EXPLORING USABILITY

DESIGN FOR DYNAMIC AND DIVERSE USE SITUATIONS

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PhD Thesis

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voor Willem Mees

Summary

This dissertation discusses the relationship between usability and dynamic and diverse use situations (DDUS) and how this relationship can be taken into account in the design process. The dynamics and diversity of use situations in which products are used influences their level of usability. To design products with a certain level of usability in intended use situations, it is therefore necessary to evaluate solutions with regard to these intended use situations. Which aspects of intended use situations are important to consider in design, depends on the generated solution. This interdependency of use situations, usability and solutions, makes it difficult to analyse and define use situations and to apply them as a frame of reference in evaluations.

It is generally acknowledged in user-centred design that it is important to describe and specify the intended use situations. It is also often mentioned that the test conditions of usability evaluations should represent the actual user, goal and environment. However, in spite of these acknowledgements, little guidance could be found on how a specification of intended use situations can lead to a frame of reference for those usability evaluations. This can particularly lead to difficulties for projects for which no suitable frames of reference are available from previous, comparable projects within the company or from generally available research on the use of the concerned type of product. This research was therefore aimed at developing a support aimed at filling this gap by guiding the creation of a flexible frame of reference which reflects the variety of intended use situations and the consequences for usability and by guiding the application of the frame of reference in usability evaluations.

The design research methodology of Blessing and Chakrabarti (2009) was used as a framework for this research, since it is specifically aimed at research which includes the development of a design support. The methodology distinguishes research stages aimed at understanding the design problem (descriptive study I), developing the design support (prescriptive study) and evaluating the support (descriptive study II). All stages were executed within this research.

In the descriptive study I stage, a study of the awareness of designers with regard to DDUS and a retrospective study of three usability oriented design projects in practice showed the difficulty of defining relevant use situation aspects at the start of a design project. A part of the use situation aspects consists of 'boundary conditions' or constraints which allow to predict what users will not do and which can mostly be defined at the start of a design project. However, both studies showed that use situation aspects that determine what users will do, can only become clear in evaluations of prototypes or comparable products. Since these use situation aspects should at the same time serve as a frame of reference

for these usability evaluations, building such a frame of reference can only be done iteratively. However, the retrospective study showed that product development teams who were initially unfamiliar to the intended use situations of the product, often only made relevant use situation aspects and connected usability issues explicit at the start of the design project. The lack of an up to date explicit frame of reference of relevant use situation aspects can negatively influence the external validity of the test conditions and focus of questions for formative usability evaluations. This can in turn lead to a lower level of quality of recommendations for adjustment of the solution and consequently decrease the chance that usable solutions are created. The retrospective study furthermore showed that knowledge of use situation aspects as well as of usability issues often remained implicit in the heads of design team members. The lack of sharing of this knowledge can influence the 'team mental model' with regard to product use. It is assumed that this lack of sharedness in the 'vision on product use' – or implicit frame of reference - can negatively influence the quality of design decisions with regard to choosing the intended use situations and the most appropriate solution alternative for it. This can lead to a lower level of usability of the final product in intended use situations as well.

Based on these insights, it was decided to develop a support which was aimed at generating a flexible frame of reference which reflects the variety of intended use situations and the consequences for usability of products for which the use situations are unfamiliar to the design team. Furthermore it was aimed at stimulating the application of this frame of reference in usability evaluations and in sharing knowledge of product use. A set of guidelines was developed to stimulate design teams to integrate the creation and application of this frame of reference in their design process. Furthermore a technique called the Envisioning Use workshop was developed, to stimulate the sharing of implicit and explicit knowledge of product use by means of creating a first frame of reference. The support was evaluated in several iterations with both practicing designers and senior design students in both simulated and real design contexts.

The main objectives formulated for the support were that it should improve the extent to which knowledge of product use is shared and that it should improve the external validity and focus of usability evaluations. The 'guidelines to design for DDUS' proved successful in stimulating the creation of an explicit frame of reference of product use which could give the required focus to usability evaluations in the student projects and also proved that they can be used to set-up externally valid usability evaluations. The developed support influenced the objective with regard to sharing knowledge of product use in a different way than expected. Instead of creating a shared 'vision of product use' through sharing an explicit frame of reference of product use, the shared vision was found to be created directly through the joint creation of such a frame of reference in the Envisioning Use technique. This insight was confirmed in an evaluation of the Envisioning Use technique in three real product development projects. The evaluation of the guidelines in the student projects furthermore showed that combining activities aimed at exploring usability with activities aimed at verifying the frame of reference, proved to be a valuable approach in creating both the explicit as well as the implicit frame of reference of DDUS and related usability issues.

Samenvatting

Dit proefschrift gaat over ontwerpen voor de dynamiek en verscheidenheid van situaties waarin producten gebruikt worden. De nadruk van het onderzoek ligt hierbij op hoe met deze gebruikssituaties rekening wordt gehouden in het ontwerpproces. De situaties waarin producten gebruikt worden zijn van invloed op het gebruiksgemak van dat product. Om producten te ontwerpen die in variërende gebruikssituaties terecht zullen komen is het daarom nodig om productontwerpen te evalueren met betrekking tot deze gebruikssituaties. Welke aspecten van de gebruikssituatie van belang zijn voor gebruiksgemak hangt echter af van het gegenereerde ontwerpvoorstel. De onderlinge afhankelijkheid van gebruikssituaties, gebruiksgemak en ontwerp zorgt ervoor dat het lastig is om te analyseren en bepalen wat belangrijke gebruikssituaties zijn. Ontwerpprocessen leiden meestal tot betere resultaten wanneer meerdere iteraties worden uitgevoerd waarin productontwerpen steeds worden geëvalueerd in gebruikstesten. Wanneer niet duidelijk is wat de belangrijke gebruikssituaties zijn, zal het daarom ook lastig zijn om te bepalen onder welke omstandigheden het ontwerp getest moet worden. Met andere woorden, het is niet duidelijk wat het referentiekader is waaraan het ontwerp moet voldoen.

In literatuur over gebruikersgericht ontwerpen wordt het algemeen erkend dat het belangrijk is om de gebruikssituaties waarop het ontwerp gericht is goed te specificeren. Daarnaast wordt vaak aangegeven dat de evaluatieomstandigheden van een gebruikstest de echte gebruiker, het echte gebruiksdoel en de echte gebruiksomgeving moeten representeren. Er wordt echter weinig richting gegeven in de literatuur aan hoe een specificatie van gebruikssituaties kan leiden tot een referentiekader voor gebruikstesten. Dit kan vooral lastig zijn bij het ontwerpen van producten waarvoor nog geen referentiekader beschikbaar is, bijvoorbeeld van voorgaande, vergelijkbare producten die ontworpen zijn binnen het bedrijf of van algemeen beschikbaar onderzoek naar het gebruik van dat type product. Het doel van dit promotieonderzoek was daarom het ontwikkelen van ontwerpondersteuning gericht op dit probleem.

In het onderzoek zijn drie fasen uitgevoerd gericht op respectievelijk het verkrijgen van inzicht in het ontwerpprobleem, het ontwikkelen van de ontwerpondersteuning en het evalueren van deze ontwerpondersteuning. Genoemde fasen zijn gebaseerd op de 'Design Research Methodology' van Blessing en Chakrabarti (2009), omdat deze methodologie specifiek gericht is op onderzoek dat resulteert in ontwerpondersteuning.

