentation with instructions that includes possible answers and inspiration.

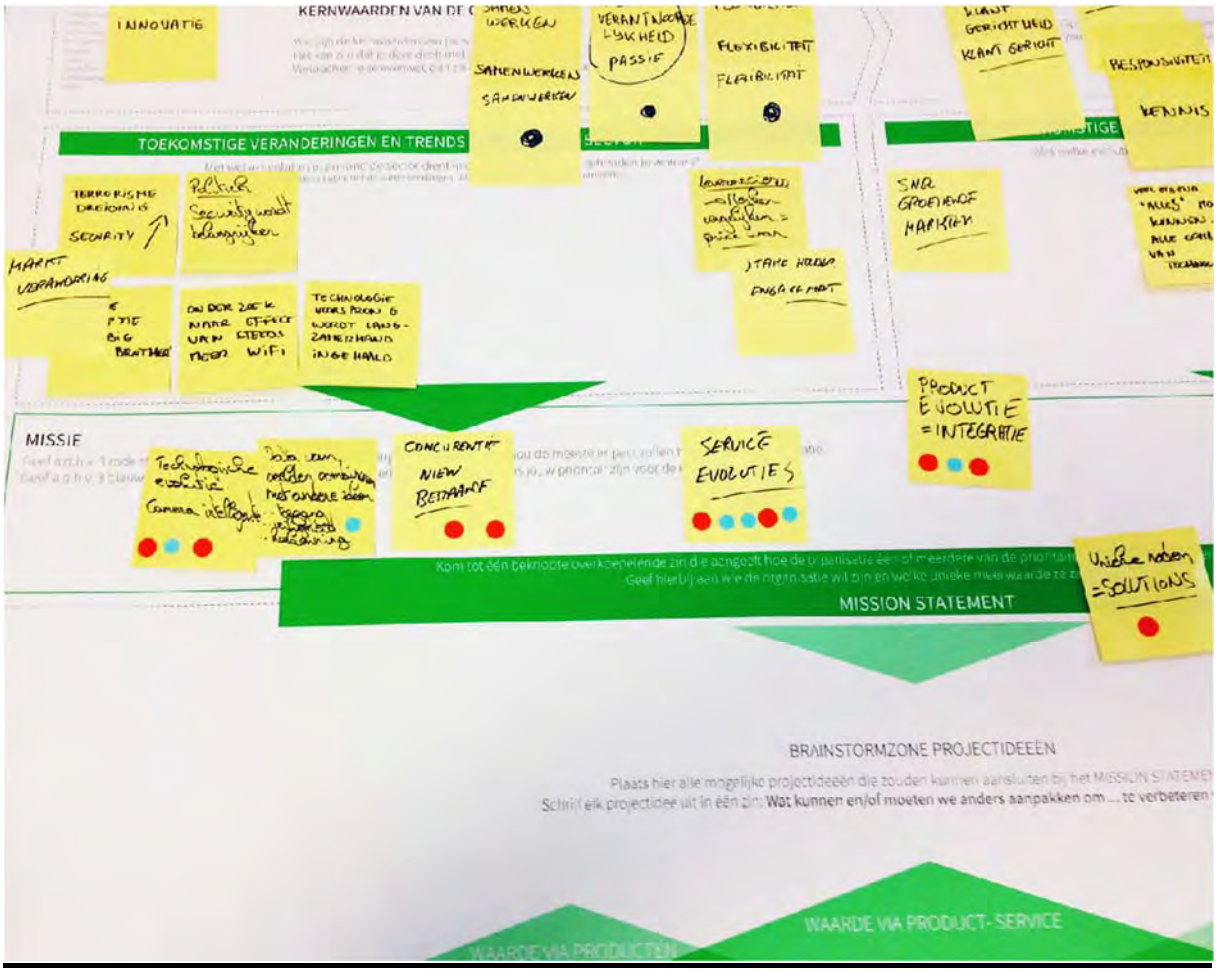


Figure 6.46 | Strategy sprint adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.5.4 STRATEGY SPRINT 2

6.5.4.1 STEP 2 // SELECTION MATRIX (TEMPLATE)

What | The strategy sprint selection matrix is a means of assessing the project ideas that are generated in the strategy sprint. It helps you to quickly go from insights to decisions. The matrix is especially useful for selecting a project that is in balance with what the organization can cope with, without forgetting to focus on creating value for users.

Why | To achieve a realistic project selection with the joint support of internal stakeholders (future project team members) and senior management, and thus create the necessary buy-in from both worlds for future actions.

How | Sort the project ideas of the strategy sprint into two main innovation categories – 'grow by optimizing the current business' and 'grow by new business' – then stick them onto the poster and decide which category the first project should focus on.

If you decide to focus on 'grow by new business', put the matrix aside and start a business model exercise to compare possible business models for the ideas. Use a 'lean canvas', a 'business model canvas' or a 'Play It Forward canvas' for support.

If decided to focus on 'grow by optimizing the current business', select the ten strongest project ideas and place them in the projects box in the selection matrix on the poster'.

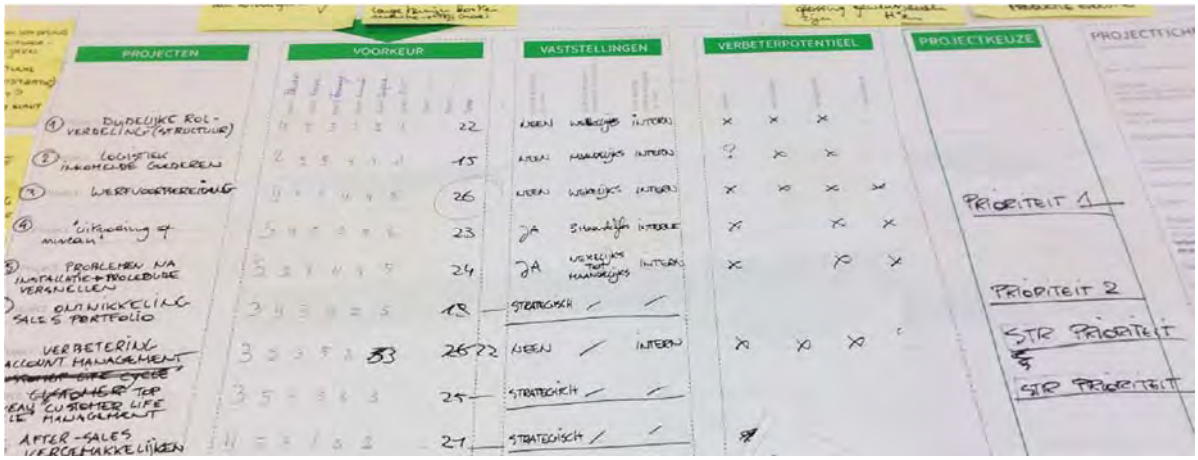


Figure 6.47 | Selection matrix adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.5.4.2 STEP 3 // PROJECT SHEET (TEMPLATE)

What | The strategy sprint project sheet makes it possible to quickly write down a first draft of the action plan for the project that has been selected during the strategy sprint workshop. The strategy sprint ends with an open discussion on what is needed to make the project succeed.

Why | To keep the momentum going that you and your team created during the strategy sprint, by ending the strategy sprint not with a selected project, but with a draft of the project plan. This way you are able to assign the first project tasks and targets to activate the team and get the project rolling. If you do not end the strategy sprint with a project framework, you increase the risk of falling back into 'business as usual' and losing the willingness to engage within your team. As a result, the project will lose importance and will be in danger of becoming a project that is eventually set aside as the order of the day prevails.

How | Fill in the project sheet by discussing the following topics with the team and coming to a conclusion for every topic.

Analysis after the project: Set a date to come together as a team and analyze the project after its completion. Focus on sharing key insights into success or failure. The knowledge for future collaborative and process improvements lies in these insights.

Figure 6.48 | Project sheet adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

6.5.5 STEP 4 // VALUE EXCHANGE BOARD (TEMPLATE)

What | A value exchange board helps a project team to find the best possible formation for developing the project effectively and efficiently, by visualizing and discussing the setup of different team formations during the development process. Using the tool allows for discussion and identification of the most suitable team formations quickly, while seeing what individuals can offer in their roles (skills), what they need to do (intangibles) and the assets they have (assets) which could benefit the team and the project.

Why | Mutual competition between individual team members can increase team productivity, but more often than not it has a devastating effect on the focus of the team and their common goal. Losing that common goal will set the team adrift, with a severe decline in effectiveness as a result. When an innovation project requires co-creation in a team with either internal or a mix of internal and external stakeholders, it is therefore best to make the collective prevail on the individual, making sure that all individual roles and the team formation are clear and in line with the common goal of the project.

How | Begin by writing down the mission statement of the leading organization (project owner), to remind the team of the focus of that organization. Write down the project objective in one sentence. 'How can we create/design/improve ... (what) for ... (whom) so that ... (goal/impact for the user)?' It is best to base the project objective on exploratory research and if this type of research is not possible then at least do a strategy sprint to form a realistic project objective. Write down which future moment(s) of satisfaction you want to achieve for your target group. Try not to focus on solutions but on the emotional impact the future outcome has to have on your users.

All individuals pick a role from the poster, write down what skills make them suitable for it, what assets they can offer to the project and what actions they have to take to fulfill the role properly. Achieve a balanced team, divide the project in at least three development phases and define missing roles or unmet needs.

*Tool originally designed by **Joumana Mattar** (Fjord Design and Innovation).*

Figure 6.49 | Value exchange board adopted from PSS Design and Strategic Rollout (Dewit et al., 2018)

Figure 6.50 | PSS Design and Strategic Rollout (Dewit et al., 2018) website

The book '**PSS Design and Strategic Rollout | tools for product-service systems**' is accompanied by tools that you can download on this page:

www.uantwerpen.be/en/projects/product-service-systems/

It provides the methodology, multiple tools and extra techniques in a specific way - introduction, instruction and inspiration - to support you in the process of designing or facilitation PSS projects.

The tools from the PSS design process in suggested order of use:

- PSS Design tools (download here)
- PSS Strategic Rollout tools (download here)

The book and its tools are available at the publisher's website: PSS Design & Strategic Rollout | Toolkit

CHAPTER 7
INTEGRATION

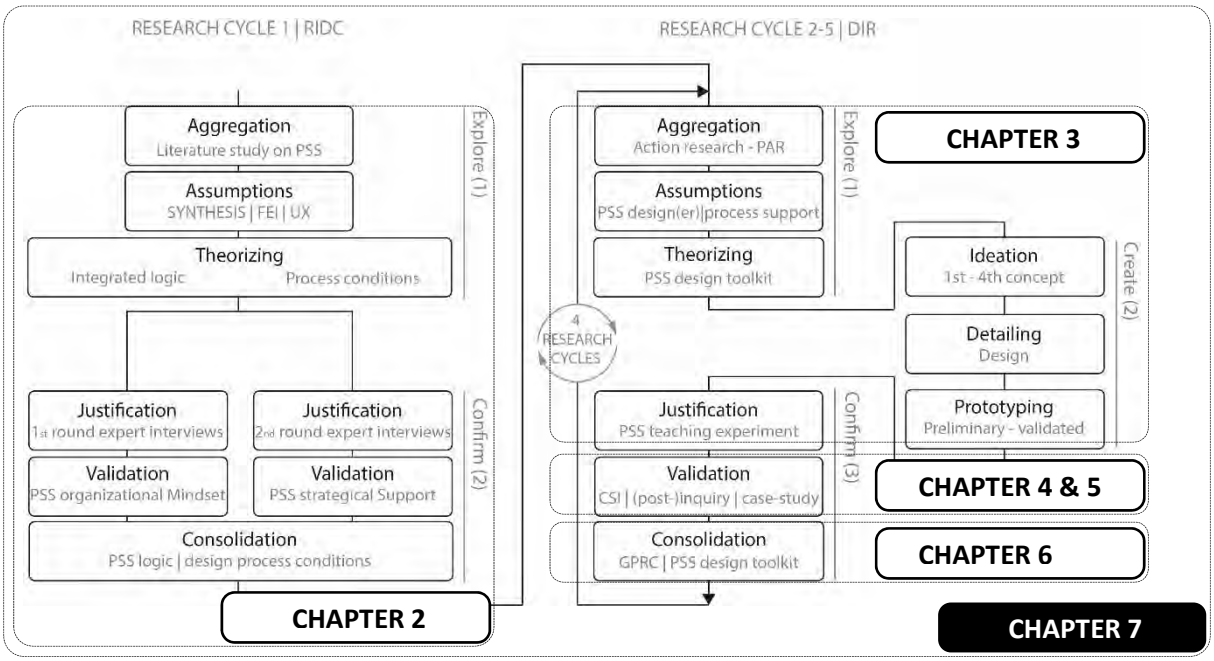


Figure 7.1 | Research design - chapters

7.1 Integrated PSS design framework

The twenty-one process preconditions (described in Chapter 2) could be interpreted as drivers for innovation, they are relevant for organizations in their transition toward an integrated logic and strategic PSS mindset. Depending on the type and extent of adoption of these preconditions, they reflect the organization's general disposition, willingness, and aim to develop and introduce more innovative new PSS. When it comes to PSS design, the experts articulated that the preconditions could work as a typology of decisions to be taken on different levels, something people can look, discuss upon, and position themselves in the transition toward integrated logic. One step further, one can also cater to these process preconditions before going to the next level in the process. On a tactical level, project management can easily connect the process preconditions to a structured coordination and facilitation of the PSS design process.

The increased complexity of a continuous product-service integration, justifies the use of the PSS design toolkit. At the end of Chapter 2, the experts deemed it a prerequisite to connect the process conditions to a more actionable approach to actually get the job done and make PSS design noticeable on each organizational level. In Chapters 2 to 5, justified and validated through a series of multifaceted confirmation methods, we have built-up this hands-on approach as a result of four research cycles and as much iterations, the final and peer reviewed version of the PSS design toolkit (Chapter 6).

In this chapter, we set the objective to consolidate the PSS design toolkit with our knowledge from the literature study and expert interviews. Therefore, we bring together the Research Cycles 1-5 by means of the ***Integrated PSS design framework*** in Figure 7.2. Respectively it ties each of the twenty-one PSS design process preconditions (Figure 2.5) together with the peer reviewed PSS design toolkit and its process (Figure 6.4). Table 7.1 visually summarizes the same relation at a glance.

When thinking about PSS as innovation strategy, this Integrated PSS design framework supports the internalization of PSS design process knowledge and allows project management to discuss each of the twenty-one process preconditions in close relation to the PSS design process and its individual tools. In this way, the process preconditions are made more actionable and lever a more performing PSS design process. Going through three levels (i.e., understand; explore; and define), the preconditions and tools in the framework can be related rather effortlessly. Stepwise we describe how specific PSS design tools address every one of the twenty-one process preconditions. If the reader wants to explore the preconditions more in depth, s/he can read how others have dealt with these conditions in practice or dive back into the theory to see how they are grounded in literature for each condition in Table 2.8. The integrated PSS design framework allows a bidirectional entry, (1) relating process preconditions to specific PSS design tools, and/or (2) applying tools during the PSS design process that address specific theory-grounded preconditions.

Preconditions / Tools for PSS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Strategy sprint 1	x						x		x	x	x	x	x					x			
Selection matrix (strategy sprint 2)		x					x	x	x	x	x	x	x					x			
Project sheet (strategy sprint 2)		x					x		x	x	x	x	x					x			
Value exchange board									x	x	x	x	x								
Context map			x		x								x								
Stakeholder dimensions					x								x								
Research questions					x								x								
Observation					x								x								
Interviewing the perspective					x								x								
Interviewing the experience					x								x								
Personas					x								x								
Factors and themes					x		x						x					x			
System map					x		x						x					x			
Value proposition					x		x	x					x					x			
Rich pictures					x								x								
Intervention strategy						x	x						x					x			
Design challenge						x	x		x	x	x	x	x					x			
Business ideation canvas			x					x	x	x	x	x	x					x			
Paradoxical thinking								x	x	x	x	x	x					x			
Lotus blossom								x					x					x			
Meta-examples													x								
Selection matrix								x					x					x			
Solution spaces			x						x	x	x	x	x		x	x	x				
Serious play scenarios													x	x	x	x	x				
Body storming													x	x	x	x	x				
Customer Journey			x										x		x	x	x				
Touchpoint matrix													x		x	x	x				
PSS map									x	x	x	x	x						x		
Conceptual model													x							x	
Interaction moodboard													x							x	
Interaction metaphors													x							x	
Narrative													x							x	
Process map													x							x	
Appropriate fidelity prototyping													x								x
Low-fidelity prototyping													x								x
Medium-fidelity prototyping													x								x
High-fidelity prototyping													x								x
Provocative prototyping													x								x
Make belief													x								x
User test													x								x

Table 7.1 | Relation between the PSS design tools and the 21 process preconditions

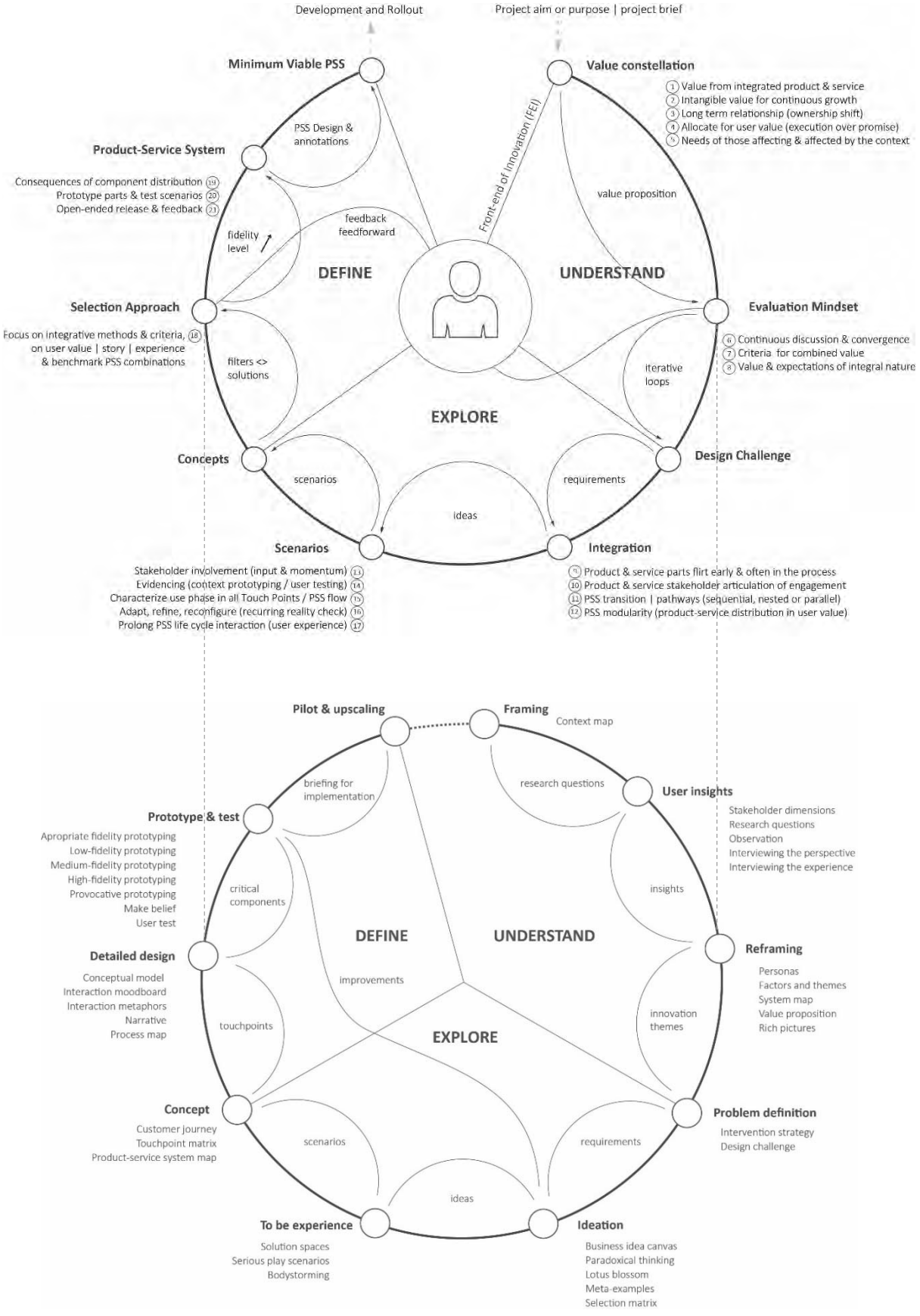
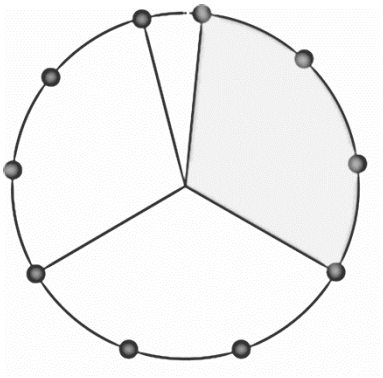


Figure 7.2 | Integrated PSS Design Framework

7.2 Bridging the PSS design process preconditions and tools



UNDERSTAND

7.2.1 Value from integrated product & service - precondition 1

On a regular basis, organizations are improving the quality of their service, solving problems related to their products or digital experiences. Additionally and increasingly, they are being faced with more complex, connected and societal issues, imposing them to combine a variety of disciplines in pursuit of an integrated approach. This is where a product-service system mindset and design methodology provides a structured and iterative process support to enable organizations to grow and be more competitive. Product-service systems require a broader scope in mind in order to understand and interpret perspectives of reality, enabling the exploration of things as they could be.