De eerste onderzoeksfase bestond uit een studie naar de mate waarin ontwerpers zich bewust zijn van de variatie van gebruikssituaties en een retrospectieve studie van drie ontwerpprojecten in de praktijk waarbij gebruiksgemak belangrijk was. Deze studies toonden aan dat het lastig is om aan het begin van een ontwerpproces alle relevante aspecten van de gebruikssituaties te bepalen. Een deel van deze aspecten betreft randvoorwaarden welke gebruikt kunnen worden om te voorspellen wat gebruikers *niet* zullen doen en welke vaak wel aan het begin van het ontwerpproces bepaald kunnen worden. Beide studies toonden echter aan dat aspecten die bepalen wat gebruikers *wel* zullen doen, vaak pas later duidelijk worden in gebruikstesten van prototypes of vergelijkbare producten. Omdat deze aspecten tegelijkertijd als referentiekader zouden moeten dienen voor deze gebruikstesten, kan een referentiekader alleen iteratief ontwikkeld worden. De retrospectieve studie toonde echter aan dat ontwerpteams die aan het begin van het ontwerpproces onbekend waren met de gebruikssituaties van het product, vaak alleen op dat moment expliciet maakten wat de te verwachten gebruikssituaties en de gevolgen voor gebruiksgemak waren. Omdat deze gebruikssituaties afhankelijk zijn van het ontwerpvoorstel, was deze eerste expliciete representatie niet actueel meer wanneer later in het ontwerpproces nieuwe ontwerpvoorstellen gegeneerd werden. Een zo ontstaan gebrek aan een up-to-date referentiekader van gebruikssituaties kan een negatieve invloed hebben op de externe validiteit van de evaluatieomstandigheden en op de focus van de evaluatievragen in gebruikstesten. Dit kan vervolgens leiden tot minder waardevolle aanbevelingen voor een herontwerp en dientengevolge tot een lagere kans dat gebruiksvriendelijke ontwerpen gegenereerd worden.

De retrospectieve studie toonde bovendien aan dat kennis over gebruikssituaties en gebruiksgemak vaak niet gedeeld werd. Dit kan een negatieve invloed hebben op het mentale model van het ontwerpteam met betrekking tot het ontwerpprobleem. Het wordt aangenomen dat dit gebrek aan een gedeelde 'visie op productgebruik' – of gedeeld impliciet referentiekader van gebruikssituaties – een negatieve invloed heeft op het maken van beslissingen met betrekking tot het kiezen van gebruikssituaties en het kiezen van het ontwerpvoorstel dat het beste bij deze gebruikssituaties aansluit. Ook dit kan leiden tot een lager niveau van gebruiksgemak van het eindproduct in de gekozen gebruikssituaties.

Op basis van deze inzichten is in de tweede fase van het onderzoek besloten om ontwerpondersteuning te ontwikkelen welke gericht was op het genereren van een flexibel referentiekader dat de variëteit aan gebruikssituaties en de consequenties hiervan voor gebruiksgemak representeert. Daarnaast was de ondersteuning gericht op het toepassen van dit referentiekader in gebruikstesten en in het delen van kennis over productgebruik. Hiertoe is een set richtlijnen ontwikkeld om ontwerpteams te stimuleren de generatie en toepassing van dit referentiekader in hun ontwerpproces te integreren. Daarnaast is een workshop ontwikkeld genaamd de 'Envisioning Use' workshop, welke tot doel had om zowel impliciete als expliciete kennis over productgebruik te delen door middel van het creëren van een eerste referentiekader. Het toepassingsgebied van de ontwerpondersteuning bestond uit producten van welke de (gevolgen van) gebruikssituaties aanvankelijk onbekend zijn voor het ontwerpteam. De ontwerpondersteuning is geëvalueerd in meerdere iteraties met zowel ontwerpers uit de praktijk als ouderejaars studenten industrieel ontwerpen, in zowel gesimuleerde als echte ontwerpcontexten.

In de evaluatiefase werden de twee hoofddoelen van de ontwerp-ondersteuning getest: het verbeteren van de mate waarin kennis over productgebruik gedeeld werd en het verbeteren van de externe validiteit en focus van gebruikstesten. In studentenprojecten bleken de richtlijnen inderdaad succesvol in het stimuleren van de generatie van een expliciet referentiekader van productgebruik welke de gevraagde focus van gebruikstesten kon verbeteren. Daarnaast bleek dat het referentiekader gebruikt kon worden om extern valide gebruikstesten op te zetten. Het hoofddoel met betrekking tot het delen van kennis over productgebruik werd op een andere manier beïnvloed dan verwacht. In plaats van de generatie van een gedeelde visie op productgebruik door middel van het delen van het expliciete referentiekader, bleek dat de gedeelde visie direct gegenereerd kon worden door het gezamenlijk creëren van dit referentiekader in de Envisioning Use workshop. Dit inzicht werd bevestigd in de evaluatie van deze workshop in drie productontwikkelingsprojecten in de praktijk. De evaluatie van de richtlijnen in de studentenprojecten liet daarnaast zien dat het combineren van het verkennen en verifiëren van variërende gebruikssituaties en de consequenties voor gebruiksgemak een waardevolle manier is voor het genereren van zowel een expliciet als impliciet referentiekader.

Preface

In 2002 I started my work as assistant professor at the University of Twente, where I could assist in developing the education program Industrial Design Engineering. Although I initially spent most of my working hours on teaching, I also got the opportunity to carry out research. I could do a PhD research project on whatever subject I was interested in. This was both a gift and a curse. I was happy that I was given the freedom to study whatever I liked, but it was difficult to find a topic that was interesting but not studied by someone else.

The topic I finally chose was inspired by my graduation project. I had recently graduated as MSc Industrial Design Engineering from Delft University of Technology. My graduation assignment, which I executed at Philips Consumer Electronics, was about the design of an innovative user interface for television. My company supervisor was curious if it would be possible to design an easy to use user interface that would be different than the 'bar of chocolate with buttons' that most remote controls looked like. Before generating solutions I investigated what the desired interaction should be between the user and the television. To get a better idea about how the television is used, I generated scenarios for different situations in which the television is used, such as watching a soccer match with friends, zapping around in search of entertainment or using the television as 'wallpaper'. Next I generated different design proposals which I compared to the scenarios. I then made a prototype of the design - a remote control and accompanying graphical user interface on the TV - which fit those scenarios best and had friends and family (including my grandmothers) test the prototype. I will not describe the final design here fully, but it did not look like a bar of chocolate with buttons and the results of the user tests were promising. My company supervisor was happy and I graduated cum laude.

Although the result of the project had been successful, my design process had only partly been based on what I had learned in the education program. The other part was based on what I intuitively thought would be an appropriate design approach. I therefore decided to dedicate my PhD project to how to approach these kind of 'usability' design projects in general. However, it took me till 2005 before I decided on the specific subject of this thesis: "design for dynamic and diverse use situations". You can read more about that in chapter 1. And now, after seven years of research, I understand what I had been doing in my graduation project: I had explored the different situations in which the television could be used and what this could mean for the interaction between situation and product (see chapter 10). The title of this thesis, 'exploring usability', therefore relates to an important result of this research. However, it also refers to the journey I made myself during this research: I explored the concept of usability and I explored what it means to be a researcher. Although I never planned to be a researcher, I was surprised by the pleasure and satisfaction the research work gave and still gives me. I therefore hope I can continue doing this type of research in the future.

This research journey became such a pleasurable experience through the kind guidance, support and help of many people. I would like to thank my supervisor, professor Fred van Houten, for motivating me to start a scientific career and for giving me the opportunity to execute this research next to my teaching tasks. Immense thanks go to Mascha van der Voort, my daily supervisor. Mascha, thank you for having me in your research group 'Use Anticipation in Product Design', thank you for inviting me to participate in the inspiring Design for Usability project, thank you for your interest in my research subject, but most of all thank you for all the time you spent on reading the preceding versions of this thesis and your valuable feedback. My gratitude furthermore goes out to my graduation committee for assessing this thesis, providing feedback and being part of the PhD defence ceremony.

I feel very lucky that I could execute my research within the Design for Usability research project. Being part of this enthusiastic team of researchers and design practitioners inspired me with many ideas for my research. I am proud that the project led to such successful research results and I hope we can continue to collaborate in the future. I owe much gratitude to Stella Boess with whom I collaborated in the development of the Envisioning Use workshop. Stella, I am very happy that we got to meet each other through the DfU project. I learned a lot from you and although our discussions often contained a lot of misunderstandings, they always resulted in unexpected ideas and insights that we could not have gained individually. I hope we can continue our Envisioning Use work in the future. Thanks to Daan van Eijk, Sonja van Grinsven-Evers, Jasper van Kuijk, Tristan Weevers and Moniek van Adrichem for organizing the DfU project, the DfU symposia, the website and the DfU methods and tools book. I furthermore would like to thank Christelle Harkema for her valuable contribution to the development of the Envisioning Use technique. To the rest of our 'cluster': Henri Christiaans, ChaJoong Kim, Peter Sonnemans: although our MUST-tool never saw daylight, our discussions were very enjoyable and helped me to define the place of my research within the complete DfU project. Finally I would like to thank the company representatives for providing the research cases and for their feedback on our research results.

I would like to express my gratitude to all design practitioners who participated in the different studies of this research. Firstly I would like to thank the members of the three design teams that participated in the retrospective studies described in chapter 3. Understanding how design for usability is executed in design practice provided indispensable input for the development of the design support. I would like to thank all designers and colleagues that participated in the awareness study described in chapter 3 and in the development of the Envisioning Use workshop described in chapter 5: JanWillem, Arie-Paul, Maaike, Wouter,

Julia, Frederik, Remko, workshop participants of the Design for Usability symposium 2009 and the designers of VanBerlo and Indes. Your feedback has been of great value for the successful development of the workshop. Finally, I am very grateful to the companies who participated in the final evaluation of the workshop described in chapter 8, for investing their valuable project time in the execution of the workshop and for their useful feedback in the group interview and the surveys.

For the student projects described in chapter 6 and 9 I would firstly like to thank all the students who participated in the two courses 'design for dynamic use' for applying and evaluating the initial version of the guidelines. Your enthusiasm and your critiques motivated me to further develop and improve the guidelines. Remko, thank you for co-supervising the first project and for your initiative to organise an appropriate case. Thanks to Ron Welberg and Johan Visser from Bongo Innovations BV for providing the carrier bike case and for the time they spent on sharing their knowledge with the students. Thanks to Jantine Medema from Philips Consumer Lifestyle for providing the Airfryer case. The 'baking session' was an excellent idea and the information you provided on the case as well as the feedback you gave to the teams was very valuable for the student work.

Both in my own studies as well as in the student projects, many people participated as end-users in the evaluation of the different products and prototypes. I am grateful to all those people for investing their time and effort in these tests. Special thanks go out to the children who participated in the Tripp Trapp and Airfryer projects: Jasmijn, Finn, Lente, Marit, Anouk, Tinka, Neill, Tatum and Ruby: dankjulliewel! Thanks to their parents for having their children participate and for taking the pictures.

I take great pleasure in thanking my youngest brother, Sander, for designing a beautiful cover and for helping me out with the graphic design. Thank you for the clean-serious–party–look! Thanks to Wieteke for your help with the photography. Furthermore I would like to thank the ladies of our secretary: Inge, Inge and Ans for their practical support in the organisation of my promotion.

Apart from all the people that were directly involved in my research, there are also many people who indirectly made me enjoy this PhD journey. I am happy that, next to my research work, I can execute my education tasks for industrial design engineering within a great team of fellow teachers. I am proud of the education program we have been developing the past eleven years. All colleagues of OPM: thank you for the pleasant distractions from the writing process at the 'koffietafel', during lunch walks, 'spelletjesborrels' and the 'batavierenrace'. Apart from my work at university I also really enjoyed the several conferences I visited. I would like to thank all the 'research friends' I made there for the inspiring and enjoyable time we spent together. Special thanks to Ingrid Moons for all the fun we have at different places around the world and for the nice conversations about work, PhD and the important things in life.

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Maaike en Wouter, bedankt voor alle goede gesprekken, fijne wandelingen, gezellige etentjes, leuke reisjes, en voor alle hulp, peptalks en steun die ik van jullie gekregen heb. Met jullie als paranimfen aan mijn zijde voel ik me vast een stuk zekerder tijdens de verdediging!

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Contents

1 Introduction

Figure 1.1: the usability of a compact camera was not optimal for making a picture of ourselves and the Mont Blanc on a cold and sunny mountain.

1 Introduction

The picture on the left page was taken in January 2010 in the Haute-Savoie in France. It shows my husband and me and the Mont Blanc. The picture was taken by my husband with a Canon compact camera. I love the picture, since it reminds me of the wonderful time we had skiing in the mountains and enjoying the beautiful views together. However, taking this picture was not that easy. Firstly, the temperature was about -20 degrees Celsius, but the buttons on the camera are too small to be able to control them while wearing gloves. This made the camera very uncomfortable to use. Secondly, evaluating the picture was difficult, since the screen was difficult to read in the bright sunlight. And thirdly, taking a picture of ourselves and the Mont Blanc was difficult because my husband could not see the preview screen when he aimed the lens at ourselves. A closer inspection of the photo reveals that the summit of the Mont Blanc is not even in the picture!

Compact cameras or 'point-and-shoot cameras' were designed to be portable and easy to use. They are popular with people who don't consider themselves photographers, but want an easy to use camera for vacations, parties, reunions and other events (wikipedia, 2012). Although the fully automatic operation and size of the camera indeed make it a successful device for those purposes, specific use situations, such as making a picture of yourself, someone else and a certain object of interest in the cold mountains, require specific characteristics from the design. When designers are working on a product which can be used in many different types of use situations, such as the compact camera, they somehow need to gain insight in what these varying use situations are and which requirements the situations pose on the design. How to deal with varying use situations when designing easy to use products is the topic of this thesis.