The **strategy sprint** (1) is meant to activate the involvement of employees in the early stages of an innovation project by setting up a discussion on the current strategy, future trends and changes necessary to make the strategy a success, prior to determining the project scope.

7.2.2 Intangible value for continuous growth - precondition 2

In the case of PSS, it is important that products and services are designed as a *combined value carrier*. Because of its integral nature, PSS design projects often involve process visualization, demonstration of *intangible value* and its relevance. The PSS design toolkit helps structure outcomes and enables readers to implement the tools in their specific context, and overcome barriers for incorporation and implementation. Therefore, it is of utmost importance to support and manage the influx of disciplines and align their underlying design processes. This toolkit offers a structured approach to tackle PSS related challenges, thus helping to grasp the complexity and finding meaning in the whole. Stakeholders need an understanding of the PSS, explore and converge upon an idea together, define tasks, responsibilities and benefits for all actors.

The **selection matrix** (strategy sprint 2) tool suggests a choice between two main innovation categories – 'grow by optimizing the current business' (exploitation) and 'grow by new business' (exploration). The essence of the **project sheet** (strategy sprint 2) is to quickly write down a first draft of the action plan for the project that has been selected during the strategy sprint workshop.

7.2.3 Long term relationship (ownership shift) - precondition 3

With people at the center, it is crucial to understand and define the different perspectives on value for those affecting the context and others affected by it. Regardless of the distribution of product and service components in the solution, value comes from both parts (PSS). How those parts work together

and how people interact with them determines the experience, the value created in the context and ultimately help sustain the ecosystem. An emphasis on either exploitation or exploration makes the distinction how projects may differ in terms of investments and benefits.

The **context map** is especially useful when trying to understand the project, the context (of use) of the (future) product-service system. Identifying the stakeholders, why and how they actually use or offer the product or service, a mapping of all the relevant places, products, services and activities, moments of use, the goals and exchanged value(s) between all of these elements (psychological, social, ecological, economic). A first part of the **business ideation canvas** maps out the opportunity space: the drives, needs and goals of the users and client; the key capacities of the organization, its ecosystems, the context of use; external opportunities and limitations; and technological possibilities. The first part of the **solution spaces** template explores the 'playground' of the future solution, exploring the potential for both the users as for the organization by playing around with specific characteristics regarding PSS and its related business concept. The future solution has to integrate the viewpoint of end-users and provider(s), therefore the future **customer journey** will present product and service touchpoints as input to discuss, improve and validate their respective value in the system.

7.2.4 Allocate for user value (execution over promise) - precondition 4

Delivering great experiences for customers requires organizations to expand their design activities beyond the silos. The alignment of product and service in the system will deliver a consistent and coherent offering together, when verifying the interest of potential users, promoting the final solution and providing value to the customer. A prolonged user interaction with product and service touchpoints allows all stakeholders in the ecosystem to grow continuously together, essential to keep the PSS alive and enable a transition that goes beyond design itself, toward meaningful innovation.

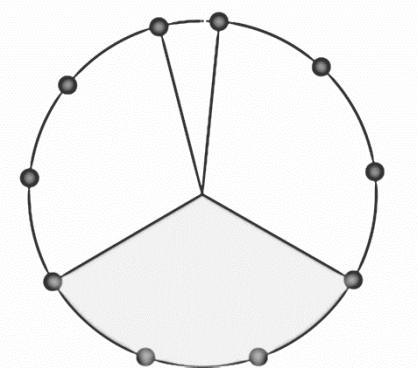
7.2.5 Needs of those affecting & affected by the context - precondition 5

The PSS design toolkit enables its users to stepwise convey insights, interact and even iterate with the client, customers and other stakeholders through different kinds of representations. It also serves as a formalized paper trail to better communicate, discuss and collaborate within the team, between departments and reads easier when pursuing buy-in, strategic rollout and upscaling of the PSS concept. The curation of tools is evident, as well as the buildup and handover between different actors in the PSS system. Moreover, it's applicable in multi-disciplinary fields of application. This toolkit offers tools as artefacts for dialogue and co-creation between all stakeholders, allowing them to become active participants in the design process.

This stage frames the context and its underlying human drives, and helps the reader to understand and reveal all possible interactions between those affecting the context and others affected by it. Insights can be obtained through a variety of methods, but it remains central to identify patterns in behavior and interactions, even if unintended. Each tool offers an interpretative lens to enable sense making of the context, in order to reframe the perspectives or to change them. Clustering promising patterns will provide the necessary support to capture the bigger themes and ultimately address the underlying phenomenon of the situation. A representation of all (re)framed insights should encourage stakeholders to discuss, interact and attain a holistic understanding of the issue.

The **context map** is especially useful when trying to understand the project, the context (of use) of the (future) product-service system. Identifying the stakeholders, why and how they actually use or offer the product or service, a mapping of all the relevant places, products, services and activities, moments of use, the goals and exchanged value(s) between all of these elements (psychological, social, ecological, economic). **Stakeholder dimensions** supports an understanding of the different perspectives, needs and expectations of the stakeholders. Therefore, it is interesting to do this exercise

together, opposed to assumptions based on desk research alone. Make a decision on those characteristics that have an influence on the product and/or service offered and specifically who is interesting to interview. The **research questions** template is used to find out what is currently (not) understood about the experience of stakeholders' interacting with the system over a whole lifetime or during a particular event. **Observation** identifies user patterns, the moments of flow, the hurdles and the unintended behaviors. **Interviewing the perspective** is interesting when one wants to capture the perspective of the stakeholder toward the problematic situation in order to design upon these perspectives or to change them. **Interviewing the experience** is used to understand the current experience of the stakeholders within the actual system. **Personas** are a useful way to communicate user insights to team members that were not involved in the field study or to clients and stakeholders that you want to involve in future workshops. **Factors and themes** are specifically used to look at the problems, identifying underlying causes and complement the user insights with economic, societal and technological developments (e.g., aging population, personal robots) and trends (e.g., self‑monitoring). A way to visualize the prior knowledge is the **system map** template, it provides structure and interrelations between the elements of the system, e.g., natural (energy and resources), human (health, skills, motivation, etc.), social (relations, collaboration), manufactured (goods and infrastructure), financial (currency, shares, etc.). Most likely, this will lead to the discovery of the leverage points (most impact) in the current system to solve the issue (or unwanted result) or instead you can choose to rethink the whole system by rephrasing its purpose. Another way is to make the **value proposition** explicit with the template, deciding how to make value for people, organizations and society at the same time, integrating the perspectives of economics, psychology, sociology and ecology. A third option is to encourage discussion, interaction, and to attain a holistic understanding of the issue by means of **rich pictures**.



EXPLORE

7.2.6 Continuous discussion & convergence - precondition 6

The prior information should be apt, to identify (together with stakeholders) the multiple ways (levers) on how to intervene in the system. If agreed upon, this sets the start to a (re)formulation of a clear design challenge (of the problem/opportunity), a convergence based on all gathered insights and relevant to rethink the whole and reframe its purpose. Because of a deep understanding of the system, requirements should come out easy, the perfect starting point for exploration. This toolkit creates a common vocabulary and grammar in the design community, on which can be built upon.

With the **intervention strategy**, one learns to understand how to intervene in the system, ways to modify the current approaches, with adequate outcomes or benefit for all stakeholders. A decision is made on which interventions to take along based on feasibility, impact and momentum. Together with the prior insights, this focus supports a (re)formulation what to design in a single, clear and agreed upon **design challenge**. This template also allows specifying **requirements** (context, interaction, product, service, rational and emotional) that address this design challenge. The requirements that make the most difference are listed (as evaluation criteria) and are used as input for ideation.

7.2.7 Criteria for combined value - precondition 7

The aim of the **strategy sprint** (1) is to create a shared understanding between actively involved internal stakeholders (future project team-members) and senior management on what their organization stands for, what the current strategy is and which projects could strengthen the current value on offer or create new value. It encourages individual stakeholders to share opinions while taking decisions as a team by quickly linking knowledge from the work field with strategic knowledge. The **selection matrix** (strategy sprint 2) is a means of assessing the project ideas that are generated in the strategy sprint. It helps to quickly go from insights to decisions. The matrix is especially useful for selecting a project that is in balance with what the organization can cope with, without forgetting to focus on creating value for users. The essence of the **project sheet** (strategy sprint 2) allows for an open discussion on what is needed to make the project succeed. To keep the momentum going that the team created during the strategy sprint, this tool enables its users to assign the first project tasks and targets to activate the team and get the project rolling.

Factors and themes identify the underlying causes, related to specific user insights, economic, societal and technological developments and trends that can be used as criteria. The **system map** helps to decide on the elements, e.g., natural (energy and resources), human (health, skills, motivation, etc.), social (relations, collaboration), manufactured (goods and infrastructure), financial (currency, shares, etc.) that have the most impact on the system. The **value proposition** provided the economic,

psychological, sociological and ecological values for people, organizations and society. The **intervention strategy** describes the ways to intervene in the system, based on feasibility, impact and momentum. And finally, the agreed upon **design challenge** and its most impactful **requirements** can serve as input for criteria, evaluating and selecting ideas for, e.g., the context, interaction, product, and service.

7.2.8 Value & expectations of integral nature - precondition 8

The stage is now set for explorative activities. Different techniques are provided to generate a large amount of opposites, alternatives and inspirational input in order to achieve solutions for the whole, as well as for its sub-challenges (functionalities it should offer to meet the client goals). It's about 'AND' thinking instead of 'OR' thinking; consciously generating unusual viewpoints enables an ideation on the extremes. The opposite of one truth may very well be another profound truth. The requirements of the first stage have set criteria for discussion, a convergence on the relative importance of each idea, bringing those ideas to the surface that have the most impact on the user and value for the client to proceed with.

The **selection matrix** (strategy sprint 2) is a means of assessing the ideas generated. The matrix is especially useful for selecting a project that is in balance with what the organization can cope with, without forgetting to focus on creating value for users. However, it is very important to make a difference and allow for 'growth by optimizing the current business' (exploitation) and/or 'growth by new business' (exploration).

The **value proposition** makes the different values explicit, regarding people, organizations and society. The **business ideation canvas** incorporates business model thinking in the ideation phase. It is better to combine the prior insights in relation to the organization's context for emerging business value instead of adding it in later stages of the process. **Paradoxical thinking** is about AND thinking instead of OR thinking. Looking at contradictory or conflicting situations, generates unusual but interesting viewpoints. The **lotus blossom** is a technique that stimulates the participants to find inspiration by looking at how others (state-of-the-art examples from your own or other domains) fulfil the design requirements. It is also possible to directly ideate on sub-challenges or sub-functions and to look for solutions in existing systems. The **selection matrix** is used to look at large numbers of ideas, and assessing their relative importance. *E.g., "value for the user" versus "value for the client" or more specific: for example, "impact on the user's lives" versus "feasibility for the client", or "impact on all stakeholders" versus "economic value for the client".* Then, come to a clear and common understanding of what the criteria stand for. If some decision criteria are more important than others, review and agree on appropriate weights.

* The *lean canvas* and/or *business model canvas* can also be used, but are better used in later stages when exploring scenarios and defining the concept.

7.2.9 Product & service parts flirt early & often in the process - precondition 9

7.2.10 Product & service stakeholder articulation of engagement - precondition 10

7.2.11 PSS transition pathways (sequential, nested, parallel, integrated) - condition 11

7.2.12 PSS modularity (product-service responsibility for user value) - precondition 12

From the problem definition onward, requirements can be translated in either a product feature, a service or even something digital and its generated data, resulting in combinations somewhere along the product-service continuum. In addition, different PSS strategies can be used, *e.g., building (new) services around, adapting them to or supporting existing products and vice versa*, to connect, assess and represent specific characteristics regarding the PSS to its related business concept. The tools

discussed below address the process conditions (9-12) as they are interrelated and allow to be used together.

First, the **strategy sprint** (1) is meant to activate the involvement of employees in the early stages of an innovation project, prior to determining the project scope. The aim is to create a shared understanding between the project team-members and senior management on which projects could strengthen the current value on offer or create new value. It encourages all stakeholders to share opinions while taking decisions as a team by quickly linking knowledge from the work field with strategic knowledge. Secondly, the **selection matrix** (strategy sprint 2) helps the people involved to quickly go from insights to decisions, in balance with what the organization can cope with, and without forgetting to focus on creating value for users. The essence of the **project sheet** (strategy sprint 2) allows for an open discussion on what is needed to make the project succeed, a momentum that enables its users (from their respective disciplines in the organization) to assign the project tasks and targets to activate the team and get the project rolling. Therefore, the **value exchange board** can be used to discuss and identify of the most suitable team, what individuals can offer in their roles (skills), what they need to do (intangibles) and the assets they have (assets) which could benefit the team and the PSS project.

A single, clear **design challenge** and its **requirements** are agreed upon. This already specifies the effect it will have on the context, what type of interaction will be sought for, and clearly separated product and service related desires. Based on the key capacities of the organization, its ecosystems, the context of use; external opportunities and limitations; and technological possibilities, the **business ideation canvas** maps out the opportunity space in order to ideate on these insights: product, service, (meta)data and the ecosystems' network. **Paradoxical thinking** generates interesting viewpoints about possible opposites for the system, and enables ways to recalibrate or even interchange product and service. **Solution spaces** create a range of different PSS scenarios and their underlying business concept in a more structured way. The **PSS map** presents the future system to stakeholders in order to discuss or to validate the solution. Finally, the **operational validation matrix** is about what-if scenarios: how to solve bottlenecks, queues? What is the minimum viable state of the system to run on break even? Reaching maximum capacity, how to optimize the process, control demand, or scale up? In case of overcapacity, how to deal with costs of staff, storage and waste?

7.2.13 Stakeholder involvement (input & momentum) - precondition 13

Where possible, test insights throughout the ideation phase and bring feedback into the process and iterate on the tools. Involving the human perspective is one thing, to build upon participants' involvement and producing solutions together with them, rather than solely documenting them, *(e.g., observation, interview, persona, etc.)* is another. Throughout the design process choose how to involve the user *(e.g., the community, different stakeholders and others affected by the context)* to ideate, check insights, compare scenarios and prototype together. Think about how this might make implementation and upscaling easier since they have come accustomed to the PSS concept through the design process already. This toolkit offers tools as artefacts for dialogue and co-creation between all stakeholders, allowing them to become active participants in the design process.

* Almost every tool allows for a specific kind of stakeholder involvement.

7.2.14 Evidencing (context prototyping / user testing) - precondition 14

Narrowing down opens up a refined exploration of the playground of your future solution, different scenarios and their underlying business models. This will enable an understanding of the consequences of the interaction with product, service and resulting overall (to be) experience. Immersion in the

relationships between people, their physical location and the things they use in that environment provides the necessary input for the elaboration and convergence into the future concept.

Serious play scenarios start from a user's standpoint and to go through all the steps of the PSS, from start to end. It enables to see how the characters act and react to the events as if they were real users. **Body storming** offers an understanding of the relationships between people, their physical location, and the things (e.g., tools, devices, materials) they use in that environment.

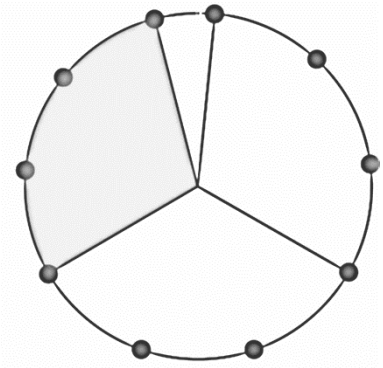
7.2.15 Characterize use phase in all Touch Points / PSS flow - precondition 15

7.2.16 Adapt, refine, reconfigure (recurring reality check) - precondition 16

7.2.17 Prolong PSS life cycle interaction (user experience) - precondition 17

The input of the exploration starts to turn into one clear concept, the beginning for the future viewpoint of (fragmented) interactions between users and the providers of the (PSS) solution. Running alongside each possible / necessary touchpoint enables a matchmaking of actions, intentions and values with different technical and non-technical system-user connections and ultimately their design. Visual compositions convey the look and feel of the system, ensuring coherence and consistency over all its touchpoints. The tools discussed below are interrelated, they allow to be used together and simultaneously address parts of the process conditions 15-17.