1.1 Design for usability

1.1.1 Why is usability important?

This research is aimed at exploring the relationship between varying use situations and ease-of-use or usability and how designers deal or could deal with this relationship. Usability is a concept that has gained increasing attention in the past decades. The first studies of usability were aimed at increasing the efficiency of software systems. For example, Nielsen (1993) showed how usability can lead to considerable cost savings for professional software users by means of increasing efficiency of employees and reducing errors. In his book on 'the design of everyday things' (1998), Donald Norman showed that usability is important for other types of products as well. Large frustrations can arise when simple products such as doors, taps and light switches turn out not to be simple at all. Whilst once usability may have been seen as a bonus, it rapidly became an expectation in the nineties, with users becoming disenchanted with products which did not support an adequate quality of use (Jordan, Thomas et al., 1996, page 1). Usability in consumer products is not only important to prevent user frustration and disenchantment. It also became established as an important issue with respect to the marketing and sales of products and is therefore of commercial value. For example, den Ouden (2006) showed that product returns are half of the time caused by non-technical failures which occur when the product does not satisfy customer's expectations, often caused by usability problems. As usability is about customer satisfaction, in the long run usability might affect repurchase intent and cross-purchasing, product returns, demand on customer support and brand perception (van Kuijk, 2010).

1.1.2 What is usability and how is it related to use situations?

The ISO 9241-11 standard provides guidance on how the usability of a product can be specified and evaluated (ISO, 1998). It defines usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". When I started this research, I was intrigued by the word 'specified' in this definition. It implies that usability can only be defined for a specified use situation, for example, the usability of the Canon compact camera for the situation in which my husband and I made a picture of ourselves and the Mont Blanc. Since industrially manufactured products are never used in just one specific use situation, the usability of these kind of products will necessarily vary. The dependence of usability on its use situation is acknowledged by many researchers. For example Nielsen(1993, page 46) stated that a designer needs to consider the entire spectrum of intended users and make sure that the interface is usable for as many users as possible. Maguire (2001) argued that it is incorrect to describe a product as ergonomic or usable, without also describing the context in which the product will be used – in other words, whom the product was designed for, what it will be used for and where it will be used. And Buchenau and Fulton Suri (2000) mentioned that "the experience of even simple artefacts does not exist in a vacuum but, rather, in dynamic relationship with other people, places and objects. Additionally, the quality of people's experience changes over time as it is influenced by variations in these multiple contextual factors."(Buchenau and Fulton Suri, 2000, page 424) From the above can be concluded that usability is a quality of the interaction of a product and a user with a certain goal in a certain context of use. The dynamics and diversity of use situations therefore result in a varying level of usability for a certain product.

1.1.3 Why is it so difficult?

Although ISO 9241-11 (1998) intends to provide guidance for design by means of specifying and evaluating usability, it does not make clear how to deal with the variability of usability in design. It only advises to describe 'the components of the intended contexts of use' in relation to target values of effectiveness, efficiency and satisfaction, but it does not indicate how to deal with the myriads of actual use situations in which products are used. The difficulty of dealing with this issue was mentioned by Norman, when he stated that "designing a system that matches the user's needs confronts the designer with a large number of issues. Not only do users differ in their knowledge, skills, and needs, but for even a single user the requirements for one stage of activity can conflict with the requirements for another." (Norman, 1986, page 43). The difficulty of dealing with the diversity of users does not only manifest itself in design, but also in design research. As Wilson (2000) stated "the natural variety within and amongst people means that unambiguous and universal evidence and design guidance are almost impossible to provide". While these researchers only refer to the variety of user characteristics, the variety of the context of use adds even more complexity to this problem. From this can be concluded that the complexity of dealing with the relationship between usability and the dynamics and diversity of use situations is acknowledged in the field of design research. However, guidance on dealing with this issue is not available. The objective of this research is therefore to provide this guidance, by further investigating the issue of designing usable products for varying use situations.

1.1.4 The usability debate

The importance of usability in relation to user experience is increasingly debated in the field of design research. Jordan (1999) presents a hierarchy of user needs based on the hierarchy of needs of Maslow. The lowest level is functionality, followed by usability and pleasure. As soon as people have fulfilled the needs lower down the hierarchy, they will then want to fulfil the needs higher up. For this reason, usability is no guarantee for the commercial advantage discussed in section 1.1.1. Jordan therefore promotes a pleasure based approach to person-centred design. This approach seems to move products beyond 'usable' to the stage where they are not only usable but also enjoyable, exciting and meaningful – pleasurable. The importance of pleasure was also mentioned in a later publication of Norman (2002) in which he stated that usable designs are not necessarily pleasurable, but surprisingly, pleasing things work better, are easier to learn, and produce a more harmonious result. Good design means that beauty and usability are in balance. An object that is beautiful to the core is no better than one that is only pretty if they both lack usability. Studies on design and emotion – such as pleasure - and 'user experience' (Desmet and Hekkert, 2007) form a growing and interesting research field. However, since there is still a lot to improve in the field of usability and product design, the research described in this thesis is primarily focused on 'lower-level' user needs with regard to usability.

1.2 Studying design for usability

Usability is an aspect of design which is studied in the research field called human factors or ergonomics. This type of research is aimed at building a body of knowledge regarding interactions between humans and their environments (including products) and methodologies for analysing and designing systems (Dul, Bruder et al., 2012). Well-known methodologies for designing usable products are usability engineering (Nielsen, 1993; Rosson and Carroll, 2002) and user-centred design (Vredenburg, Mao et al., 2002). Research on design for usability is part of the larger field of design research, a relatively young research field. There is no common view yet as to what design research attempts to investigate, what its aims are and how it should be investigated (Blessing and Chakrabarti, 2009, page 4). Definitions of design research often include the aim to improve design in practice, such as the aforementioned aim of human factors research of providing methodologies for analysing and designing systems. Initially, this practical aim was the main focus of design research, rather than the aim to better understand design. This lack of understanding of the design activity itself in design research is more and more critiqued (Dorst, 2007; Stolterman, 2008). Blessing and Chakrabarti mention that this focus on improving design instead of on gaining understanding is surprising, because the development of support that is intended to improve design is likely to be far more efficient and effective if design is better understood (Blessing and Chakrabarti, 2009, page 4). Therefore, before developing guidance on dealing with the relationship between usability and the dynamics and diversity of use situations in design, a better understanding of this issue should be gained.

A first necessary step is to investigate the general characteristics of 'design'. Herbert A. Simon defined design as "the process by which we devise courses of action aimed at changing existing situations into preferred ones" (Simon, 1996, page 111) . It is an activity which includes both creativity as well as analytical reasoning (Dorst, 2006; Lawson, 2006; Cross, 2007). In order to design, designers have to draw on knowledge from areas as diverse as physics, chemistry, mathematics, engineering sciences, economics, aesthetics, ergonomics, psychology and sociology, as well as on methods and tools to support the application of this knowledge (Blessing and Chakrabarti, 2009, page 2). Design is therefore a complex activity. Stolterman (2008) argues that approaches and methods developed in design research should not necessarily be aimed at reducing this complexity, since "it (this complexity) is obviously something that gives designers rich experiences and variation, and makes it possible for them to be surprisingly creative in their design adventure. Complexity is probably even a required condition for innovative and creative design to happen" (Stolterman, 2008, page 58). To be able to develop successful guidance, the focus of design research, and thereby of this research, should therefore be on understanding rather than reducing the complexity of design.

Additionally, the success of to be developed guidance will depend on the extent to which it fulfils the needs of practitioners. Wixon (2003) argued that in the field of usability a growing body of literature on usability methods is unhelpful or even irrelevant to the practitioner. Therefore there is a gap between usability in research and practice (Norman, 2010). To understand and support designing usable products for dynamic and diverse use situations, it is therefore firstly necessary to investigate this problem in the context of design practice. Secondly, as suggested by Wixon (2003), the developed guidance should preferably be evaluated in vivo, by applying it to real products in real design contexts by real designers. Therefore, I approached this research by gaining a solid understanding of the topic of designing for dynamic and diverse use situations in design practice before developing design guidance, and by involving designers in the evaluation of the support as much as possible. This research approach is further specified in the next section.

1.3 Research plan

1.3.1 Objectives

The main objective of this research is to explore the relationship between usability and the dynamics and diversity of use situations (DDUS) and how it can be taken into account in product design. The ultimate goal of this research is to provide practical guidance for product designers in design practice on dealing with DDUS by means of the development of a design support. The main research questions that need to be answered to be able to develop a successful design support are:

1. Which aspects of design and of use situations influence the usability of products with DDUS?
2. What is the difficulty of designing for DDUS?
3. How does existing research support design for DDUS?
4. How do designers in practice currently deal with DDUS?
5. What is the desired situation with regard to designing for DDUS?
6. How can designers be supported in designing for DDUS?
7. Does the developed support have the desired effects?

The research is focused on the field of product design, because the type of objects designed within this field can encounter a large diversity of users, goals and contexts of use. The to be developed guidance is therefore expected to contribute most to this field. The research encompasses all design activities within the product development process in which usability of the final product can be influenced, including analysis, synthesis, evaluation and decision making (see for example Roozenburg and Eekels, 1995). Since products are mostly developed in multidisciplinary design teams in product design practice, the research focuses on developing guidance for design teams. When I use the term ‘designer’ I refer to any member of this multidisciplinary design team, unless indicated otherwise.

1.3.2 Research framework

The above mentioned objectives of this research include both an understanding of design for DDUS as well as the development of a support that is intended to improve design for DDUS. The Design research methodology (DRM) of Blessing and Chakrabarti (2009) was chosen as a framework to answer the research questions, since this methodology integrates the development of understanding and the development of support in research. According to Blessing and Chakrabarti (2009, page 5) these two main strands of research are closely linked and should therefore be considered together to achieve the overall aim of design research: to make design more effective and efficient, in order to enable design practice to develop more successful products.

DRM consists of four stages: research clarification, descriptive study I, prescriptive study and descriptive study II (Blessing and Chakrabarti, 2009, page 14). The DRM framework is shown in figure 1.2. The research clarification stage is aimed at finding evidence or indications that support the researcher's assumptions in order to formulate a realistic and worthwhile research goal. The descriptive study I stage is aimed at understanding the existing situation. The prescriptive study stage is aimed at the development of a support aimed at transferring the existing situation in a desired situation. Finally, the descriptive study II stage is aimed at investigating the impact of the developed support and its ability to realise the desired situation. DRM furthermore shows that design research can contain many iterations and stages can be executed in parallel. All mentioned stages are covered in this research. The next section further introduces the research approach within each stage and how the stages are connected.

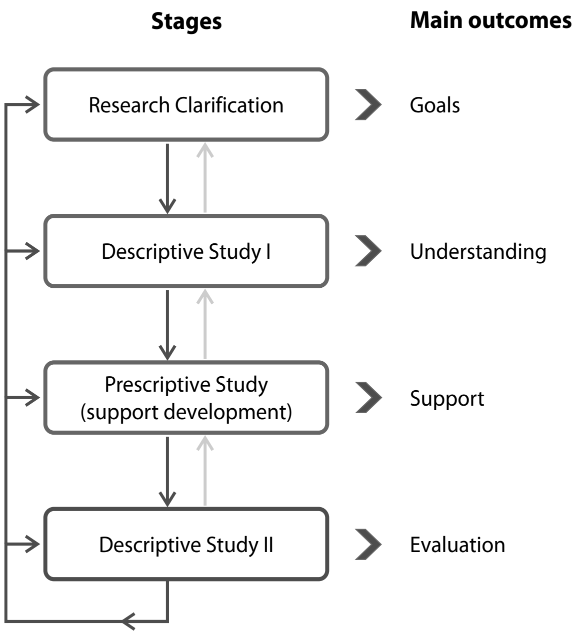


Figure 1.2: DRM framework (adapted from Blessing and Chakrabarti (2009))