Solution spaces create a range of different PSS scenarios and their underlying business concept in a more structured way to and understand the consequence/influence of your choices on the interaction with product, service and resulting overall experience. **Serious play scenarios** brings ideas that were not thought of before. By playing, adapt the product-service system as soon as problematic situations occur, or find new and better ideas. With **body storming**, display new possibilities and challenging problems when aligning the relations between people, their physical location, and the things they use in their environment. The **customer journey** will demonstrate all relevant product and service touchpoints as input to discuss, improve and validate their respective value in the system. Finally, the **touchpoint matrix** template serves to verify and refine the PSS scenario/concept by visualizing the connections between the system (artefacts, digital services, physical services, and context) and the user's actions, intentions and values.



DEFINE

7.2.18 Focus on integrative methods & criteria, on user value | story | experience & benchmark PSS combinations - precondition 18

This toolkit offers tools and techniques that alternate between whole thinking and particle thinking and helps to zoom in and out. It is not necessary - or realistic - to follow and execute all of them, but one should at least reflect on each step and judge whether you have enough understanding of the whole and the parts to proceed. All prior tools together have respectively added to continuous evaluation (discussion) and selection (convergence), and enable to proceed with one final PSS concept. For this we refer to the criteria brought forward in preconditions 6 to 8.

7.2.19 Consequences of component distribution - precondition 19

A stepwise visual representation of the future PSS helps to discuss on operational validity with all stakeholders.

The **product-service system map** presents the future system to stakeholders in order to validate the solution. What-if scenarios are a perfect way to start a discussion by means of the **operational validation matrix**, it enables stakeholders to verify, refine or recalibrate the product and service components of the system.

7.2.20 Prototype parts & test scenarios - precondition 20

This stage bridges the gap between the current knowledge and the target knowledge of the user - what one has in mind about the product/service, which parts should be understood by whom - through actual design/interface representation. Visual compositions convey the look and feel of the system, providing an identity to novel or unfamiliar system functionalities and a possible entrance point and inspiration for prototyping the products and services in the system. A report of the connected events makes it easier to present the final concept to all stakeholders. Detailed, step-by-step showing the front- and backstage activities and their related consequences, needed to deliver the PSS.

The **conceptual model** is a schematic representation of the concepts a user should understand in order to be able to interact with the system. An **interaction mood board** describes the staged context through visual compositions of colors, materials, expressions, etc. that together convey the look and feel of the system. **Interaction metaphors** are used to turn a novel interaction into an intuitive and comprehensible one. Use the **narrative** to present the final concept to the stakeholders. It is a report of connected events, actual or imaginary, presented in a sequence of written or spoken word and still or moving images. The **process map** is a systematic diagram that shows the activities needed to deliver the product-service from the business point of view. Once the process is mapped out, it is much easier

to explore the capacity and the limitations of both product and service and where there might be a problem. This will allow to clearly defining the required investments and the strategy for growth of the PSS. Estimate for each step what is needed to actually perform the task: Who will carry out the task (e.g., person(s)/role(s), computer, system, etc.)? How much time will this take? What is needed to perform the task (e.g., inputs, tools, environment, etc.)? Identify the bottlenecks, typically causes by capacity and timing issues and improve the process to solve them.

7.2.21 Open-ended release & feedback - precondition 21

The goal of designing the critical components with an increasing level of fidelity is to focus on getting a good understanding of a concept's core functionality before moving on to the bells and whistles that might be required (question the level of fidelity required at every iteration of the concept, some parts can be more detailed than others). Another method is to deliberately prototype product-services to provoke emotions or reactions among the stakeholder group, and facilitate 'lip-loosening' conversations. Unfinished prototypes make it more clearly to the stakeholders that it is work in progress, enabling people to react more freely. Prototypes are learning material, later on they become the showcase of the end-result. We anticipate you will end up with a very different kind of briefing for implementation and a solution that clarifies tasks, responsibilities and benefits for all possible stakeholders, and they will have a better understanding and verified interest in the PSS.

Appropriate fidelity prototyping questions 'prototype fidelity' throughout the entire design process. A design team should be aware of what the goal of a prototype is at every stage in the design process. **Low-fidelity prototyping** is used to test the solutions fast and at low cost. **Medium-fidelity prototyping** provides enough detail to enable the testing of the main functionalities and interactions, it is clear what to build, but it is still a search for the most optimal interaction design. **High-fidelity prototyping** comes close to a final product and/or service, able to examine usability questions and make conclusions about how behavior will relate to use the system. Finally, to get feedback from 'real' stakeholders at specific points throughout the design process, there are a couple of options. Deliberately make prototypes of products and/or services to trigger emotions or reactions amongst the stakeholder group, called **provocative prototyping** and requires less time-intensive methods. Similarly to **make believe**, by pretending that something is real, one can trick stakeholders into believing that a prototype actually works or that a service is real in order to experience what it would be like to have it in place. Ultimately, during the **user test** the future PSS is tested with real stakeholders using prototypes in a context as real as possible. The intention of the test is to efficiently learn in practice what works and what doesn't work before actually building the system.

7.3 Conclusion

Many people are interested in the tools and its hands-on approach of design-related methods. A PSS approach tends to open up knowledge and empathize with the user and his/her context. It strengthens, professionalizes and supports the innovation process and makes it more adept to technological, economic and societal trends. The aim is often to perform research and create relative knowledge, externalizing it throughout the organization to make it more implementable. Already in the (early) strategy making of a company. Integrating five research cycles brings us toward a formalized process of tools and conditions that establish a sense of urgency and highlights the need for change, developing a vision and strategy for innovation integrating both products and services.

We refer back to Table 2.8 to relate the PSS design toolkit and its individual support to the twenty-one process preconditions, and its contextualization by the experts. The table provides the opportunity to read in two directions, from strategic over tactical to operational and vice versa. Taking into account 1 or more specific conditions, one can easily see which tools are necessary to address it on an operational level. Whilst designing, one could see what the actual objective is on a more tactical and strategic level for an improved communication.

We conclude this chapter and link back to the main research question.

This chapter integrates the knowledge from our five research cycles, enabling a layered and fully complementary view on the synthesis approach for executional interventions at the strategic, tactical and operational level when dealing with the PSS design process, its tools and an integrated mindset.

In sum, we provide appropriate support for an operational integration of the product and service side in the PSS design process. For this purpose, we bring forward the process preconditions in relation to the PSS design toolkit to arrive at relevant prescriptions and an actionable approach, both part of the improvement of the synthesis approach.

CHAPTER 8

SYNTHESIS

8.1 Synthesis of the study

On a daily basis, technological changes, social issues, environmental consequences and wellbeing challenge public and private organizations worldwide in general, pushing user expectancy levels toward new standards. As such, organizations need to systematically rethink their businesses.

Rather than designing single products (the traditional basis of product development), the wicked problems that companies face in their daily challenges require a much broader view and seem to be forcing them to explore new paths for innovation. The field of product development and innovation are undergoing this prominent evolution, into the design and development of product-service systems. From traditionally being very goods-dominant, PSS enables the creation of innovative interactions between consumers, the products and services they use and the providers offering the system.

Following the plea for methodical structure for doing design research to contribute to the design discipline itself (Beck & Stolterman, 2016; Cross, 2006; Horváth, 2008; van Aken et al., 2016), we thus used 'framing methodologies' as a strategy for our research design. Both *Research in Design Context* (RIDC) and *Design Inclusive Research* (DIR) provided a methodological approach, structure, process flow and set-up of research actions (Figure 8.1), a basis for the conceptualization of our research strategy.

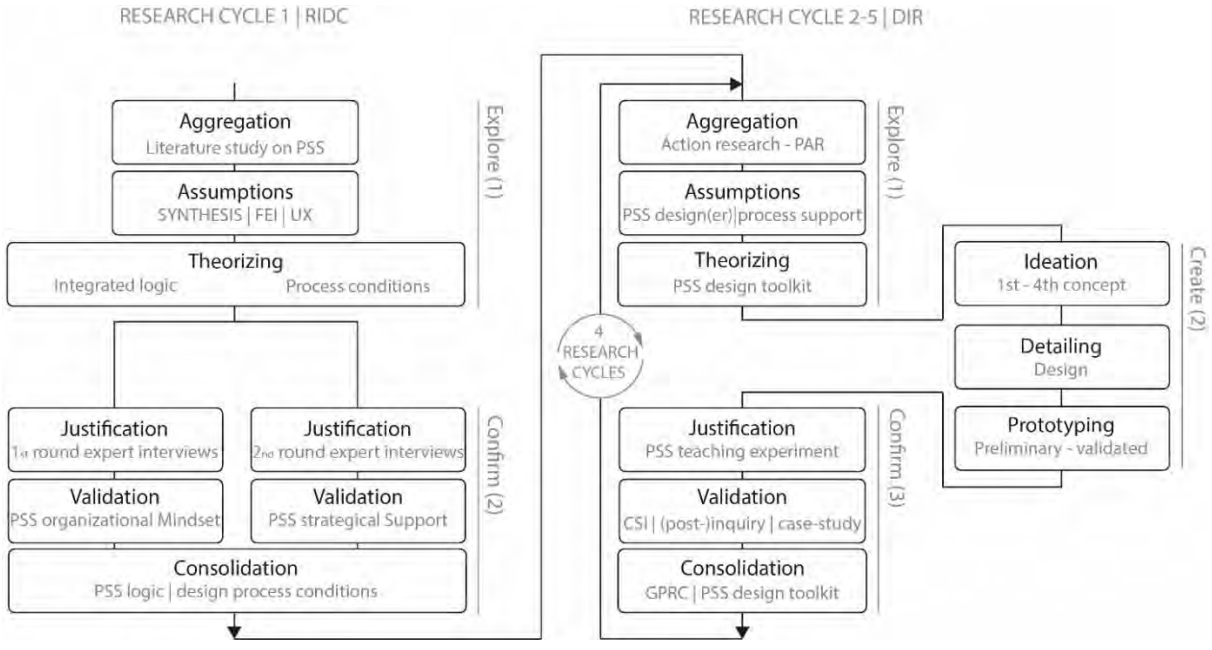


Figure 8.1 | Research cycles 1-5 (condensed view)

The systematic structure allowed us to explore, create and confirm PSS design knowledge in the context of design (RC1) and by involving design in the research itself (RC2-5). Our theories were justified, validated and consolidated under specific conditions and in a multifaceted manner, proving our assumptions true and reliability of the data and results.

Based on RIDC from Chapter 2 (see Section 8.2.1), we were able to confirm our assumption for Research Cycle 1, resulting in a **PSS logic** and PSS **design process conditions**, that can have an impact on strategic and tactical level in the organization: *In support of the synthesis approach, a focus on the Front-End of Innovation and User Experience will (1.a) add to a better understanding of PSS, and (1.b) complement the current product-service transition.*

Based on the DIR framing methodology in Chapters 3-6 (see Section 8.2.2 to 8.2.4), we had the opportunity to build, apply and verify our results from Research Cycles 2-5. It results in an operational **PSS design toolkit** that confirms our assumption for this part of the research: *A synergistic interaction between products, services and people in a PSS requires a reinterpretation of existing design approaches that positively influences (2.a) the design process, (2.b) the designer and (2.c) ultimately the design itself.*

As a result of RC1-5 (Chapter 7), an **integrated PSS design framework** can be used in an instrumental way to design and implement a PSS design process to achieve desired outcomes (Simon, 1997). Consequently, this is an answer to our initial and main research question: *How can a synthesis approach be strengthened or advanced?* The synthesis approach directly contributes to design knowledge. Our design research investigates how people design, and how that might best be nurtured in design education. We also studied the process of design (design praxeology), the development and application of processes, tools and techniques that aid the designer. And finally, as a result from design practice, our knowledge resides in the output of the design process, interesting, because a design contains knowledge of what things should be (Cross, 2006).

This dissertation explicitly adheres to an integrated reasoning on the process of PSS design. As a research concept and phenomenon, we emphasize that PSS requires a ***synthesis approach*** to cope with a design process that has wider boundaries, a different context and other output expectations for organizations dealing with evermore-complex issues. In order to do so, organizations are required to methodically rethink their design processes to intentionally integrate both product and service components into a system. Therefore, we have created an integrated PSS design framework, its preconditions and actionable toolkit to enable synthesized thinking and doing, instead of maintaining the dichotomy. Central in this design research, the ***synthesis approach*** merges this diversity of disciplines and their underlying processes and emerges characteristics of innovation that did not exist at the underlying level, or were not recognized in the preceding approaches. Synthesis accentuates the context, mutual relationships and the whole, symbolizes a more integrated approach to problems, and a total view instead of the fragmentary.

8.2 Contributions to the theory of design and the act of designing

Both the theory of design and the act of designing are constituents of Design Science (Cross, 2006), both co-exist and are interrelated through knowledge. Technically speaking, design knowledge resides partly in informal knowledge (intuitive and common sense), and partly in formal knowledge (scientific and disciplinary). Supported by our empirical findings and experience by interacting with organizations in students' design projects in a PSS context (Webster & Watson, 2016), **we present the most important findings in relation to its contribution to design science and design research** (Chapter 1). We pay specific attention to its relevance for practitioners and academics in the field of PSS design.

8.2.1 PSS logic and design process preconditions

In an attempt to strengthen the synthesis approach, we delineate the rise of the product-service system and identify the foundations for integrated PSS design. Systematically combining theory and practice enabled us to develop an insight on how to increase a company's support of the PSS design process. Studying the phenomenon in design context (Chapter 2), we considered two alternative courses of action to bridge the gap, design knowledge about 'integrated logic' and 'process preconditions', both to be confirmed with empirical data from our conducted expert-interviews. We have put an effort in characterizing product-service terminology, drivers and the accompanying transition dynamics (pathways).

An organization requires a PSS mindset in order to provide appropriate support for an operational integration of the product and service side in the PSS design process. If not, middle management will all too often be confronted with accountability, implementation (e.g., industrial release) and performance (e.g., production process), instead of 'PSS' as such. Another argument for concentrating on the user's experience (with the PSS) as the distinguishing factor opposed to predominantly economic or eco-efficient motives.

If the organization really is curious to know what customers or users want and say, than they just cannot start with a predefined end in mind at the beginning of the process. (expert)

Product-service systems set other focal points and different expectations, therefore the same KPI's for product and service do not work ((e.g., process precondition 6, 7 and 8). The process benefits from **continuous evaluation and selection in function of filters, rather than in function of solutions**. For evaluative or design process support purposes, the twenty-one preconditions can be applied as **checklist** when moving on to the next level, or as a **discussion tool** that considerably adds to the design process (Valencia et al., 2015). It's also interesting to observe how these twenty-one preconditions are currently in place and whether or not they are still relevant after some time (Dewit, 2016). The related PSS design preconditions framework is compatible with the PSS design toolkit, and together its findings are relevant and useful in other theories used for the integration of products and services.

A systematic combining logic provided a clearer view on how to approach and confirm our research assumption for this part of the research: *In support of the Synthesis Approach, a focus on the Front-End of Innovation and User Experience will (a) add to a better understanding of PSS, and (b) complement the current product-service transition.* Thus contributes to our main research question on how to advance the synthesis approach.

8.2.2 Design process

Based on our assumption for Research Cycles 2-5, we focus on the influence of the PSS design toolkit on the design process in general. **One of our main concerns here was whether we were making the PSS design toolkit (our Creative Support Tool) actionable for its target audience. Can we ultimately speak of a synergistic interaction between products, services and people?**

The PSS design toolkit takes its user(s) through three phases of the FEI, a first to understand the purpose or goal, a second to explore the character of product, service and system, and a third to simulate and define them in the environment in which these perform together. Following a reasonably structured process seems to lead to greater design success, the key is to keep the approach flexible (Simon, 1997).

Each step in the PSS design process aims to motivate activity, which in turn will generate new goals and situations, constantly providing a fresh starting point for design activity. New prospects are opened up, envisioning possibilities and elaborating on them is a valuable experience in itself (Simon, 1997).

First, during the '*understand*' phase, framing and reframing are used as a process of pattern synthesis, a continuous effort to understand relationships and interactions between people, places, artefacts etc. (Kolko, 2010) (e.g., tool: context map). **Framing** the situation becomes the technique to organize the structure of inference making (Klein & Moon, 2006), and the setting of some problems to be solved (Schön, 1984). However, project briefings or problems can be rather vague, and it is because of the designer suggesting possible solutions that the clients' requirements and criteria become clear. The designer's very first conceptualizations and representations of the problem and solution are therefore critical to the procedures that will follow. For that reason, the design process should be comprehensible for all (Cross, 2006). With PSS, the client will be seen as a player in the game, with a possible redefinition of its role in nowadays' more complex and user-centered society (e.g., tools: context map, stakeholder dimensions, etc.). **Reframing** attempts to replace the above frame in a new perspective, with an emphasis on finding relationships and patterns between elements, and forcing an external view of things in a new context (Kolko, 2010). These patterns will enable the designer to assign value(s) to incomplete paths, the next point for exploration (e.g., tools: factors and themes, value proposition) (Simon, 1997). Specifically with the notion of ill-defined (or wicked) problems, designers should be apt to deal with the complexity that comes with designing PSS. Their mode of problem solving is solution-focused, their mode of thinking constructive by nature (e.g., tool: design challenge and requirements).

Secondly, when learning about the nature of the problem, designers *'explore'* and suggest the nature of its possible solution or things of value, which do not yet exist. Going through a number of requirements (e.g., tool: design challenge) and addressing them as sub-problems, designers are able to recognize emergent features and sequentially develop properties of a possible solution concept. Another possibility is to use exploration as a way to make the shift to (new) alternatives (e.g., tool: lotus blossom, paradoxical thinking). This will avoid the designer to arrive at only one proposal and a very biased view. This is why it is important to have at least two radically different solutions. The role of the conjectured solution is a way of gaining understanding of the design problem, and the need, therefore, to generate a variety of solutions precisely as a means of problem analysis (Cross, 2006) (e.g., tool: solution spaces). This tool will assist the designer to enable an exploration of constraints and requirements, in terms of converging on a matching problem-solution pair. The way in which we evaluate and select solutions, adequately grows together with the structured approach of the PSS design toolkit, gathering information, and prioritizing criteria. Considering all the possible solution

spaces that meet the constraints of the design challenge, the designer must find the particular solution concept that meets the requirements of the goal and maximizes the utility function (Simon, 1997). Unless provided by the designer, the set of alternative solutions - to compare with - is not given. In addition, s/he must try to represent the differences between the desired and the present, using satisfactory methods. These methods make use of comparisons between designs in terms of better and worse but seldom provide a judgement of best (e.g., tools: COCD, selection matrix; process precondition 21).