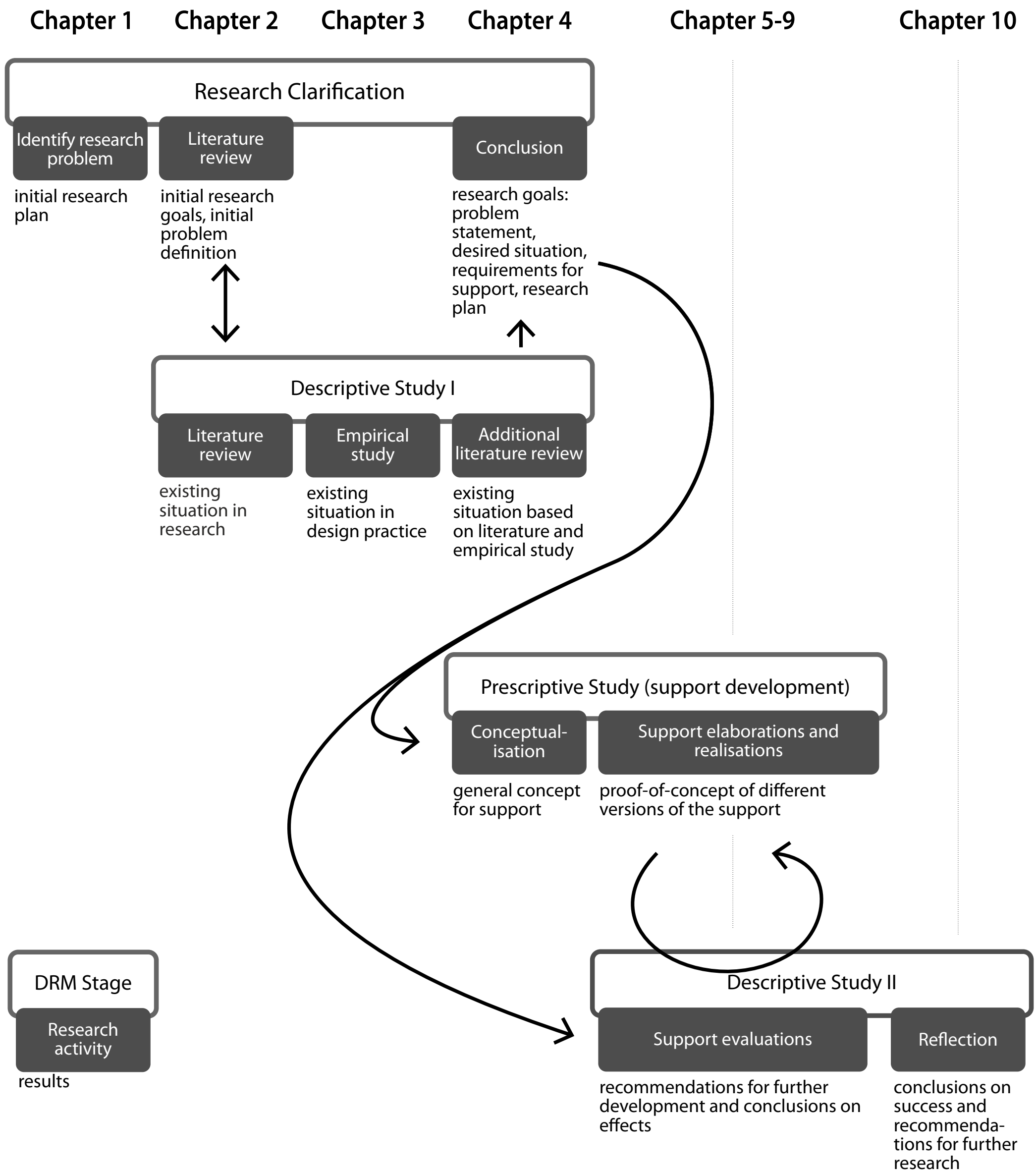


Figure 1.3: research approach according to DRM and thesis outline.

1.3.3 Research approach and thesis outline

As mentioned previously, DRM is used as a framework for this research on design for DDUS. The outline for the research is shown in figure 1.3. The first part of the research is aimed at gaining understanding of this topic and setting goals for further research. Since goals were formulated based on insights in the existing situation with regard to designing for DDUS, the research clarification stage and descriptive study I stage were executed in parallel. Insights in which aspects of design and of use situations influence the usability of products with DDUS (research question 1), the difficulties of design for DDUS (research question

2) and how existing design methods and approaches support these influences (research question 3) was gained by means of a review of literature on usability in general and on existing support for designing usable products, as well as by means of a review of the dynamics and diversity of use situations of some products. This review based research is described in chapter 2 and results in an initial problem definition. To gain more insight in the existing situation and to answer the question how designers deal with DDUS in design practice (research question 4), an empirical study was conducted in design practice . This study included a design experiment to investigate if designers are aware of DDUS and a retrospective case study to investigate how designers had dealt with DDUS in a specific design project. This study is described in chapter 3. Chapter 4 completes the insights in the existing situation by means of an additional literature review with regard to the most important insights gained in design practice. Conclusions were drawn from comparing the literature review and empirical study. This included the generation of models of the existing situation as well as of the desired situation, and a list of requirements for the development of a support (research question 5). Furthermore, an initial support concept is presented in chapter 4, which was based on the requirements.

In conformance with the earlier mentioned statement of Wixon (2003) that the success of the support depends on the extent to which it fulfils the needs of practitioners, an iterative approach was chosen to further develop the support. In multiple iterations different versions of the support were created and evaluated with experienced designers and/or students of the master Industrial Design Engineering. The support development in the prescriptive study stage gave answer to research question 6: how can designers be supported in designing for DDUS? In the several iterations, the evaluations in the descriptive study II stage revealed whether the developed support had the desired effects (research question 7). The developed support consists of a workshop technique and a set of guidelines. The different versions of both support tools and the evaluations are described in chapter 5 to 9. Chapter 4 gives a more detailed introduction to this development process. Chapter 10 concludes this thesis with a reflection on the most important findings and recommendations for future research.

2

Design For Ddus

2 Design for DDUS

The first research question formulated in chapter 1 is 'which aspects of design and of use situations influence the usability of products with dynamic and diverse use situations?'. This chapter investigates this question with regard to the content of the design problem and the emerging design solution, the design process, the designer and the design context. This chapter structure is based on a framework proposed by Dorst (2007) who states that to describe an area of complex creative human endeavour like design, all aforementioned elements should be considered. In section 2.1 I will firstly give a definition of dynamic and diverse use situations and I will describe the implications of DDUS for usability by means of product reviews and a literature analysis. This is the *content* of the design problem. The consequences of this design problem for creating solutions is described in section 2.2 by means of an analysis of the design problem for a specific product. The topic is then further explored with regard to the *process* of dealing with the design problem of DDUS in section 2.3. This study investigates how current design methods and approaches take DDUS into account in the design process by means of a review of literature. A final literature review gives insight in the influences of the *designer* and the *design context* on design for DDUS (section 2.4).

Since the goal of the study described in this chapter is to further clarify the goals of the research on design for DDUS, it can be considered the 'research clarification' stage of Blessing and Chakrabarti's design research methodology (Blessing and Chakrabarti, 2009). In line with that framework, this chapter therefore concludes with the formulation of an initial problem definition. The chapter also gives first insights in the existing design situation with regard to design for DDUS. According to the design research methodology this is part of the descriptive study I stage, which ultimately results in a model of the existing situation. This model – called the reference model – will be introduced in chapter 4, based on the findings in this chapter and a further elaboration of the descriptive study I stage in chapter 3.

2.1 The design problem of dynamic and diverse use situations

Dynamic and diverse use situations are defined as: **the use situations of products that are used by varying users, with varying goals and/ or in varying contexts of use**. Dynamic use situations refer to the change of situations in time for one product. For example, one day you might use your car to drive to your work to be in time for a meeting, while the next day you might use it to transport your groceries from the supermarket to your home. Diverse use situations refer to the change of situations in time and space for different versions of the same product. For example, someone else might possess the same type of car, but only uses it for recreational purposes, for example going on vacation.

This section firstly gives insight in the dynamics and diversity of use situations of different types of products and the consequences for usability. Next, the attributes of usability are described, followed by a definition and discussion of the use situation elements user, goal and context of use. Finally, different levels of dynamics and diversity are introduced as well as different types of solutions which can be used to accommodate products to DDUS.

2.1.1 The dynamics and diversity of use situations of products

As opposed to tailored products, all industrially manufactured products will encounter to some extent a variety in use situations. However, this level of variety of use situations can differ strongly per type of product. Depending on the specificity of the chosen target group, most products encounter different kinds of users. Large varieties in users are for example seen with products which concern automated services, such as box offices which are replaced by ticket vending machines and travel agencies that are replaced by online stores. In those kind of walk-up-and-use products (see for example Nielsen, 1993), product developers have no choice but to design a product that is appropriate for all users. In other cases, companies can choose to aim their product design at the needs and characteristics of a specific type of user. This is advocated by for example Cooper (1999) who states that you will find that the features that please some users will interfere with the enjoyment and satisfaction of others. He argues that trying to please too many different points of view can kill otherwise good products.

Secondly, the goals or purposes that products are used for increase when more functions are integrated in one product. A well-known example is the Swiss army knife which can be used for purposes such as cutting paper, opening wine bottles and removing splinters. A more recent example is the design of cell phones. From ordinary cell phones users require that they can make and receive phone calls, store a list of frequently called people, keep a list of frequently called people and a list of who has called the phone and who has been called, take photographs, play music, listen to a call with loudspeaker or earphones and send text messages (Norman, 2010). The introduction of smart phones has added even more needed functions to this list. According to Norman (1999) multipurpose products are always complex: 'Try to make one device do many things and complexity increases'.