Thirdly, as a result of trying out a wide range of acceptable solutions, the designer can *'define'* its limits (Cross, 2006). As designers are accustomed with the ability to translate abstract patterns of user requirements, organizational and social needs into concrete patterns of an actual design, we consider the PSS design toolkit to guide designers through its process in support of this creative leap. The constant process of diverging and converging, appropriate fidelity prototyping and frequent checks with relevant stakeholders and how it affects their engagement in the PSS, are the building blocks of the final concept. Also typically to the topic of PSS and its evolving nature, the designer has to take future flexibility into account. This is why we have added this quality to the definition of PSS:

> *The PSS aims to sustain the ecosystem and allow continuous growth, essential to keep the PSS alive and enable the transition that goes beyond the design itself.* (Dewit et al., 2018)

The PSS design toolkit (e.g., solution spaces) enables the designer and the client to think about the modularity of the offering, the choice for deliberate component distribution of product and service, and leaving room for prolongation (e.g., process precondition 20 and 21).

Ultimately, we assert that four iterations of the PSS design toolkit have strengthened the integrated design process and contributes to design knowledge in general. Hence, it confirms our research assumption for this part of the research: *A synergistic interaction between products, services and people in a PSS requires a reinterpretation of existing design approaches that positively influences (2.a) the design process.* Thus contributes to our main research question on how to advance the synthesis approach.

8.2.3 Design education

Based on our assumption for Research Cycles 2-5, we have tested the influence of the PSS design toolkit in design education, with a focus on the people (students) that are actually going through the design process. **Our concern here was whether we were making the right Creative Support Tool. How does the PSS design toolkit support the designer and does it affect his/her skills and mindset?**

The increasingly blurring boundaries between product and service, harsh competition on customer value and more complex societal issues force companies to a more integrated logic. As a result, also designers must now be capable of designing these integrated offerings (PSS). To integrate both product and service effectively and cope with nowadays' increased complexity, a tailored approach to design education is required in order to move with industry demand. Product-service system design aims to providing a structure through which a successful conversion can occur (Ryan, Tormey, & Share, 2013).

In his book *designerly ways of knowing*, Cross (2006) describes some **principal criteria for design education**; (1) valuable knowledge must be transmitted, where manner and matter are important, (2) student's self-awareness and awareness of what and why s/he is learning, deliberately designed to enhance & develop students' intrinsic cognitive processes & abilities, and (3) related to cognitive perspective, students' behavior that is connected to the ability to know how to go through the PSS design process, that is valued as much as the outcome. We assert that the PSS design toolkit tends to address these criteria, respectively through the topic of PSS and its integrated design process, multiple (peer-) evaluations, a logbook to keep track of individual and group decisions and effort. Finally, a systemic lens that makes the student connect with something more or at least different from before in their design practice.

In line with the subject of **representation** (more profoundly discussed in the subsequent Section 8.2.4), a designers' process remains largely tacit knowledge (even for the designer). The continuous process of interaction between different modes of cognition is difficult to externalize. It's important for design students to explicit their *doing, making and inventing* to provide a better understanding of the process, and enabling communication with others or even across fields by means of a tangible trace (Cross, 2006; Simon, 1997).

In contrast to intuitive procedures, design education concentrates on teaching more rational, systematic approaches, codified into 'design methods'. However, it may appear that skilled designers in practice often proceed in a rather ad-hoc and unsystematic way, a **systematic approach** can be helpful to students. Radcliffe and Lee (1989) found that the use of more 'efficient' design processes correlated positively with both the quantity and the quality of the students' design results. We cannot compare our results to any ad-hoc tools or other way tested in the IPO Project - Integrated Systems. However the results from the CSI psychometric evaluation do compare the effect of the PSS design toolkit opposed to an expected level of creativity support for e.g., the factor *'results worth effort'*, coming out as one of the more important factors. We also triangulated these results by means of the post-inquiry, where seventy out of one hundred and nine students stated that they would not be able to produce the same result without using the PSS design toolkit. We can conclude that the students need a strategic approach to the overall process, based on controlled practice and the development of technique. Combined with our earlier argument on representation, we deem this PSS design toolkit and its process not only complementary, but a necessity for design students to take this skill into practice after. However, following a reasonably structured process seems to lead to a greater design success opposed to rigid, over-structured approaches. The key remains the flexibility of the approach (Cross, 2006). It's not necessary, nor realistic to follow and execute all PSS design tools, but at least for each step reflect on whether there is enough understanding of the whole and the parts to proceed along the process (Dewit et al., 2018).

Design students also have to take another point into consideration and instead of pushing that, the PSS design toolkit helps them to **postpone a definitive choice of design ideas**, necessary to enable the possibility of alternative solutions. This comes down to the readiness to leave the first idea behind, for this we refer to The Fringe Benefits of Quitting[22]. The initial design ideas exert a dominant influence on subsequent problem-solving directions, even when severe problems are encountered, a considerable effort is made to make the initial idea work, rather than to stand back and adapt a fresh point for departure. Novices often pursue a 'depth-first' approach to a problem, sequentially identifying and exploring sub-solutions in depth. They can also become 'fixated' on a particular solution possibility. Experts usually pursue predominantly 'breadth-first' and are more willing to reject an early solution in the design process (Cross, 2006).

Concerned with how things ought to be, the skillset of the designer has to enable the creation of prospective products, services, and in our case even systems, a context that requires a breadth-firth approach. A **systemic lens** comes with wider responsibilities to society, since a multiplicity of stakeholders is affected by its reframed context. When considering design criteria, the designer has to outweigh value for the client with the more complex world in which we actually live, the individual needs or the end-user and the possible externalities to society (Simon, 1997).

Finally, just as realized plans may be a source of new experiences, so **new prospects are opened up at each step in the process of design**. Designing is a kind of mental window shopping, purchases do not have to be made to get pleasure from it (Simon, 1997).

Through iteratively experimenting the various instantiations of the PSS design toolkit in design education, we were able to observe a positive influence on the designer to the design process in support of the designer. Thus, we confirm our research assumption for this part of the research: *A synergistic interaction between products, services and people in a PSS requires a reinterpretation of existing design approaches that positively influences (2.b) the designer.* Thus contributes to our main research question on how to advance the synthesis approach.

[22] Liz Danzico - https://vimeo.com/91852710

8.2.4 The topic of design and representation

Dealing with a more complex context of PSS, we applied a multidisciplinary approach to the creation of the PSS design toolkit. Our assumption for research cycles 2-5 stated, that **applying the PSS design toolkit (design process)** in the IPO Project: Integrated Systems (design education) **would have an influence on the output (the design itself)**. When integrating tools with a background in systems and systemic design, interaction design, and human centered design, it is essential to communicate the whole, human interaction and intangible aspects of the system.

According to Maussang et al. (2007), one of the main challenges regarding PSS tools in general, is the lack of clear representation capabilities during the process. Presentation and visualization often involve communicating and demonstrating the value of intangible aspects that are, due to the lack of experience in developing integrated PSS offerings, difficult to understand (Kowalkowski & Kindström, 2009). **Visualization techniques play a critical role in the front-end of innovation**: immaterial elements of the project need to be captured together with the storyboards that explain their relevance (Morelli & Tollestrup, 2006). Unfortunately, most existing studies on PSS process visualization are based on tools such as the Service Blueprint (Lim, Kim, Hong, & Park, 2012), whereas the structure of PSS process visualization should be designed with a broader scope of PSS in mind. Compared to words alone, insights and abstract matters are best conveyed through different kinds of representations and rapid visualization to give stakeholders a concrete view on the future solution, because of its integral nature (De Lille et al., 2012). Therefore, Ceschin et al. (2014) zoom in on the necessity of PSS process visualization, aimed to: (a) explore the interest of potential partners in a solution idea, by presenting the idea and its possible benefits; (b) make new partners converge upon an idea, defining, for each actor, tasks, responsibilities and benefits; (c) verify the interest of potential users; and (d) promote the final solution.

Everything around us (e.g., clothing, furniture, machines, communication systems, etc.) has been designed, and the quality of that design effort profoundly affects our daily lives. Therefore, the skill to produce efficient, effective, imaginative and stimulating designs is important to all of us. Externalizing the designer's way of thinking - especially in the earliest stages - makes the design process comprehensible and thus more valuable for everyone involved. When reading Nigel Cross (2006) on the topic of representation, we can connect his reasoning to our arguments for the 'visual'. He reasons that there may be distinct limits to the amount of verbalizing in design ability. Nonverbal thought and representation aids internal thinking and communicating ideas and instructions to others. The reliance in design upon e.g., sketching, drawing, modeling, diagrams, cognitive mapping and flowcharts supports the generation of solutions and the very processes of thinking about the problem and its solution. Drafted concepts are there to be criticized, but are also part of exploration. This **'representation' enables designers to handle different levels of abstraction simultaneously, exploring constraints and requirements, and promoting the recognition of emergent features and properties of the solution concept**, even the unintended consequences (e.g., process condition 14 and 20), and the surprises that keep the exploration going in the reflective conversation with the situation (e.g., process condition 6).

Herbert Simon (1997) confirms the above view, but extends it with the necessity of **representation when it comes to complexity and systems thinking**. Thus also putting emphasis on the need for knowledge and techniques for dealing with that, and to achieve simplification with the right representation.

> Solving a problem simply means representing it to make the solution transparent. If the problem solving could actually be organized in these terms, the issue of representation would become central (Simon, 1997).

Within PSS design, we aim at discovering a process description of the path that leads to a desired goal. *"Given a blueprint, to find the corresponding recipe"*. Simon (1997) also gives a second respectable argument in support of how we approach PSS, being the ability to communicate across fields. Dealing with a multitude of stakeholders and designing with a systemic lens, designers have to be explicit about what is involved in creating a design and what takes place while creation is going on, e.g., our own thought processes, evaluating, selecting, defining, etc.

Jon Kolko (2010) provides an even clearer argument when it comes to 'communication'. If designers describe their process as a way of organizing complexity or finding clarity in chaos, they have to go beyond the mere attempt to organize, manipulate, prune, and filter gathered data into a cohesive structure for information building. Kolko (2007) also elaborates on 'synthesis' (opposed to analysis) as an essential part of design, it reveals a cohesion, and pushes toward organization, reduction and clarity in a continually forward growing design (process). He argues that aspects of the design process such as drawings are visible to non-designers, but specifically the 'synthesis' part is often a more inward-looking activity, less obviously understood, or even completely hidden from view. So when synthesis is conducted as a private exercise, there is no visible connection between the input and the output, and often even the designers themselves are unable to articulate exactly why their design insights are valuable. In any case, **the relation between design research and design ideas should be clear**, otherwise the client is not aware of the various internal deliberations that have occurred and then doesn't see the value in a discovery phase and will discount its value. If they do not see anything of value, they assume the phase to be a waste of resources.

This is exactly why PSS design aims to put representation central throughout the entire process, as an exercise together with the client, stakeholders, end-users, etc. The PSS design toolkit provides its user(s) with the rationale of the phase s/he's in, some instructions, inspirational examples and a customizable template in order to map it all out. At first, large sheets of paper will appear messy, yet the designer will have made substantial progress. S/he will have identified themes, and will better understand the problem s/he is trying to solve, moreover the designer will have discovered the whole (Fallman, 2003). Connecting these insights, we claim to bridge or at least address the lack of formality with the PSS design toolkit, producing physical output, themes, and design ideas that are not arbitrary when compared to the research data. It should be rather immediately clear how one derived the one from the other, and **besides representation, also formalization is necessary**. The PSS design toolkit aims to provide a structured process, comprehensible output and is supported by understandable documentation.

With the PSS design toolkit, we hope to stress the necessity of a formal period allotted for this core process of insight development, with formal deliverables associated with these methods. Once externalized, the ideas become real and they become something that can be discussed, defined, embraced, or rejected by any number of people. Kolko (2010) elaborates on tangible representation, and defends the use of (paper) templates, big sheets of paper and blank walls. For the designer, making data tangible in the physical realm in one cohesive visual structure (e.g., the tool templates), the designer is freed of natural memory limitations of the brain (cognitive realm) and the artificial organizational limitations of technology (digital realm) and enabling him or her to see the entire set of data at one time.

The output of the design process, and the amount of effort students have put in the final result is of value itself. However, it also conveys an interesting message on representational value of the design process as well.

Growing steadily in its approach, the PSS design toolkit has the goal to externalize the different modes of cognition that the designer goes through (by means of a formalized design process and its templates), positively influencing communication of the design(ed) output to different stakeholders. Consequently, we confirm our research assumption for this part of the research: *A synergistic interaction between products, services and people in a PSS requires a reinterpretation of existing design approaches that positively influences (2.c) the design itself.* Thus contributes to our main research question on how to advance the synthesis approach.

8.3 Propositions

The reasoning for propositions may come from three main sources of this design research: theoretical explanations, past empirical findings, and practice or experience (Webster & Watson, 2016). The succeeding propositions summarize the theoretical contributions of this design research. Supported by our empirical findings and experience in interacting with projects and organizations in a PSS context, we pay specific attention to its relevance for academics and practitioners in the field of PSS.

Table 8.1 | Research propositions

Proposition 1	A synthesis approach complements the current product-service transition and adds to the field of PSS, ensuring a synergetic interaction of products and services in the system and thus creating more value for the customer.
Proposition 2	For a complementing 'integration', product and service sides need to 'flirt' early and 'date' regularly throughout the design process, we therefore advocate a FEI approach for PSS where the UX has an intermediate role throughout the entire process.
Proposition 3	We evolve toward an integrated logic, where intangibles reflect society's omnipresent share of the product-service provision in an ever more growing experience economy. More specifically, through integration - a clear understanding of - the user's perspective becomes a focal point in the integral nature of PSS as a substitute for the technological or process-oriented motivation for innovation.
Proposition 4	With a focus on the system in PSS, all stakeholders come into play; the one(s) providing / affecting the context, the ecosystem and those affected by it, the user - and his/her resulting experience through interaction with the system's components.
Proposition 5	The PSS pathways explicitly visualize and support with what type of approach an organization chooses to gradually integrate product and service.
Proposition 6	PSS hints the organization to move toward more long-term oriented thinking to achieve its objectives. In order to provide the capability for growth of the PSS together with changing needs of the user, C-level management (and resources) must enable the capacity to lock in and prolong the interaction with the user.
Proposition 7	The research provides understanding of the front-end preconditions that lever PSS design capacity for both manufacturing and service provider context. It thus provides a current situation of an organization that serves to establish a change in the current process of designing new products or services.
Proposition 8	PSS design requires 'staged' gates that symbolize a constant discussion and convergence attitude, preferably in filters of continuous evaluation and selection, rather than in filters of functionality.
Proposition 9	Supported by the twenty-one PSS preconditions, the integrated PSS design framework provides a demonstrative process to consecutively design a system that integrates products and services, in order to achieve a valued outcome from the user's perspective and iteratively revealing related lifecycle implications.
Proposition 10	The PSS design toolkit provides a process for early representation, enabling the demonstration of value of integrated PSS offerings and its intangible aspects.
Proposition 11	The PSS design toolkit plays a critical role in the FEI, also the immaterial elements of the project can be iteratively revealed in the process to explain their relevance.
Proposition 12	The structure and process of the visualization of the PSS design toolkit has a multidisciplinary scope in mind.
Proposition 13	Different kinds of representations in the PSS design toolkit verify the interest of multiple potential users and stakeholders, providing a concrete image of the future solution.
Proposition 14	The PSS design toolkit supports future generation designers in (deep) exploration of the context and management of an increasingly complex design process.

8.4 Discussion

8.4.1 Design research

Without neglecting the benefits of other research designs and methodologies, we have applied design research (Section 1.3) as a means to contribute to the theory of design and the act of designing on PSS.

"There are things to know, ways of knowing them and ways of finding out about them that are specific to the design area." (Cross, 2006)

8.4.2 Limitations of the study

Below, we discuss the potential limitations in our research design, how they affect the interpretation and quality of our data and the ability to generalize our findings.

As discussed in **Chapter 1**, there is no such thing as applying product-service systems in the 'field of design', which as category or research area does not even exist in Web of Science, the term 'design' can cause misinterpretation quite easily. Because of the chosen terminology, it seems to reflect only one specific research area – design, whereas this research on product-service systems actually has its multifaceted reach within a diverse set of scientific categories. It is not our intention to over-claim the results of this study, but not surprisingly 'design' is usually a part of every innovation process and has a unifying factor among the more established 'sciences'. Therefore, we integrate the concept of 'exploration' (opposed to the exploitation) into our methodology to explore new PSS ideas, and focus on the FEI, user experience and synthesis approach, thus limiting the scope of our study.

Using a purposeful sampling strategy in **Chapter 2**, the results can be subject to bias and we do not attempt to generalize its results. The subjects in this small (five) nonprobability sample were selected on the basis of their accessibility and purposive personal judgment (Section 2.2.2). We did not highlight individual background or original/specific domain knowledge the interviewees stem from, because we focus on a synthesis approach. The results were presented as joint findings - focusing on the transition toward PSS.

In **Chapter 3**, we justify the PSS design toolkit on the basis of how it has been made and its effectiveness by means of a teaching experiment (Gravemeijer & van Eerde, 2009). When referring to the term *experiment* throughout this dissertation, it should not cause any confusion with the 'true experiment' used as scientific research method. Firstly, we did not use a control group along with an experimental group; we are not comparing a pre-given form of experimental design education with a traditional setting. And secondly, opposed to logical deduction, the justification of our design does not concern truth, but effectiveness: this is our design (an answer to a design problem), this is how we have tested it in various contexts, and this is how the design solves the problem or satisfies given specifications (van Aken et al., 2016).

Chapter 4 covers the validity of the PSS design toolkit, proves that the PSS design toolkit works and produces the desired results. The usage of CSI shows stable and reliable results on the creativity support of the PSS design toolkit (discussed in Section 4.3.1.4), and specifically for *exploration, results worth effort and expressiveness* the post-inquiry confirms those results. However, given that our data is based on self-reports of student perceptions, we acknowledge that it is possible the tool did not help them at all, and they only thought it did. Furthermore, the CSI only measures creativity support (whether the process/tool creatively supports the designer during their process) and does not quantify or evaluate creativity; the design being valuable, new and surprising (Grace, Maher, Fisher, & Brady, 2015). Consequently, yet also subject to perception, it remains difficult to claim the real quality of the design. Therefore, we cannot claim any reflection of this quality apart from a formative evaluation (by the expert panel and involved companies) of the design and its process of their final grade and the CSI's factorization results of the PSS design toolkit supporting creativity.

Chapter 5 is about the practical relevance of the PSS design toolkit. The cases demonstrate the effectiveness of the PSS design toolkit during the teaching experiment, but also proves to contribute to the field of PSS (both peer-reviewed proceedings). However, we do not follow an exploratory case study approach (Eisenhardt, 2011; Yin, 2016), discussed in Section 5.2.2. Consequently, we do not aim to develop a science of the average, nor do we want to generalize its findings. Rather, by presenting these two cases, we try to build a science of the particular and produce insight (thick descriptions) and analyses of problem, context, interventions and outcomes in what is case-specific.