Finally, many products encounter variety in contexts of use. This is particularly the case for mobile devices, caused by the ever increasing opportunities of wireless networks and improving battery capacity which makes it possible to use those devices in any kind of environment. In the design and research field concerning mobile devices, this context aspect has gained an increasing amount of attention since the end of the previous century (see for example, Johnson, 1998; Rodden, Chervest et al., 1998), resulting ultimately in a complete mobile human computer interaction (HCI) community and dedicated research centers, such as the Mobile Life Center (Holmquist, Höök et al., 2007). However, context of use is also an important varying aspect for mobile products which do not depend on wireless networks and battery capacity such as bicycles, watches and baby strollers or non-mobile products which have a context which is variable itself. An example of the latter is a system to control the intensity and distribution of light in lecture rooms with varying educational practices and compositions of the student group (see figure 2.1).

As discussed in chapter 1, usability of products does not only depend on the product characteristics, but also on its use situation. That means that when products are used in varying use situations, the level of usability will vary as well. This can result in conflicting requirements and compromising products, such as illustrated in the example of the light system.

To be able to take a use situation into account in a user centred design process the designer needs to know which aspects of a product's use situation influence usability in which way. Therefore the following sections describe the elements of both usability and use situations in more detail.

2.1.2 Usability issues

According to the ISO-definition, usability can be decomposed into effectiveness, efficiency and satisfaction (ISO, 1998). These higher level usability elements cannot directly be observed. Therefore lower level usability issues need to be defined which allow the measurement of usability. These include general usability issues such as user comfort, learnability, guessability, safety and expert efficiency (see for example, Nielsen, 1993; Jordan, 1994; Rubin, 1994; Welie, van der Veer et al., 1999; Shackel, 2009)). For example, a higher level of comfort can lead to more satisfaction. More specific usability issues can be defined with regard to the to be designed product. For example, for a bicycle comfort can relate to the comfort of the grip or the comfort of the body position. When usability issues are unintended they are referred to as usability problems. When usability issues are desired they can be referred to as usability 'goals'.

To be able to distinguish the most relevant use situation aspects it should be clear how a certain use situation influences a specific usability issue which is indicated as being of importance. This can again be illustrated by means of the bicycle example. In case of a touring bicycle the issues 'comfort of body position' and 'visibility in traffic' will probably be most important, but in case of a racing bicycle the issue 'efficiency with regard to speed' will be more important. The first type of bike requires a solution that offers users their preferred comfortable body position, while the second type of bike requires a solution that offers the most aerodynamic body position. So in the first case the designer needs to know something about variation in preferences of users and in the second case the designer

Dynamic lighting

This year, a new control device for the audio-visual system was implemented in our lecture rooms. This included an automated system for the control of the lights. The developers of the system had presupposed two presentation situations:

1: traditional lecture without the use of a projector. The lights are on (figure 1)

2: traditional lecture with the use of a projector: the lights are dimmed (figure 2)

A third presentation situation was not accounted for: having students work on assignments while showing examples on the projector (figure 3). Both students and instructors started to complain immediately after the implementation of the system, since they could not do their work in the dimmed lights. Therefore, a single button was added to the control panel to allow to manually increase or decrease light intensity by means of a smart (or complex) combination of actions.

This example shows that the requirement of situation 1 and 2 (projector on, lights off) conflicts with the requirement of situation 3 (projector on, lights on)

This is an example of how the dynamics of the context of use can influence the usability of a product or system.

Figure 2.1: an example of how the dynamics of a lecture room can lead to conflicting requirements for design

needs to know about expected air conditions and wind resistance of the equipment of the user. This means that the relevancy of use situation aspects depends on the usability issues that will define the success of a product. The next section gives an overview of use situation aspects that are often of influence to usability.

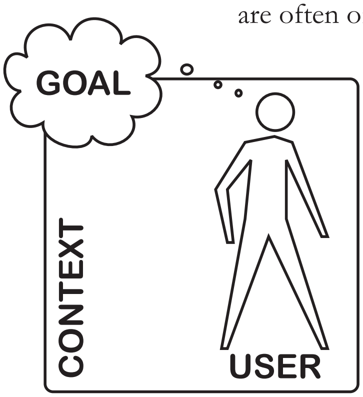


Figure 2.2: use situations are defined by the user, goal of the user, and context of use

2.1.3 Use situation aspects which influence usability

Use situations are defined by the user, goal of the user and context of use (see figure 2.2). These elements are taken from the ISO 9241-11 definition of usability which defines usability as "the extent to which a product can be used by specified users to achieve specified goals with efficiency in a specified context of use" (ISO, 1998). In this section these elements and how they can influence usability are explained in more detail.

User

When considering the user of a product in relation to usability, the question is which characteristics of the user influence usability. From a comparison of different studies and definitions can be concluded that these characteristics include (domain) knowledge, skills, experience, education, training, physical attributes, motor and sensory capabilities, personal traits, cultural background, age, gender, disabilities, literacy and income (ISO, 1998; Jordan, 1998; Shneiderman, 2000; Nielsen, 2002; Kim and Christiaans, 2011). Within these characteristics, one can distinguish characteristics that have a clear direct influence on usability and those that influence usability indirectly. An example of such a directly influencing user characteristic is the often mentioned level of experience with the product itself or with other similar products, also often referred to as novice and expert users. This aspect is likely to affect how easy or difficult it is to complete a particular task (Nielsen, 1993; Jordan, 1998). The indirectly affecting characteristics are the ones that can be considered labels for groups of users that have certain other directly influencing characteristics. For example, demographic data such as age, gender and cultural background correlate to user characteristics such as physical strength and body dimensions which in their turn influence usability issues such as comfort and physical effort. Since these indirect relations can only be analysed statistically, they are only useful for general guidelines on designing specific types of products for certain target groups (see for example, Kim and Christiaans (2011)). Therefore, in this research only directly influencing user characteristics are considered. Without claiming to be complete, figure 2.3 gives some examples of types of influencing user characteristics.

Goals

Goals of users are important to consider because they define why somebody uses a product. ISO 9241-11 (1998, page 4) states that goals may be decomposed into sub goals which specify components of an overall goal. Cooper (1999) states that when interaction designers analyse goals to solve problems, they find much better solutions. Cooper distinguishes personal goals and practical goals. Personal goals concern issues like having fun or not making mistakes, while practical goals are the goals directly related to product use. For example, a user's practical goal might be to watch TV and take advantage of all the TV's features, while personal goals are that the user does not want to be made feel stupid. Cooper states that the essence of good interaction design is devising interactions that let users achieve their practical goals without violating their personal goals (Cooper, 1999, page 150). Therefore it is important to consider both types of goals. Preferences are added as an additional goal type to distinguish goals in relation to the preferred behaviour of the product, such as the level of sound volume.