In **Chapter 6**, we have presented the final version of the PSS design toolkit, which has been subject to the GPRC procedure. The GPRC label reinforces the transparency in the production of academic books, and ensures that the content has been peer reviewed according to international academic standards (Verleysen & Engels, 2013). However, it remains a quality label that has been awarded by the Flemish Publishers Association the GPRC label in Flanders and therefore subject to a discussion on its international relevance and generalization possibilities.

Chapter 7 brings the twenty-one preconditions and related PSS design conditions framework in close relation to the PSS design process to enable this shift and its necessary support. We do not claim to create new theory, rather we aim to integrate our knowledge and extend existing theories on PSS. In addition, the PSS design toolkit offers tools and techniques that alternate between whole and particle thinking. A logical and rational process has been set up, however, it is not necessary – or realistic – to follow and execute all of the tools. Nevertheless, one should at least reflect on each step whether there is enough understanding of the whole and the parts to proceed.

Obviously, there are some general limitations with respect to the fields of application. In a related study (Coreynen et al., 2017), we found that companies experience barriers that are generally related to either design or rollout. For instance, in terms of PSS design, goods-dominant companies value mainly tangible forms of innovation, and in terms of PSS rollout, such companies lack both the culture and structure to implement new service business models. Moreover, an organizational logic in support of a transition toward PSS is noted as the necessary basis, and without such a logic, the company is unlikely to make progress in either PSS design or rollout. Therefore, also other factors, e.g., the institutional context, the strategic implementation and change management approach have to be taken into consideration in order to have an impact on a successful PSS transition.

8.4.3 Consolidation with other theories on PSS

Throughout the progressive integration of product and service, there has been a clear movement away from the real root(s) of PSS (Haase et al., 2017). It feels like there is a rebound effect on the terminology and use of PSS itself. Business modeling, 'eco'-efficiency and cost reduction feed the same mouths now as they did before. Therefore, we asked experts on the matter of PSS what they and their customers think and feel about evolution of value creation as part of the rise of the product-service system itself. It seems clear that we have moved to meaningful innovation where the user's experience, the ecosystem and society at large is to profit from any organizational aim whatsoever.

In this research, we have concentrated on the delivery of value to the customer as the distinguishing factor to provide support for product-service integration. Nevertheless worth mentioning (but out of the scope of this PhD), sustainability, business, and digitization are inevitably related with the design of product-service systems. Currently, it is hard not to bear the design related externalities or rebound effects in mind. Beyond the necessity of exploration, every organization will confront the PSS with an exploitative lens, economic motive, focusing on implementation and performance. It is undeniable, that product and service have grown toward each other because of evolutions in smart sensors providing data for every stakeholder, but also an interface side that has taken the form of screen-rich applications and other types of interfaces. For every lens, we provide a short rebuttal how our design research can have a positive effect, in an attempt to merge these theories in future research.

8.4.3.1 Consolidation with business

On several occasions, we took the opportunity to talk with *Linda Ryan* on the topic of PSS and integrated logic. Linda Ryan works both academically and professionally in the field of PSS, her PhD (at the Institute of Technology Sligo) is about *facilitating the transition from goods to service provision* and is she is now Lecturer in Design Innovation at Maynooth University, Ireland. Besides her lectureship, she's also Director of https://www.designintervention.ie/ providing mentoring, training & consultancy services for the private & public sector, specializing in: business strategy development through design thinking; UX/UI development, from user research to prototype; product development, from concept to design for manufacturing; and service development, from concept through user experience development to delivery.

She took the time to apply her specific lens on the PSS design toolkit and the possibilities or limitations of generalization toward industry.

Table 8.2 | Limitations for generalization (by Linda Ryan)

Time allocated	When it comes to the allocation of time, industry requires quick turnaround, workshops can't go into the level of detail of the PSS design toolkit. Often however, companies have a lack of insight into the specifics of alternative examples, this is primarily due to the lack of exploration in the early stages.
Terminology and theory	Industry is quite unfamiliar with design terminology, which can cause a barrier to understanding.
Structure	The PSS design toolkit (containing 'looser' steps) and its process, industry tends to think quite linearly. They need to see the overall process to understand what they are trying to achieve. Often, they are not used to an open format structure. The tools need to provide a structured approach with high levels of guidance and direction with clearly defined outputs from the offset.
Limited exploration	A significant section of the PSS design process is in the exploration of the user and their unmet needs. Due to time constraints, this section is significantly limited in industry as staff are focused on the in-house product/process and the key outputs. Often companies are 'scared' of engaging with customers in case of negative feedback, or they are too far from the front operations to have any insight into the customers unmet needs/wants.
Importance of team dynamics	Who sits on the team is vitally important in industry. Particularly the larger organization. As the work load is often divided between staff (front line and back line) and not all staff have the power to implement change (managers, owners, etc.), the teams must be carefully chosen for full representation of all departments of the organization to allow a complete picture of the PSS to be understood and captured, and for solutions to be implemented.
Follow the money and quantify the results	The focus on user value in the PSS design toolkit is relevant, but since industry is more monetarily focused, organizations struggle with the questions like: how much that user value really worth, what resources we have and need, how much the current solution costs in comparison with the new PSS, how long it takes to roll it out and get a return on investment? It's not enough to have a PSS which meets user needs, it has to be financially feasible, sustainable and profitable!

This brings us to a discussion on ambidexterity (Agostini, Nosella, & Filippini, 2016), which has been regularly debated and considered to be a crucial capability for long term firm survival and development (Stoimenova & De Lille, 2017). Organizations are confronted with the tension between exploitation activities that refers to refining and extending their existing business, while simultaneously trying to find new opportunities that correspond to exploration activities. The PSS design toolkit covers the explorative activities, but also offers the opportunity to switch sides (of the book) and engage in PSS strategic rollout for a more exploitative approach to PSS.

8.4.3.2 Consolidation with sustainable PSS

During the industrial product-service systems (IPS²) conferences, we have met a lot of interesting people that were eager to discuss the approach of this design research and connect their knowledge on PSS with ours. This is also how we were introduced to Louise Laumann Kjaer, who also works both

academically and professionally in the field of PSS. She did her PhD in *Product/Service Systems from an environmental perspective* at the Technical University of Denmark. She developed guidelines for evaluating the environmental performance of Product/Service-Systems (PSS) based on Life Cycle Assessment (LCA) methodology. Her type of PSS are performance-based business models that can facilitate transitioning to circular economy and more sustainable ways of fulfilling needs - for both businesses and consumers. However, the potential environmental benefits are not a given and proper evaluation methods are needed in order to support the development of sustainable PSS. Her work has a strong focus on the Maritime Industry, viewing PSS from a customer perspective. After frequent talks and exchanging toolkits, she concluded with the following:

I think it could be very interesting to try to combine our insights and perhaps combine the two by identifying sustainability assessment tools that could "add another layer" throughout the design process. We could create some sort of matrix with the design process on one axis and the guide steps on the other axis and identify proper tools for sustainability assessment to be used within each.
(Louise Laumann Kjaer, 2018)

We can only foster these kinds of research collaborations, since the contemporary sustainability agenda worldwide has shaken everybody's conscience and we would definitely benefit from a consolidation of our PSS insights.

In relation to that, we were asked to contribute to a report from the European Union *'A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions'* (Crippa, M. et al., 2019). Below we shortly describe the paragraph that was included in this report with a reference to the PSS design toolkit:

"Early stage (FEI) product-service system design influences the interaction with the end-user, which determines (e.g., environmental) impact of the PSS during and after the use phase. The service component ensures a consistent value delivery through the multiple touchpoints where the user interacts with the provider. Furthermore, current value creating should be more systemic, usually and preferred combined in a multi-stakeholder platform or ecosystem, enabling an easier full lifecycle thinking and even increasing companies to capturing value. We hope to move beyond the dichotomy and more into the system. The aim is to both exploit and explore, building a foundation for new product-service systems that concentrate on the delivery of a meaningful value proposition for the customer, ecosystem and society with a focus on the integration. In order to consolidate this knowledge, we need to go way beyond the current PSS typology and related business models (Tukker & Tischner, 2004) that were initially aimed on sustainability and a decreasing level of products relatively to its counterpart, the service. With regard to typical industrial practice, we've seen business models slide from product-oriented, over use-oriented to result-oriented value propositions, and naturally this affects the (e.g., financial) structure of the related company, but it remains the same product in a different package and actually seldom with direct sustainable benefits. What we aim to reach with the above argumentation, is to design, develop and deliver product-service systems (1) by putting the user (as in 'the citizen' or end-user) at the central stage and thereby all of his/her interactions with the system. We can then directly cause behavior change in the way people interact with these PSS. (2) By facilitating change toward sustainable living, and ultimately (3) facilitating systemic changes in our contemporary consumption toward a truly sustainable society. Specifically PSS design allows us to shape that influence, where it is about an interaction with the system and its underlying mechanisms to put more subjectivism in our daily usage of things. If we have an active interaction with the system, it automatically increases our responsibility with it and imply a prolonged relation with its providers (Verbeek, 2011)."

8.4.3.3 Consolidation with smart PSS

Product-service systems (PSS) provide an opportunity to create innovative interactions between consumers, the products and services - in that sense hybrid by nature - they use and the providers offering the system. In contrast to traditional services related to products, the service component of a PSS significantly adds value to the experience of the consumer. We can also use 'smart' in relation to PSS, because advances in information and communication technology have made it possible to combine products and services in innovative ways. PSS are introducing several elements to a design process that require a thorough rethinking of how designers and other stakeholders should relate to this. The main challenge is to manage the variety of underlying design processes at play during the design of PSS: electronics design, software design, service design and product design (Valencia et al., 2015). By merging these disciplines, we stress the need for a design approach that copes with this increased complexity, and places the user experience and interaction as a central element instead of the technological possibilities.

Developing a methodology with tools and techniques for designing product-service systems, has to comprise systemic fundamentals that address societal issues on a higher level. Ecosystems and platforms (van Dijck, Poell, & de Waal, 2018) cannot ignore the possibilities of the 'connected', offering people more personalized services and contribute to innovation and economic growth of the PSS providers and society in general. Whether rent an apartment in a foreign city using Airbnb, hail a cab using Uber, or share the inner city electric step experience when unlocking your BIRD with a QR code, the aim is to optimize the user experience in exchange for valuable information for the stakeholders for a consistent and a trustworthy backlog, *e.g., changes to existing features, bug fixes, infrastructure changes or other activities*. As a way to retrieve feedback from *the* user's interaction with product and service, digitalization ensures visual compositions to convey the look and feel of the system in a close, prolonged and more intensive relation to the provider. Moreover, it allows all ecosystem stakeholders to align product and service in the offering, ensuring coherence and consistency over all its touchpoints and grow continuously together. However, the way sensors are now seamlessly entering our daily lives, aim to reveal how people are motivated and inspired and in its turn enables a matchmaking of actions, intentions and values with different technical and non-technical system-user connections and ultimately their design. If we trust on and increasingly depend on resources that require consistent connectivity, we must not overlook the purpose of the offering itself. Digitalization is not a purpose in itself, rather a means to provide a higher value for both the user and the ecosystem.

8.5 Meta-learnings and avenues for future research

An organization requires a PSS mindset in order to provide appropriate support for an operational integration of the product and service side in the PSS design process. Building on top of 'the existing' is main management logic, but with a focus on *exploration* in PSS design, we introduce a new logic that requires dynamic capabilities to guide organizations through the process of imagining and envisioning what the future value proposition might be.

Specifically with the complexity that comes with designing PSS, it is essential to communicate the whole, human interaction and intangible aspects of the system, handling different levels of abstraction simultaneously. It is about achieving simplification with the right representation, visible to non-designers and with the ability to communicate across fields. Designing PSS also comes with wider responsibilities to society. *Exploring* possible solutions concerns how things ought to be, the PSS design toolkit opens up new prospects at each step in the design process and typically postpones a definitive choice of design ideas.

Besides a change in understanding and learning, it is also important to acknowledge that for someone a PSS approach can be new, and that it in itself could bring some value.

Five generations of students that have used the PSS design toolkit are now in working industry. It would be interesting to see the professional effects of designers graduating with this knowledge, a follow-up study on the internalization of the PSS design philosophy, methodology and its tools. It will provide a broader look on design practice in terms of representation of PSS in the design process and usage of tools in daily collaboration or projects, its possible hurdles or positive effects on their career path.

Our evaluation of the toolkit's efficacy using the Creativity Support Index helps to demonstrate the ways in which the toolkit supports creative PSS design. There are a number of ways that we could further make use of the CSI to study the PSS toolkit in the future. We could learn considerably from others implementing using the toolkit in teaching and using the CSI to validate our results. Finally, it would be great to see how the PSS design toolkit we created compares with other sets of tools for PSS design and the CSI would be a good metric for undertaking such a comparative evaluation, because of the factor breakdown. However, it would be interesting to see how the toolkit supports the creative work of professionals (rather than students) engaging in PSS design.
So opposed to an educational setup, company-specific constraints (money, time, resources, dynamic capabilities, etc.) set additional boundaries to the implementation of PSS design knowledge. To embed the twenty-one preconditions and the methodology of the PSS design toolkit in the innovation process of a company, we need to investigate into the next level of PSS design toolkit implementation, beyond the 'normative' map and into the 'real world' territory. Furthermore, typically to PSS, there is the lack of capacity to getting it done in organizational context, so we need to understand and to prepare companies to upscale from current to future state (design for transition). A thought-provoking idea, is to integrate and verify tools therefor in the current PSS design toolkit as a necessary extension.

As industry might already be implicitly doing the same thing, without having it as formalized as in this process, it is necessary to develop metrics for companies to capture and evaluate the true value of the twenty-one PSS design preconditions, toolkit and its outcome. *E.g., How to get a grip on the outcome, what is to be expected? When are we doing it right? Related to the value of the work during the PSS design process, what to achieve? What to expect? What is different in PSS opposed to earlier concepts?* Similar, nonetheless different than CSI - measuring creativity support - it would be interesting to understand what kind of conventions (different from its predecessors) are suitable to measure the creativity of PSS concepts as an outcome of this process.

Outside our country borders, researchers and practitioners are also using the PSS design toolkit. Architecture students have applied it in Riga, Latvia; it's part of a product engineering course at the University of Sao Paolo in Brazil; students at the Technical university of Denmark in Copenhagen use it to conceptualize IP; and at the Linköping University in Sweden two researchers are about to implement it at the Department of Management and Engineering. We hope on closer collaboration and feedback to produce additional information for consolidation with other research areas and fields of application.

Referring to Section 8.4.3.2, we want to look into the applicability of the PSS design toolkit and its process preconditions in sustainable theories on PSS. Vice versa, it is evenly fascinating to integrate the principles, preconditions and tools of sustainable innovation into our PSS design toolkit and perhaps add another layer throughout the design process. In order to do so, we will follow the same design research approach as in this dissertation to explore, create and confirm a unison in approaches in close collaboration with other (already connected) research groups on this research area.

8.6 Articles in submission procedure

8.6.1 Designs[23]

Working title: Toward an integrated PSS design framework, a delineation of product-service systems and their characteristics

After submitting a paper to the Special Issue "Design of Product-Service Systems" of the Designs Journal, we received major revisions, but were asked to resubmit the article for a regular entry in the Journal.

8.6.2 Journal of Design Research[24]

Working title: Using the Creativity Support Index to Evaluate the PSS Design Toolkit

Together with one of the people that created the CSI (Celine Latulipe), we have submitted this article to the Journal of Design Research.

[23] https://www.mdpi.com/journal/designs
[24] https://www.inderscience.com/jhome.php?jcode=jdr

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Lukas Van Campenhout, **Els Du Bois, Sarah Rohaert** and **Dries De Roeck** (maybe less frequent, but as intense), I am convinced we share the same dedication to the dream that is Product Development. All of our aspirations seem to have become reality in our office, for me at least 'the 3.13' was a gateway to unprecedented reflective conversations. My fellow-design researchers, I really think we have something unique going on.

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To my **family** and **friends**, you may (or may not) have noticed my absence from time to time. Still, I have felt your invisible hand and used the qualities that connect us. If it is any consolation, I think it has been a part of me for quite some time that finally grabbed hold of me, and I took a deep dive into one of the world's finest design sciences there are, product development.

Writing this thesis reminds me of the adventures of Andy Griffiths (writer) and Terry Denton (illustrator), *The 13-Storey Treehouse*. The story follows Andy and Terry, living in a 13-storey treehouse, struggling to finish their book on time among many distractions (usually absurd, but speaking to everyone's imagination). In August 2018 their latest version *'De waanzinnige boomhut van 104 verdiepingen'* got released, we also saw the theatre show in which the plot – as usually – is determined by 'meneer Grootneus' the publisher that forces Andy and Terry to impossible deadlines and related escapades. This was the perfect way to explain my journey to my kids. Some way or another, they see the relation to the book, and my apologies to the members of the jury, whom I might have depicted as 'meneer Grootneus' by occasion.

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Appendix I

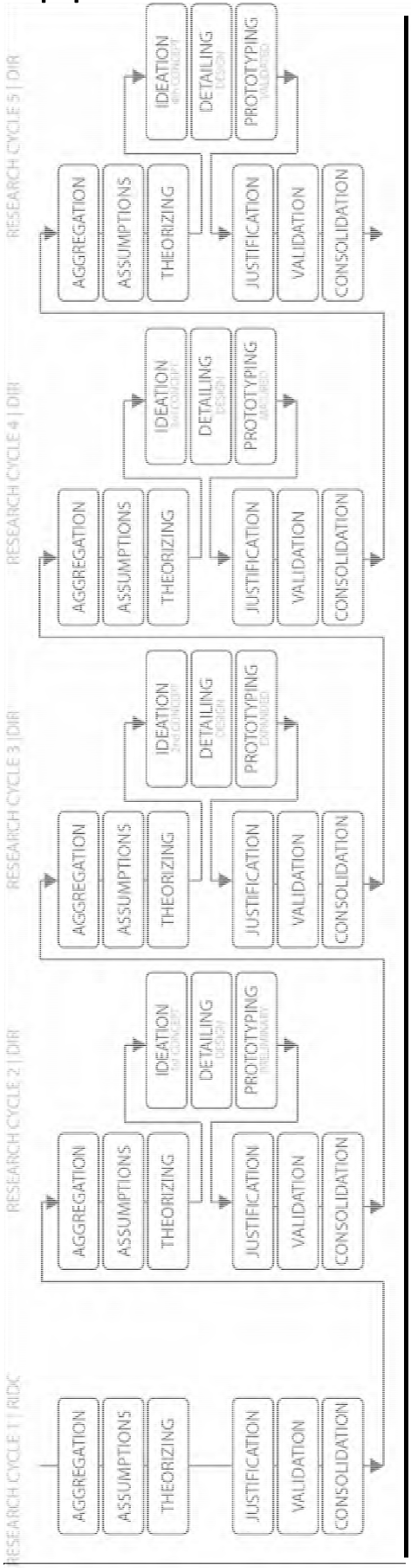


Figure 1.4 | Research Design

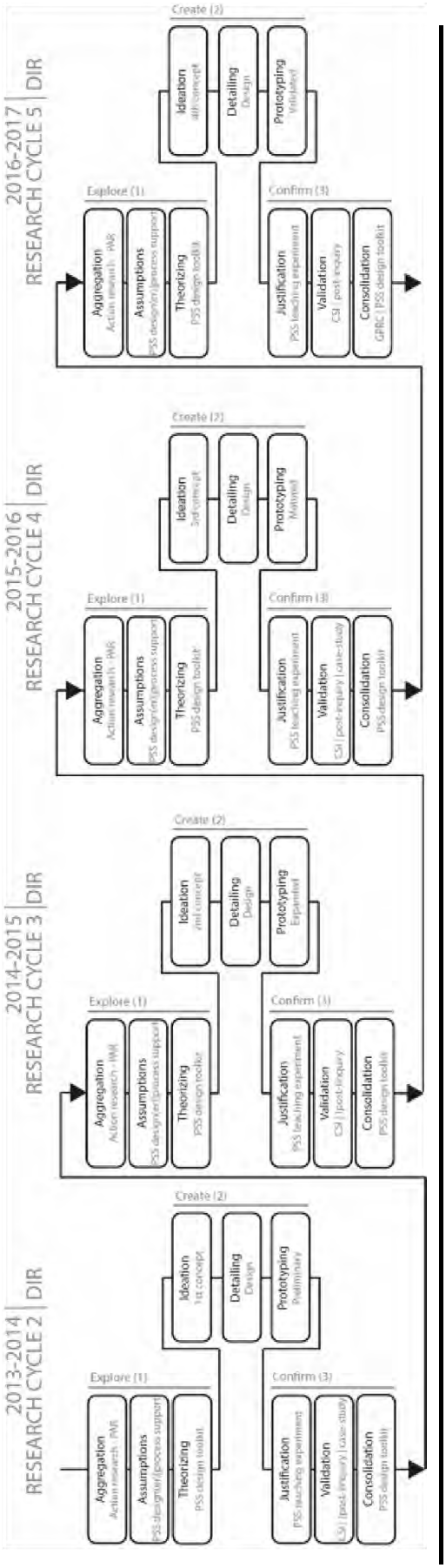
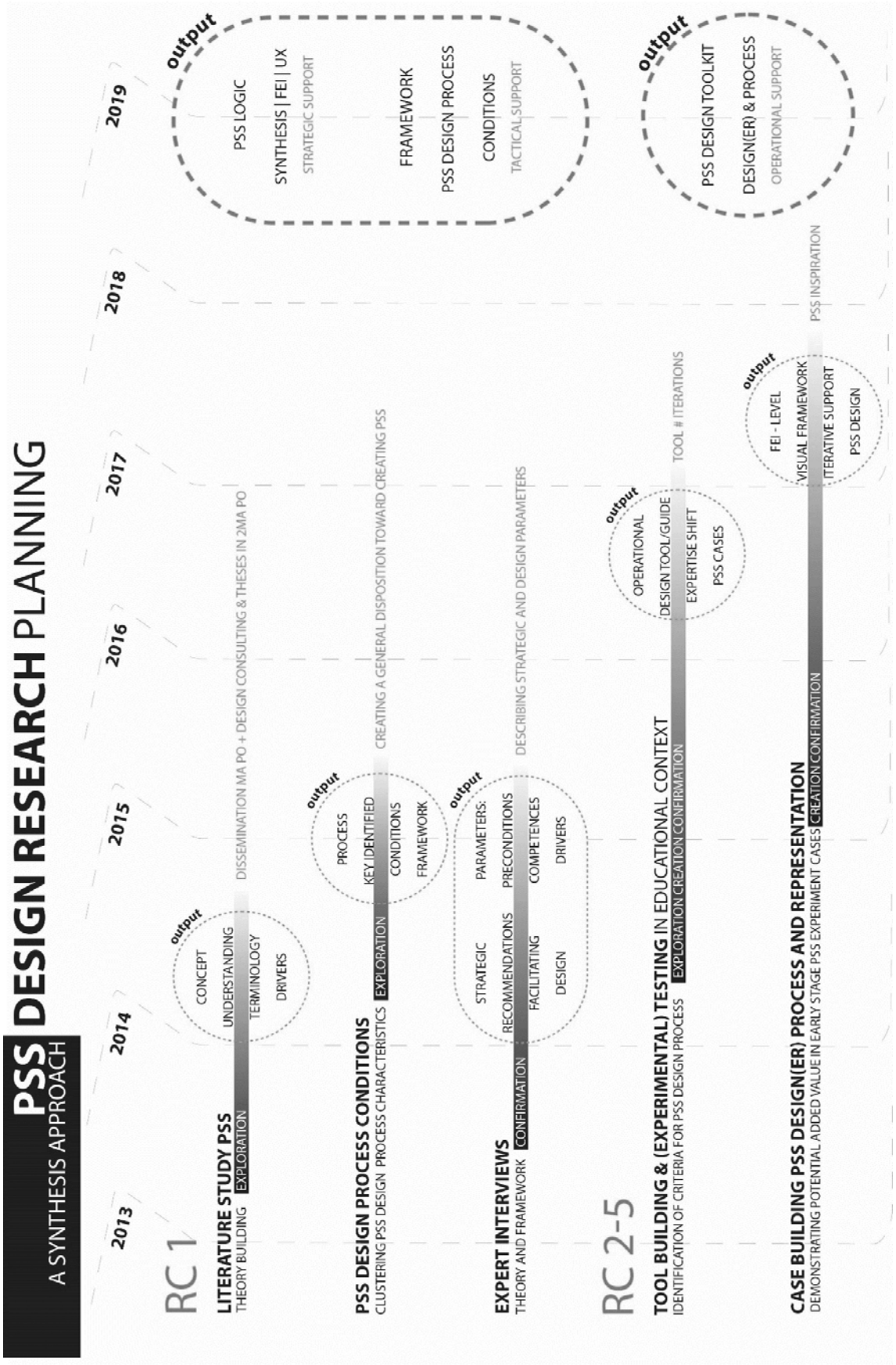


Figure 1.6 | Research cycles 2-5 | DIR

Appendix II



Design research planning

Appendix III

During the research, a number of publications and non-written output have been generated. The statistical overview was taken from the institutional repository[25]. Two articles are ready to be submitted to 'Designs' and 'Journal of Design Research') by the Summer of 2019. Listed below are the details.

	Total	2014	2015	2016	2017	2018	2019
A1 Journal article	1					**1**	**(2)**
A3 Journal article	1					**1**	
Design object	1	**1**					
H1 Book chapter	4					**4**	
H3 Book chapter	1	**1**					
MA2 Book as author	1			**1**			
ME1 Book as editor	1					**1**	
P1 Proceeding	9	**2**		**4**	**2**	**1**	
P3 Proceeding	3	**2**	**1**				
Service	1		**1**				
System	1		**1**				
	24						

List of publications

P1 Proceeding

Somers, L., Dewit, I., & Baelus, C. (2018). **Understanding product-service systems in a sharing economy context - A literature review**. In Procedia CIRP (Vol. 73, pp. 173–178). Elsevier B.V. https://doi.org/10.1016/j.procir.2018.03.317 (Somers, Dewit, & Baelus, 2018)

Dewit, I., & Matthyssens, P. (2017). **A prelude for PSS : practice consolidating theory**. In E. Bohemia (Ed.), Design Management Academy International Conference : Research Perspectives on Creative Intersections (pp. 471–484). Design Management Academy. (Dewit & Matthyssens, 2017)

Dewit, I., Cobben, B., Goovaerts, B., Van Steenkiste, C., & Jacoby, A. (2017). **Representing a Case-Based Interpretation of the PSS Design Toolkit**. In Procedia CIRP (Vol. 64, pp. 247–252). Elsevier B.V. https://doi.org/10.1016/j.procir.2017.03.077 (Dewit et al., 2017)

Dewit, I. (2016). **Front-end Conditions for Product-service System Design**. In Procedia CIRP (Vol. 47, pp. 42–47). Elsevier B.V. https://doi.org/10.1016/j.procir.2016.03.114 (Dewit, 2016)

Dewit, I., Van Den Bossche, E., Veelaert, L., & Zoons, L. (2016). **GRAND.C, Beyond the temporality of nodes**. In Proceedings - D and E 2016: 10th International Conference on Design and Emotion - Celebration and Contemplation (pp. 347–356). ISBN 978-94-6186-725-4 (Dewit, Van Den Bossche, et al., 2016)

Demyttenaere, K., Dewit, I., & Jacoby, A. (2016). **The Influence of Ownership on the Sustainable Use of Product-service Systems - A Literature Review**. In Procedia CIRP (Vol. 47, pp. 180–185). Elsevier B.V. https://doi.org/10.1016/j.procir.2016.03.071 (Demyttenaere et al., 2016)

Dewit, I., De Roeck, D., & Baelus, C. (2014). **Roadmap and toolbox for the ideation stage of the development process of product service systems**. In International Conference on Engineering and Product Design Education E&PDE (pp. 54–59). https://doi.org/10.13140/2.1.2375.1045 (Dewit et al., 2014)

Dewit, I. (2014). **Towards a propensity framework for product-service transitions**. In Proceedings of TMCE 2014 : 10th International conference on Tools and Methods of Competitive Engineering, Budapest, Hungary, May 19-23, 2014 / Horvath, I. [edit.]; Rusak, Z. [edit.] (pp. 325–338) ISBN 978-94-6186-177-1 / 978-94-6186-176-4 (Dewit, 2014)

[25] https://repository.uantwerpen.be/desktop/irua

Non-written output

System Dewit, I., Van Den Bossche, E., Zoons L., & Veelaert L. (2015). **Grand.C : Grootouders en kleinkinderen connecteren d.m.v. cultureel erfgoed en interactief product-dienst systeem**

Service Dewit, I., & Van Den Bossche E. (2015). **Memendo : leidraad ter versterking van het netwerk van de rouwende**

P3 Proceeding

Dewit, I. (2015). **Product service system design : facilitating experience value representation**. In A-DEWS 2015 : Design Engineering in the Context of Asia : Asian Design Engineering workshop, 29th-30th October 2015, The Hong Kong Polytechnic University - 2015, (pp. 45–50) (Dewit, 2015)

Dewit, I., & De Roeck, D. (2014). **The front-end of product service system design, a case analysis**. In International Conference on Service Sciences and Innovation 2014 (ICSSI 2014) (pp. 1–6). (Dewit & De Roeck, 2014)

Dewit, I., & De Swert, E. (2014). **Supporting frame for experience design in front-end methodology**. In International Conference on Service Sciences and Innovation 2014 (ICSSI 2014) (pp. 1–6). (Dewit & De Swert, 2014)

H1 Book chapter

Dewit, I., Van Ael K., De Roeck D., & Baelus C. (2018). **PSS design : define**. In PSS design and strategic rollout : tools for product-service systems / Dewit, Ivo [edit.] - ISBN 978-90-5718-660-8 - Antwerp, UPA, 2018, (pp. 132-183)

Dewit, I., Van Ael K., De Roeck D., & Baelus C. (2018). **PSS design : explore**. In PSS design and strategic rollout : tools for product-service systems / Dewit, Ivo [edit.] - ISBN 978-90-5718-660-8 - Antwerp, UPA, 2018, (pp. 84-131)

Dewit, I., Van Ael K., De Roeck D., & Baelus C. (2018). **PSS design : understanding**. In PSS design and strategic rollout : tools for product-service systems / Dewit, Ivo [edit.] - ISBN 978-90-5718-660-8 - Antwerp, UPA, 2018, p. 14-83

Dewit, I., De Rijck R., & Coreynen W. (2018). **PSS strategic rollout**. In PSS design and strategic rollout : tools for product-service systems / Dewit, Ivo [edit.] - ISBN 978-90-5718-660-8 - Antwerp, UPA, 2018, p. 192-211

H3 Book chapter

Dewit, I. (2014). **Product-dienstcombinaties en gebruik(er)servaring**. (p. 57). In Deckmyn, S., Leyssens, J., Stouthuysen, P., & Verhulst, J. [edit.] (2014). Product- dienstcombinaties. In Product-Dienst Plan C Nieuwe businessmodellen in de circulaire economie (p. 113).

A1 Journal article

Coreynen, W., Matthyssens, P., De Rijck, R., & Dewit, I. (2018). **Internal levers for servitization: How product-oriented manufacturers can upscale product-service systems**. International Journal of Production Research, 56(6), 2184–2198. https://doi.org/10.1080/00207543.2017.1343504 (Coreynen et al., 2017)

MA2 Book as author

Dewit, I., Van Ael, K., Baelus, C., De Roeck, D., De Rijck, R., & Coreynen, W. (2016). **Product Service System Design | Strategic Rollout toolkit**. (Dewit, I. Ed.) (p. 212). University Press Antwerp (UPA). Retrieved from http://www.aspeditions.be/nl-be/book/product-service-system-design-product-service-system-strategic-rollout/15791.htm ISBN 978-90-5718-593-9 (Dewit, Van Ael, et al., 2016)

A3 Journal article

Dewit, I. (2018). **Product-service systems : beyond the dichotomy and into the system**. In Touchpoint : the journal of service design - ISSN 1868-6052 - 9:3(2018), (pp. 73-77) (Dewit, 2018)

ME1 Book as editor

Dewit, I., Van Ael, K., De Roeck, D., Baelus, C., De Rijck, R., & Coreynen, W. (2018). **PSS Design and Strategic Rollout: tools for product-service systems**. (I. Dewit, Ed.) (p. 220). University Press Antwerp (UPA). Retrieved from https://www.aspeditions.be/nl-be/book/product-service-system-design-product-service-system-strategic-rollout/15791.htm ISBN 978-90-5718-660-8 (Dewit et al., 2018)

AppendixIV

Concept-centric approach to the PSS related terminology

PSS related terminology and concepts	Authors
Experiences or satisfaction	Pine and Gilmore, 1999; LaSalle and Britton, 2003
Functional (total care) products	Alonso-Rasgado, 2004; Sundin et al., 2005 (in Maussang, 2008)
Functional Product Development	Brännström et al., 2001
Functional sales	Vijaykumar, 2012; Stahel, 1997; Lindahl and Ölundh 2001
Functional thinking	Hesselbach, 2011
Hybrid product service / offering	Panshef et al., 2009; Lehtinen , Grönroos, 1986
Integrated solutions	Vijaykumar, 2012; Tukker and Tischner, 2004
Integrated systems / systems integration	Alonso-Rasgado, 2004; Davies, 2004, 2005
IPS² Industrial product service systems	Welp, 2008; Grönroos, 2009; CIRP, 2009, 2010
IPSE (integrated PS engineering)	Lindahl et al., 2006
Marketable offering	Shostack, 1977
Product service combinations / mixes	Tukker and Tischner, 2004
Product service integration	Aurich et al., 2006; Cascini et al., 2010; Oliva and Kallenberg, 2003; Cohen et al., 2006; Rosen et al., 2003; Vandermerwe and Rada, 1988; Buchanan, 1998
Product-service	Tukker and Tischner, 2004; Mont, 2004; Manzini and Vezzoli, 2002
SD logic	Vargo and Lusch 2004, 2008 ; Kowalkowski, 2010
Service economy	Fuchs, 1965; Vyakumar and Vasantha, 2011
Service engineering	Tomiyama, 2001; Sakao and Shimomura 2007
Service product	Leiponen, 2002; Johne and Storey, 1998; Edvardsson and Olsson (in Secomandi and Snelders, 2011); Shostack, 1977; Corkindale et al., 1989 (in Chan, 2003); Rust et al., 1996 (in Chan, 2003); Chan, 2003; Lovelock, 2001 (in Johne and Storey, 1998)
Service/product engineering (SPE)	Sakao and Shimomura, 2007 and Shimomura, 2009
Servicification	Fuchs, 1965 ; Drejer, 2004
Servicizing	White, 1999
Servitization	Vijaykumar, 2012 ; Vyakumar and Vasantha, 2011
Soft products	Vijaykumar, 2012
Synthesis approach	Drejer, 2004; Coombs and Miles, 2000
System	Tukker and Tischner, 2004
Systemic solutions	Morelli, 2002

Appendix V

Literature review derived PSS preconditions used as discussion material in round two of the expert interviews

Preconditions built up around value constellation (exploration level):

1. Recognize the potential of PSS opportunities (Tukker & Tischner, 2004) and think more in terms of product service systems.
2. State early 'freedom to operate' requirements for an IP strategy, constructing good contracts with other providing stakeholders in the (eco)system (Tukker & Tischner, 2004).
3. Discuss and explore a possible longer or different pay back. In modern business PSS are no longer provided by linear supply chains made up of producers, assemblers and distributors, but by groupings of firms that operate in what authors have termed value constellations tied together by a business innovation strategy (Normann & Ramírez, 1993). The flow of PSS is therefore not directly linked to the flow of money and making it difficult to compare costs, benefits and economic reward (Cantamessa, 2011; Johne & Storey, 1998; Nijssen et al., 2006; Tukker & Tischner, 2004).
4. Allocate means for a higher brand execution (user experience design) opposed to lower brand promise (communications through PR and advertising) (Tukker, 2004; Vandermerwe & Rada, 1988).
5. Consider co-creation in a broad sense, build strategic relations with executors, actors, stakeholders, customers, clients, (information) network(s) and a range of separated disciplines for the design of PSS (Van Erp, 2011; Drejer, 2004; Morelli, 2002; Tukker & Tischner, 2004). The multiplicity of needs and inputs are essential elements in the front-end of PSS development and design (Müller et al., 2009; Van Halen et al., 2005). User centered and service-dominant principles are vital to ensure that the design addresses the whole user experience (International Organization for Standardization, 2010).

Preconditions with reference to the evaluation criteria (ideation level):

1. Recognize the potential of PSS ideas (Tukker & Tischner, 2004).
2. Since a precise separation between products and services is not feasible during the development or during the delivery phase (Meier et al., 2010), decide on similar project gates for products and services. In order to integrate product and service design processes, the same syntax and semantics that are used to describe product attributes should be used for service attributes. It is vital that managers and engineering designers recognize both the differences between product and service design and the strategic linkages between the two areas (Kindström & Kowalkowski, 2009).
3. Include explicit evaluation and selection criteria (Vasantha et al., 2012), because it's more than a trade-off between function and cost of realization (Isaksson et al., 2011). The go / no go decision criteria should also include immaterial value created by PSS, such as a better market position, image, convenience, risk reduction, better customer relation etc. (Tukker & Tischner, 2004).
4. Expect a difference in testing a PSS idea, because intangible aspects like the user experience set different expectations on the product and service part in the offering (Tukker & Tischner, 2004).

Preconditions concerning integration (ideation level):

1. Acknowledge the integration of how product and service work together instead of designing of separate elements (Van Erp, 2011; Johne & Storey, 1998; Sadek & Köster, 2011).
2. Consider interdependencies already in the front-end of PSS development (Kowalkowski, 2010; Müller et al., 2009; Sadek & Köster, 2011; Vasantha et al., 2012).
3. Decide if the product has to be designed to meet the service aspects and vice versa (Sadek & Köster, 2011; Tukker & Tischner, 2004).
4. Recognize (1) differences between product and service design and (2) strategic linkages between products and services (Johne, 1993; Kindström & Kowalkowski, 2009; Kowalkowski, 2010; Nijssen et al., 2006).

Preconditions concerning time and interaction scenarios (ideation level):

1. Co-create on different levels, actively involve executors, actors, stakeholders, clients, (information) networks in the front-end of PSS design. Put customer needs and inputs central in different stages of the development according to user centered and service-dominant principles (Van Erp, 2011; Drejer, 2004; International Organization for Standardization, 2010; Morelli, 2002; Müller et al., 2009; Tukker & Tischner, 2004; Van Halen et al., 2005).
2. Provide insights in front- and back office implications and their lines of visibility (Edvardsson & Olsson, 1996; Johne, 1993; Johne & Storey, 1998; Lievens, 2000; Menor et al., 2002; Nijssen et al., 2006).
3. Characterize the use phase in PSS through planned or designed events and organize the flow (Eekels, 1994; McAloone & Andreasen, 2004; Morelli, 2002).
4. Align different time frames and make sure that both product and service are defined in interaction with user (Morelli, 2002).
5. Aim to design for a higher brand execution, opposed to a lower brand promise (Tukker, 2004; Vandermerwe & Rada, 1988).

Preconditions to be designed and combined to jointly fulfill customers' needs in relation to the product/service definition (Ceschin, 2012; Goedkoop et al., 1999) (definition level):

1. Describe value in each part and making explicit to what extent products and services are mixed (Tukker & Tischner, 2004).
2. Consider prerequisites for products and services, rather than for product or service separately (Edvardsson & Olsson, 1996); (Nijssen et al., 2006). And by adding products or services to the offering, consider their consequences in the design, determine utilization and reactions to PSS, effects and side-effects (Eekels, 1994; McAloone & Andreasen, 2004). And consequently ensure that all variables are catered for as far as possible (Morelli, 2002).
3. Translate needs and requirements into clear product and service attributes and specifications using the same syntax and semantics to describe them.
4. Consider that provision of services involves a number of tangible and intangible elements, the supply of products relies on culmination of a long chain of services (Cooper & Evans, 2000; Tukker & Tischner, 2004).

Preconditions regarding evaluation / selection (definition level):

1. Enable possibilities for early prototyping and open-ended releases, providing a means for a better assessment of the outcome. The most appropriate design for a PSS cannot be achieved without iteration (International Organization for Standardization, 2010).
2. Use the criteria to evaluate and select the PSS idea, because the inclusion of intangible aspects, like the user perspective and experience sets different expectations on product and service part (International Organization for Standardization, 2010; Tukker & Tischner, 2004).

Appendix VI

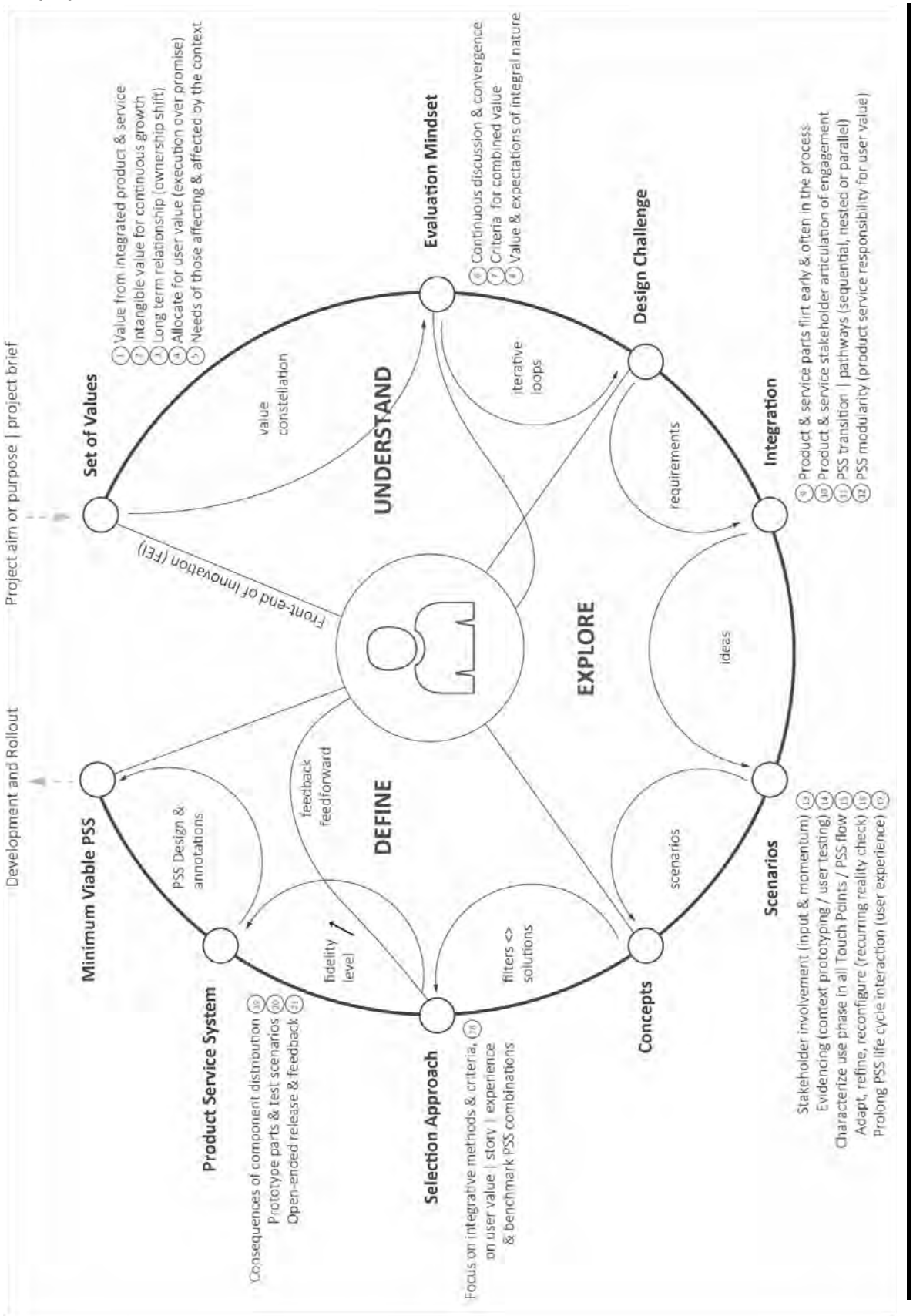


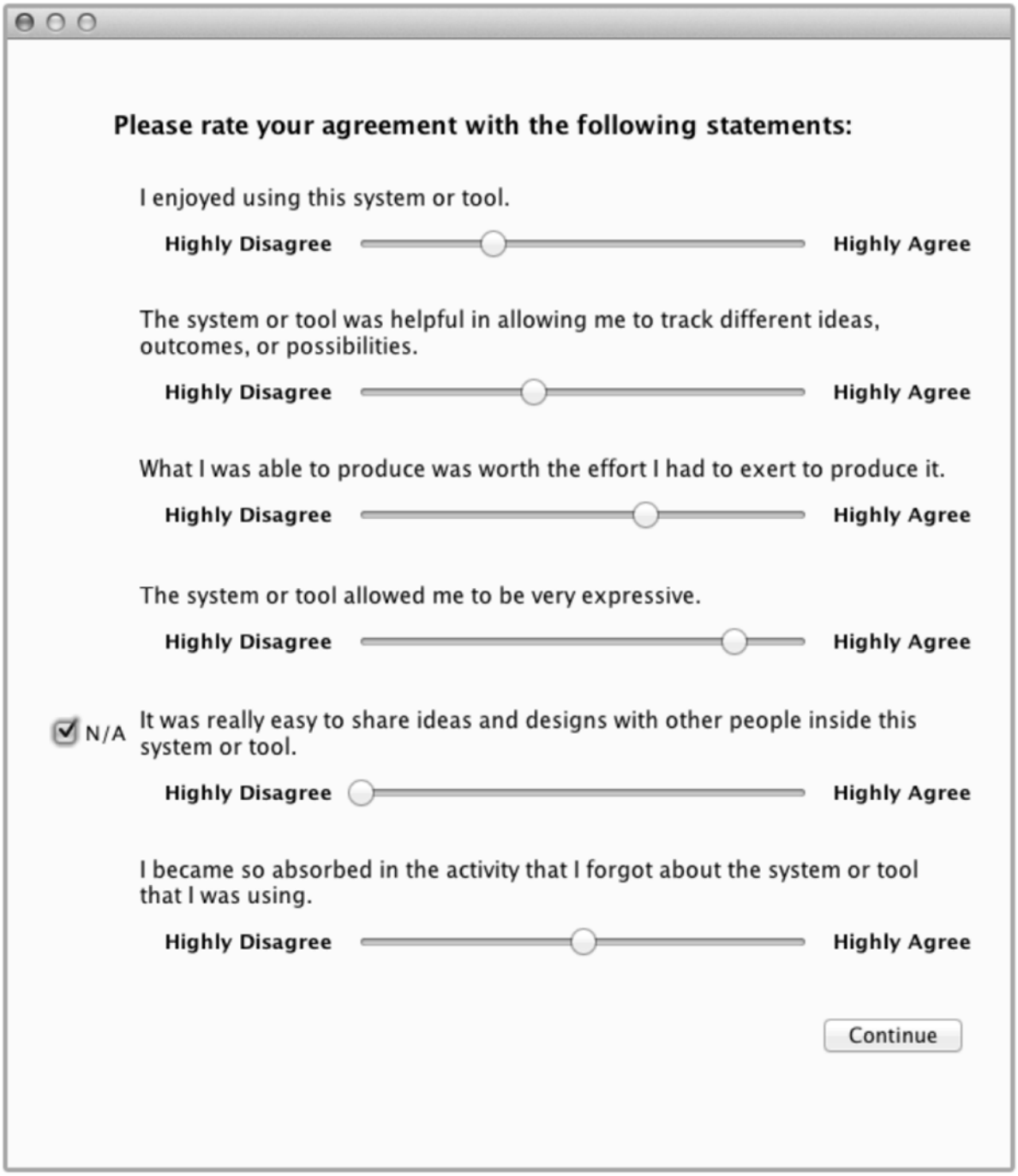
Figure 2.5 | PSS design conditions framework

Appendix VII

The definitions of the CSI factors are listed in the table below. They also serve as the 12 agreement statements on the CSI. Each agreement statement is answered on a scale of “Highly disagree” (1) to “Highly agree” (10). In deployment, the factor names are not shown, and the participant does not see the statements grouped by factor.

Collaboration 1. The system or tool allowed other people to work with me easily. 2. It was really easy to share ideas and designs with other people inside this system or tool.
Enjoyment 1. I would be happy to use this system or tool on a regular basis. 2. I enjoyed using the system or tool.
Exploration 1. It was easy for me to explore many different ideas, options, designs, or outcomes, using this system or tool. 2. The system or tool was helpful in allowing me to track different ideas, outcomes, or possibilities.
Expressiveness 1. I was able to be very creative while doing the activity inside this system or tool. 2. The system or tool allowed me to be very expressive.
Immersion 1. My attention was fully tuned to the activity, and I forgot about the system or tool that I was using. 2. I became so absorbed in the activity that I forgot about the system or tool that I was using.
Results Worth Effort 1. I was satisfied with what I got out of the system or tool. 2. What I was able to produce was worth the effort I had to exert to produce it.

Screenshot of 6 of the 12 agreement statements in the CSI's user interface.



Screenshot of 2 of the 15 paired-factor comparisons in the CSI's user interface

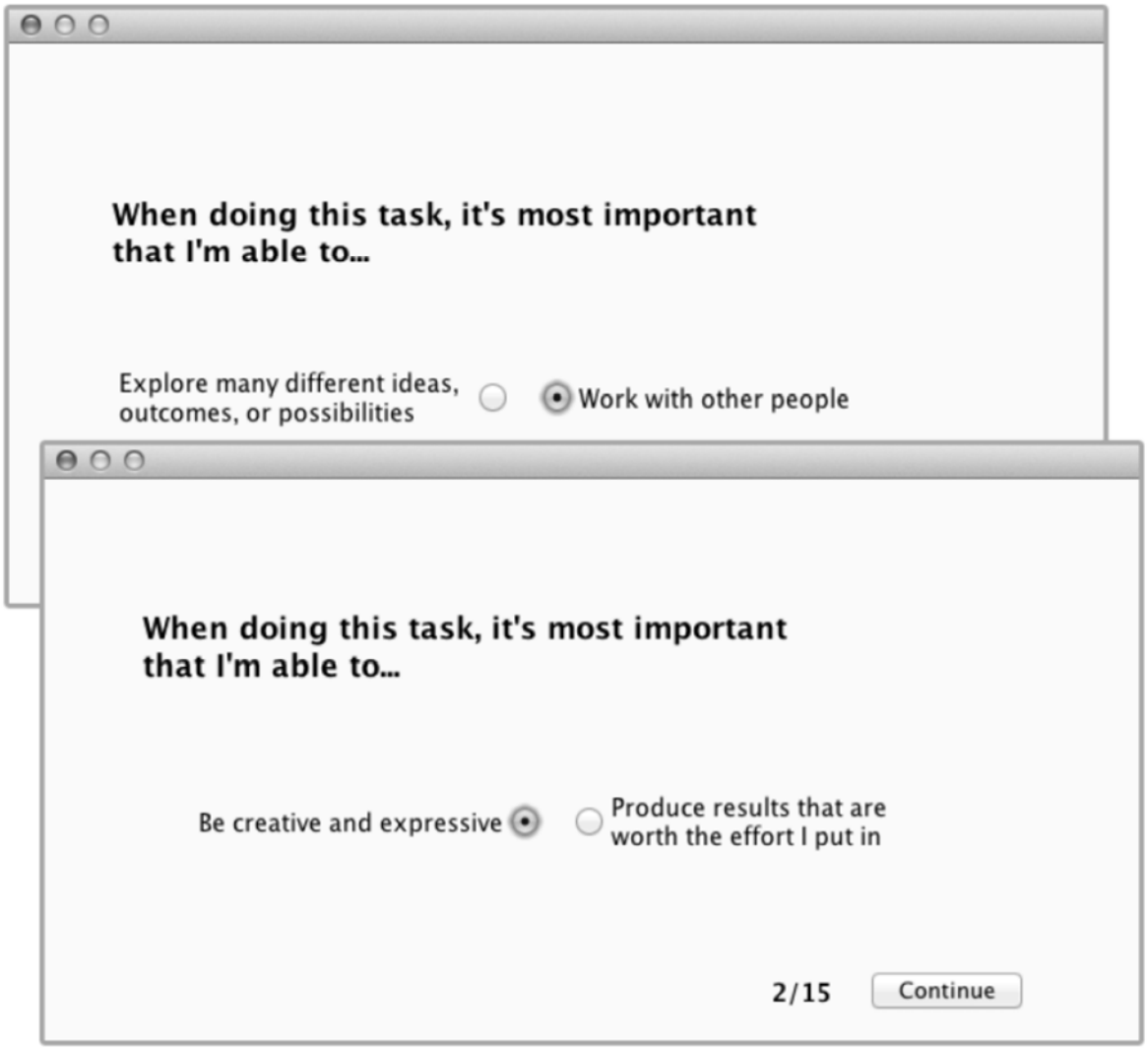


Table 4.3 | Factor agreement statements, priority counts per year and aggregated over four years in the final column.

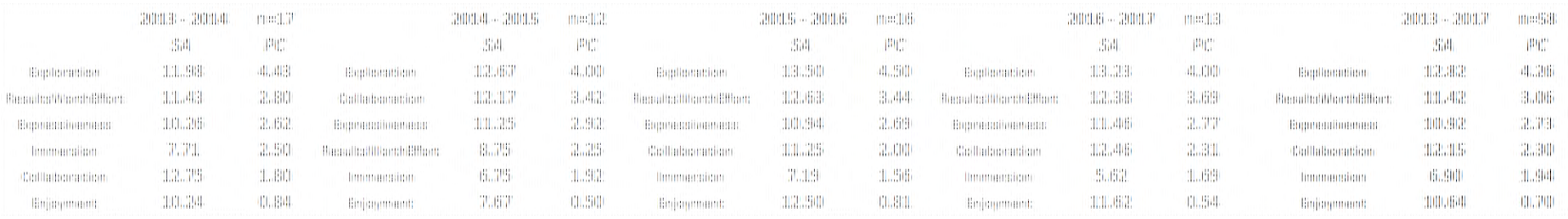


Table 4.4 | CSI results and variability

Year	*CSI Total Score*	*CSI Standard Deviation*
2013-2014	56.3	12.6
2014-2015	54.1	8.1
2015-2016	60.1	9.7
2016-2017	57.8	11.8
2013-2017	**57.1**	**10.8**

Table 4.5 | Reproducibility of agreement statements and the standard deviation of agreement statements across teams

Average Differences between Agreement Scores

	Collaboration	Enjoyment	Exploration	Expressiveness	Immersion	ResultsWorthEffort	Average
2013-2014	1.25	0.92	1.41	1.19	0.82	1.86	1.24
2014-2015	1.17	1.00	0.83	1.42	1.08	1.25	1.13
2015-2016	2.50	1.63	1.50	1.81	0.94	1.38	1.63
2016-2017	2.31	1.46	2.15	1.92	0.85	1.46	1.69
2013-2017	1.80	1.25	1.47	1.58	0.92	1.49	1.42

Standard Deviation of Agreement Scores across Teams

	Collaboration	Enjoyment	Exploration	Expressiveness	Immersion	ResultsWorthEffort	**Average**
2013-2014	3.07	3.65	2.64	3.77	3.19	3.19	**3.25**
2014-2015	3.16	4.25	2.27	1.66	2.56	3.31	**2.87**
2015-2016	4.04	2.88	2.25	2.49	4.17	3.52	**3.22**
2016-2017	2.63	3.07	2.95	3.04	2.90	3.99	**3.10**
2013-2017	**3.27**	**3.81**	**2.55**	**2.89**	**3.33**	**3.70**	**3.26**

Table 4.6 | Standard Deviation of Priority Counts across teams per factor and per year

Standard Deviation of Priority Counts across Teams

	Collaboration	Enjoyment	Exploration	Expressiveness	Immersion	ResultsWorthEffort	**Average**
2013-2014	1.17	1.02	0.72	0.66	0.95	1.24	**0.96**
2014-2015	1.44	0.80	1.60	0.79	1.24	1.48	**1.23**
2015-2016	1.37	1.22	0.63	1.20	1.26	1.31	**1.17**
2016-2017	1.32	0.88	1.29	1.48	1.32	1.11	**1.23**
2013-2017	**1.41**	**1.00**	**1.07**	**1.04**	**1.22**	**1.36**	**1.18**

Furthermore, we have evaluated the variability of the results between the years (see Section 4.3.1). **Appendix VII** shows the averages and counts of the agreements statement and the priority counts by year. Therefore, we have run an ANOVA analysis to test the hypothesis that the (CSI) scores are the same over the years.

Appendix VII bis shows the ANOVA table for the agreement statements. Only for Enjoyment and Results Worth Effort the ANOVA table reveals a different score over the years. For the other factors, the ANOVA table shows a high level of stability in the measurements with p-values well above 30%. A post-HOC analysis with the Tukey HSD test was performed to identify the significant differences between the years on the Enjoyment and Results Worth Effort scores. For both scores only year 2014-2015 is significantly (α= 0.05) different and scoring lower than in the other years. Between the other years also Enjoyment and Results Worth Effort scores are stable with p-values >30%.

ANOVA

Average		Sum of Squares	df	Mean Square	F	Sig.
Collaboration	Between Groups	5,113	3	1,704	,626	,602
	Within Groups	147,140	54	2,725		
	Total	152,253	57			
Enjoyment	Between Groups	44,145	3	14,715	4,896	,004
	Within Groups	162,286	54	3,005		
	Total	206,430	57			
Exploration	Between Groups	5,467	3	1,822	1,129	,346
	Within Groups	87,157	54	1,614		
	Total	92,624	57			
Expressiveness	Between Groups	3,113	3	1,038	,485	,694
	Within Groups	115,524	54	2,139		
	Total	118,637	57			
Immersion	Between Groups	8,521	3	2,840	1,028	,388
	Within Groups	149,224	54	2,763		
	Total	157,745	57			
Results Worth Effort	Between Groups	30,220	3	10,073	3,297	,027
	Within Groups	164,971	54	3,055		
	Total	195,191	57			

Appendix VII bis | the ANOVA table for the agreement statements over the years

Appendix VII ter shows the ANOVA table for the priority counts. Only for Collaboration and Results Worth Effort the ANOVA table reveals a different priority count over the years. For the other priorities, the ANOVA table shows a high level of stability in the measurements with p-values well above 30%. A post-HOC analysis with the Tukey HSD test was performed to identify the significant differences between the years on the Collaboration and Results Worth Effort priority counts. For Collaboration priority only year 2014-2015 scores significantly (α= 0.05) different and higher than in the other years. For Results Worth Effort priority only year 2014-2015 scores are significantly (α= 0.05) lower than the scores in year 2016-2017. Between the other years all these priority scores are stable with p-values >25%.

QANOVA

Count		Sum of Squares	df	Mean Square	F	Sig.
Collaboration	Between Groups	20,593	3	6,864	3,963	,013
	Within Groups	93,543	54	1,732		
	Total	114,136	57			
Enjoyment	Between Groups	1,371	3	,457	,446	,721
	Within Groups	55,343	54	1,025		
	Total	56,714	57			
Exploration	Between Groups	3,109	3	1,036	,897	,449
	Within Groups	62,384	54	1,155		
	Total	65,493	57			
Expressiveness	Between Groups	,681	3	,227	,199	,896
	Within Groups	61,516	54	1,139		
	Total	62,197	57			
Immersion	Between Groups	8,427	3	2,809	1,995	,126
	Within Groups	76,018	54	1,408		
	Total	84,444	57			
Results Worth Effort	Between Groups	16,463	3	5,488	3,315	,027
	Within Groups	89,407	54	1,656		
	Total	105,870	57			

Appendix VII ter | the ANOVA table for the priority statements over the years

Appendix VII quater shows the ANOVA table for the CSI overall score. This shows stability of the CSI score over all four years with a p-value >50%

ANOVA

CSI Score	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	259,751	3	86,584	,738	,534
Within Groups	6333,528	54	117,288		
Total	6593,279	57			

Appendix VII quater | the ANOVA table for the CSI overall score over the years

With respect to the reported results on agreement statements, priority scores and the overall CSI score, we conclude that the values reported in Tables 4.3 to 4.6 are stable over the years. The overall average CSI score (Table 4.4) of 57.1 is expected to be a stable benchmark for this tool. It can serve as reference when the CSI metric is used to evaluate the applicability of the PSS design toolkit in other cases and in other circumstances. [54;60] is the 95% confidence interval for the average CSI It should be noted that the variability of a single measurement, as indicated by the standard deviation, is significantly larger than the confidence interval we established for the average CSI measurement.

Appendix VIII

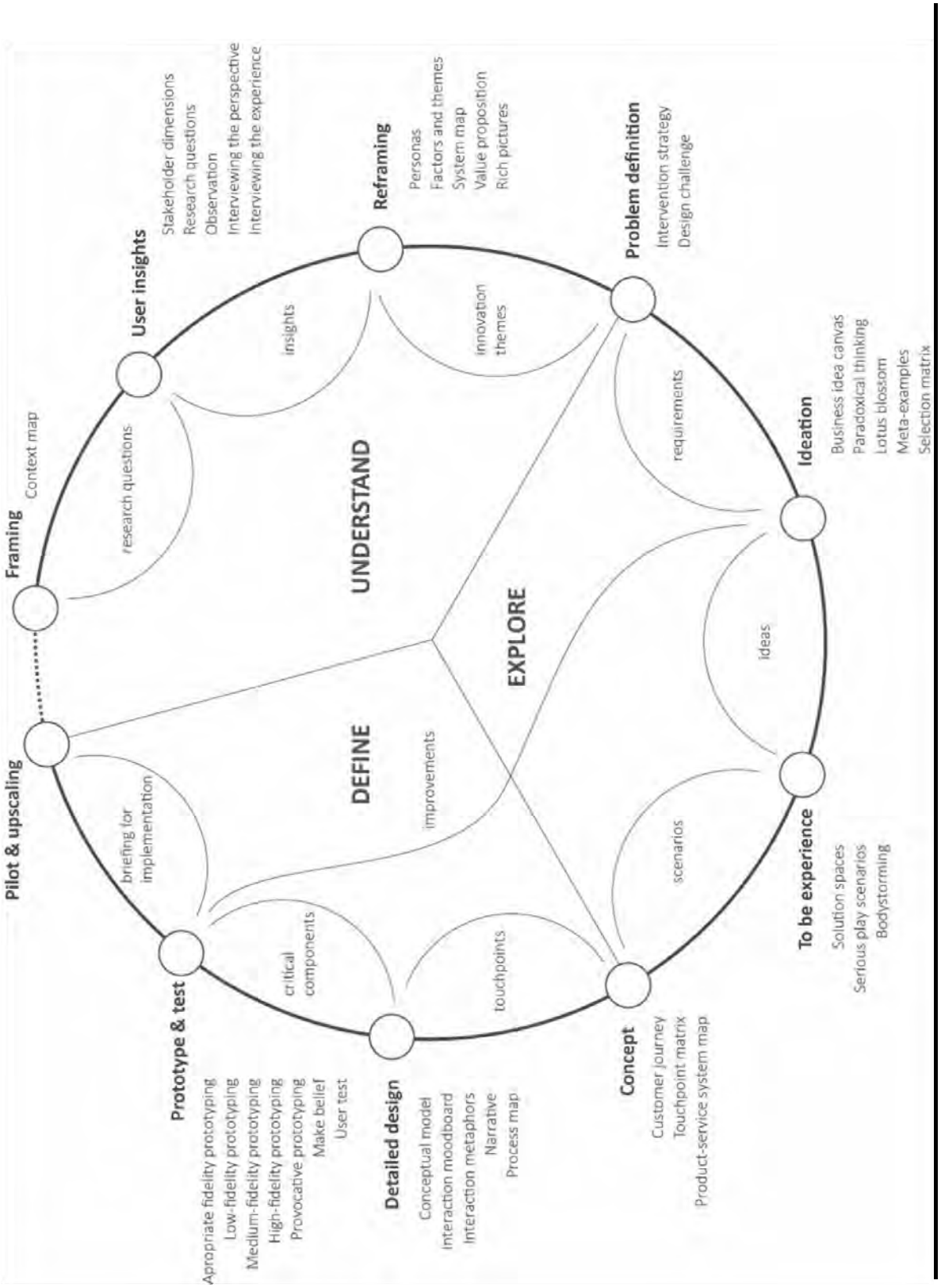


Figure 6.4 | PSS design process - level Understand

Appendix IX

PSS #4 - Met de PSS Toolkit staan bedrijven steviger in hun schoenen

door Antwerp Management School op 4 jan 2017 ,
Business Design & Innovation

http://blog.antwerpmanagementschool.be/nl/pss-4-met-de-pss-toolkit-staan-bedrijven-... 26/01/2017

Het IWT TETRA project "Interne hefbomen voor het creëren van succesvolle PSS" is niet alleen leerzaam voor studenten Productontwikkeling, maar biedt ook de deelnemende bedrijven de nodige inzichten. PSS (Product-Service Systemen) worden voor bedrijven steeds belangrijker om zich te kunnen onderscheiden. Op 22 december werd de PSS Design/Strategic Rollout Toolkit gepresenteerd in de Winkelhaak. Bij de ontwikkeling en toepassing van deze toolkit stonden verschillende bedrijven – waaronder BORGInsole – aan de basis. (Bekijk het fotoverslag)

BORGInsole

"Een product niet zomaar als product aanbieden", zegt Gratienne Sioncke, dat is een van de belangrijkste inzichten geweest. In 2015 was ze nog vrouwelijk ondernemer van het jaar, en nu doen zij en BORGInsole enthousiast mee aan het PSS gerichte project. Ze is voorzitter van de case study bedrijven waarop de tool gebaseerd is. Haar bedrijf is gespecialiseerd in de productie van zolen en biedt podologen eigenlijk een "totaalpakket" aan. Ze leveren hen scanners en camera's, produceren zolen, etc. Sinds kort, gemotiveerd door het IWT TETRA project, kunnen podologen ook een licentie van hun SoleApp huren. Daarmee ontwerpen ze zelf de zool, die BORGInsole vervolgens maakt. Die zool is niet zomaar een product, maar een oplossing voor een probleem, "wij verkopen een oplossing."

Service

Daarnaast is het belangrijk dat service niet stopt wanneer een klant een aankoop heeft gedaan. Podologen die producten van BORGInsole gebruiken, kunnen intekenen op een "verlengde garantie op de fabrieksgarantie", wat betekent dat ze altijd updates en upgrades van hun systeem ontvangen, zodat ze er optimaal mee kunnen blijven werken. Ze willen daarnaast ook dat hun tool niet zomaar gebruiken, maar ze goed leren gebruiken. Daarom bieden ze nu ook opleidingen aan. Zo worden hun klanten experts van het product, in plaats van consumenten.

Toolkit

De toolkit geeft bedrijven de kans om met een frisse blik naar zichzelf te kijken. Dat heeft voor Gratienne Sioncke verassend goed gewerkt. Binnen de deelnemende bedrijven werd door middel van een workshop de dialoog geopend. Zo kwamen ze er bij BORGInsole achter dat de managers en de directie toch wel op dezelfde lijn zaten. "De dag van vandaag spreken onze managers daar nog altijd over", ze noemen het zelfs een van de topmomenten van 2016 binnen hun professionele ontwikkeling. Alle ideeën werden samengebracht op een simpele, maar visuele manier: enorm veel post-its, die ze in kolommen op de kast plakten. Op deze manier worden de verschillende perspectieven binnen een bedrijf samengebracht. Voor een succesvol product service-systeem is het namelijk van belang dat het idee doorheen het hele bedrijf verspreid is. "Die post-its hangen nog altijd bij ons op de kast."

Samenvatting

Wetenschappelijke en sociale relevantie

Dagelijks dagen technologische veranderingen, sociale kwesties, milieu en welzijn het bedrijfsleven en de overheden wereldwijd uit, waardoor de gebruikersverwachtingen en het nieuwe normaal telkens en vooral sneller evolueren. Organisaties kunnen niet anders dan mee met deze evolutie en zijn genoodzaakt zich aan te passen en nieuwe wegen voor innovatie te verkennen, door middel van het ontwerp en de ontwikkeling van productdienstsystemen (PSS). Een mogelijkheid bestaat erin om een product uitbreiden met een (aan)gepaste dienstverlening, en vice versa. Maar PSS maakt het ook mogelijk om nieuwe systemen te ontwerpen en innovatieve interacties te verkennen tussen consumenten, hun ervaring met nieuwe product-dienstcombinaties en de aanbieders ervan.

Positionering en afbakening

Bij de **synthese-benadering** (integratie van product en dienst) stellen we in dit onderzoek enkele foci voorop. Naast exploitatie, is vooral de **exploratie** van nieuwe mogelijkheden bij het ontwerpen van PSS, cruciaal voor het overleven en de ontwikkeling van organisaties op lange termijn. Deze exploratie dient te gebeuren in de **vroege stadia van innovatie** (FEI). Finaal, en in tegenstelling tot overwegend economische of ecologische motieven, concentreren we ons in deze studie op de **ervaring van de gebruiker** als onderscheidende factor, het belang en de betekenis ervan in hun leven.

"Als een organisatie echt nieuwsgierig is om te weten wat klanten of gebruikers willen, dan kunnen ze niet starten met een reeds vooraf gedefinieerd idee aan het begin van het ontwerpproces." (expert)

Methodologie

Als onderzoeksstrategie gebruiken we de methodologie *design research* (*ontwerpend onderzoek*). De aanpak, structuur, processtroom en opzet van onderzoeksacties zijn gebaseerd op twee vormen, nl. *Research in Design Context* (onderzoekscyclus 1) en *Design Inclusive Research* (onderzoekscycli 2-5). De systematische structuur laat ons toe PSS-gerelateerde ontwerpkennis te verkennen, creëren en bevestigen, respectievelijk door middel van *onderzoek in de context van ontwerpen* en door een *ontwerp in het onderzoek* te betrekken. Onze theorieën zijn gerechtvaardigd, gevalideerd en geconsolideerd onder specifieke omstandigheden en op een veelzijdige manier, om onze assumpties en de betrouwbaarheid van de gegevens en resultaten te bewijzen.

Ondersteund door onze empirische bevindingen, ervaringen van organisaties en ontwerpprojecten van studenten in een PSS-context, presenteren we de belangrijkste inzichten met betrekking tot de bijdrage aan ontwerpwetenschappen (design science) en ontwerpend onderzoek (design research). We besteden specifieke aandacht aan de relevantie ervan voor practici en academici op het gebied van PSS-ontwerp.

PSS logica en randvoorwaarden

Bij de synthesebenadering schetsen we de opkomst van PSS en identificeren we de basis voor geïntegreerd ontwerp(en). Onderzoekscyclus 1 toont het belang aan van een correcte ondersteuning bij het geïntegreerd ontwerpen (van PSS) door de combinatie van theorie en expertinterviews. Een optimale ondersteuning bij het PSS-ontwerpproces, dient vanuit strategisch en tactisch niveau in een organisatie rekening te houden met een geïntegreerde logica en visie op PSS, randvoorwaarden (evaluatiedoeleinden) eigen het PSS ontwerpproces én mogelijke transitiepaden op weg naar die synthese.

In onderzoekscycli 2-5, ontwikkelen we een ontwerpproces, tools en technieken specifiek voor PSS, die rekening houdt met deze geïntegreerde logica. We onderzochten de invloed ervan op het ontwerpproces (ontwerppraktijk van studenten), de ontwerper en het uiteindelijke ontwerp zelf.

Het ontwerpproces

De resulterende *PSS design toolkit* integreert o.a. human centered design, interaction design, en systems thinking in één methodiek en neemt zijn gebruiker(s) mee door drie fasen. De eerste fase dient om de context te begrijpen en het doel te bepalen, een tweede fase om nieuwe producten, diensten en systemen te bedenken en uit te werken tot op het niveau van een finaal concept, en een derde fase om het scenario te simuleren, relevant voor en in de context van de gebruiker. Elke stap in het PSS-ontwerpproces is bedoeld om activiteit te motiveren, die op zijn beurt nieuwe doelen en situaties zal genereren, en telkens een nieuw startpunt biedt voor het ontwerp.

De ontwerper

Om te bepalen in hoeverre de PSS design toolkit de ontwerper ondersteunt en welke invloed het uitoefent op diens vaardigheden en denkwijze, experimenteerden we met de verschillende iteraties ervan in onderwijscontext. Als gevolg van geïntegreerde logica, moeten ontwerpers nu ook in staat zijn om geïntegreerde oplossingen (PSS) te ontwerpen. Hij/zij moet kunnen omgaan met de waarde voor de stakeholders, individuele behoeften van de eindgebruiker én verantwoordelijkheden ten aanzien van de samenleving. Het is daarom belangrijk dat ontwerpers hun ontwerpproces expliciet en begrijpelijk maken voor anderen (over de disciplines heen). Deze 'ontwerpmethode' gaat op een systematische manier te werk, maar laat flexibiliteit van de aanpak toe. Het is niet noodzakelijk, noch realistisch om alle PSS design tools te volgen en uit te voeren, maar in elk geval is er voor elke stap een reflectie nodig of er voldoende begrip is van het geheel en de delen om verder door het proces te gaan. Het is daarom ook belangrijk dat de studenten een definitieve keuze van ontwerpideeën uitstellen, noodzakelijk om alternatieve oplossingen mogelijk te maken. Als we het effect van de PSS design toolkit vergelijken met een verwacht niveau van creativiteitsondersteuning, komt ook duidelijk *exploratie* naar voor als de belangrijkste en meest ondersteunende factor. De PSS design toolkit en bijhorende ontwerpproces is noodzakelijk voor ontwerpstudenten om deze vaardigheid daarna in praktijk te brengen.

Het ontwerp

Een van de grootste uitdagingen met betrekking tot PSS-tools, is het gebrek aan duidelijke representatiemogelijkheden tijdens het proces van de waarde van het geheel, de menselijke interactie en immateriële aspecten van het systeem. De PSS design toolkit speelt daarin een cruciale rol, het veruitwendigt de manier van denken van de ontwerper en maakt het PSS ontwerpproces begrijpelijk en dus waardevoller voor alle betrokkenen. De toolkit stelt ontwerpers in staat om verschillende abstractieniveaus tegelijkertijd aan te pakken.

Dit proefschrift plaatst een geïntegreerde aanpak voor het ontwerpen van PSS centraal. Daarom bakenen we een PSS logica en bijbehorende randvoorwaarden (relevante voorschriften) af ter ondersteuning van het ontwerpproces, en creëren een PSS design toolkit (bruikbare aanpak) om de synthese tussen product en dienst mogelijk te maken, in plaats van de tweedeling te handhaven. Met de nadruk op de context, onderlinge relaties en het geheel, bereiden we toekomstige generaties ontwerpers voor op uitdagingen die gepaard gaan met het ontwerp van productservicesystemen.