Although ISO 9241-11 states that tasks are activities undertaken to achieve a goal (ISO, 1998, page 4), the terms 'goals' and 'tasks' are often used interchangeably in literature on user centred design. For example, Shackel (1984) states that tasks can mean anything from the total job down to the smallest subtask. However, there is a clear difference between the higher level 'task' which describes the goal of the user and, a 'sub task' which depends on the interaction between a specific product and a specific use situation. For example, Cushman and Rosenberg (1991) describe the following subtasks for the tasks 'installing batteries in an 'electronic photographic flash unit': locate battery compartment door, open battery compartment door, insert batteries (correctly oriented), close battery compartment door. These tasks describe an ideally executed interaction between a perfect user who 'correctly inserts the batteries' in a specific design with a battery compartment. However, it is easy to imagine

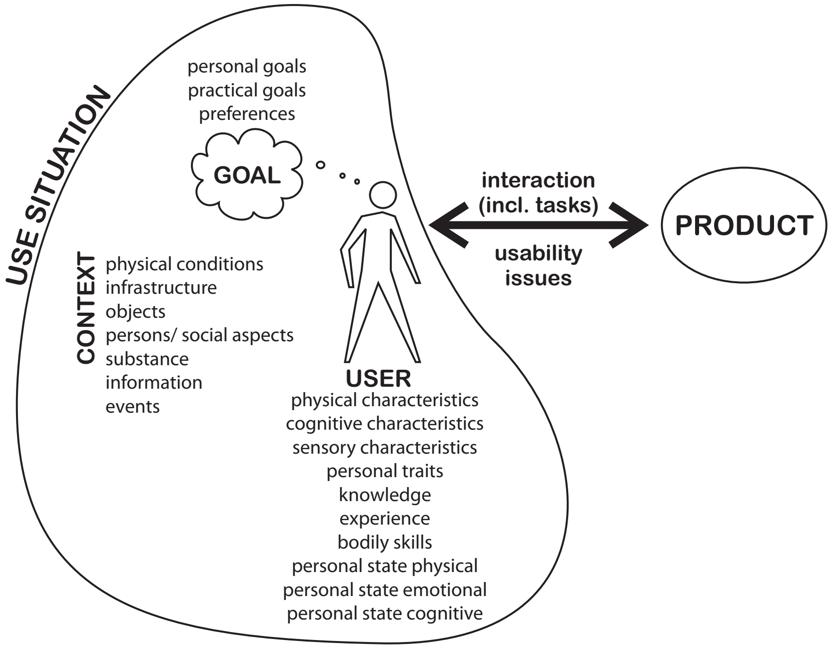


Figure 2.3: examples of different types of use situation aspects related to the user, his or her goal and the context of use. An encounter of a specific use situation and the product leads to a specific interaction with specific usability issues.

other tasks occurring in an interaction with this battery compartment, such as 'not finding the battery compartment'. As Cooper (1999) states: goals are steady, while tasks are transient. Since thus the task is not part of the use situation, but merely a result of an encounter of a product with a certain use situation, tasks are not considered to be an element of use situations in this research. Instead they are a part of the interaction between a specific product and a specific use situation and are addressed as such (see figure 2.3).

Context of use

ISO 9241-11 is ambiguous on what constitutes the context of use, which is defined as users, tasks [it is not clear if this refers to goals or subtasks], equipment, and the physical and social environments in which a product is used (ISO, 1998, page 2). This does not correspond to the definition of usability in the same standard which distinguishes the context of use from the user and her goal. Similarly the contextual design method, developed by Beyer and Holzblatt (1998) includes goals and tasks in the definition of the context of use which is further referred to as the 'customer's workplace'. The definition of context of use in this research deviates from this by including every element in the use situation that is not part of the user, goal, product, or interaction itself, but does influence that interaction. These aspects can include physical aspects such as light and noise, objects, and social aspects such as societal attitudes, the technical environment such as network connectivity and information and events (actions and reactions produced by features of the setting) (Shackel, 1984; Schilit, Adams et al., 1994; Maguire, 2001; Rosson and Carroll, 2002).

The types of use situation aspects which are mentioned in literature as being important in influencing usability depend on the type of product or system the source is concerned with. Most research on usability has been conducted in the software domain, particularly aimed at improving work situations, such as in computer-supported cooperative work (CSCW). Consequently, relevant use situation aspects are related to that domain. Often there is large attention for the work environment and the knowledge and experience of the user. The development of mobile applications has extended the definition of context of use to a broader environment, although its software background is strongly reflected in the mentioned importance of context aspects such as networks and information. In this research I consider products with or without software. Therefore, in this research we define use situations as **all relevant characteristics of the user, goal and context of use, which are not part of the interaction or the product itself** (Brouwer and van der Voort, 2006). The next section describes the extent to which these types of aspects can *vary*, followed by an analysis of relevant use situation aspects of a specific product: a bicycle.

2.1.4 Levels of variety of use situations

Figure 2.4 different levels of variety of use situations for the Stokke TrippTrapp chair

To be able to accommodate solutions to DDUS, it was assumed to be useful to consider the extent to which use situation aspects, such as described in the previous section, vary. Different types of solutions can be created for different levels of variety of use situations. Three variety levels can be distinguished: within a use session (here defined as dynamic session level), between use sessions of the same product (here defined as dynamic product level) and between products of the same series (here defined as diversity level). The different levels are illustrated by means of the example of the Stokke Tripp Trapp chair shown in figure 2.4. A simple study was conducted among acquainted families to analyse the different use situations in which they used their Trip Trapp chair. The dynamic session level contains aspects that vary during a use session, for example the positions of the child. The dynamic product level contains aspects that vary between use sessions of a single product, for example the goal of using the chair (eating or playing a game) or the user characteristic of the chair (the dimensions of the family member that sits on the chair). The third level is the 'diversity level' and concerns aspects that vary between different products of the same series, for example different preferences of different families with regard to the appearance of the chair and the different furniture arrangements in which the chair is positioned.

In summary, use situation aspects can be categorised by type: user, context or goal and by level: diversity between products and dynamics between use sessions and within sessions. This is illustrated in figure 2.5. In the next section I will show the complexity of the influence of DDUS on usability by means of an example, a bicycle.

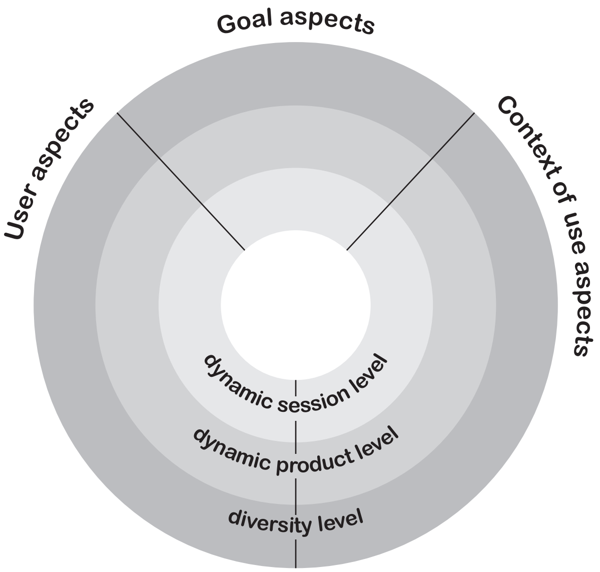


Figure 2.5 use situation aspects can be categorised by type and by variety level

Dynamic session level

(within use sessions): the position of the child can vary.

The chair allows the child to both sit, stand and reach for something on the table

Dynamic product level

(between use sessions): within one family, different members use the chair for different purposes.

The chair allows to play the guitar, work at the table, or use it like a step stool

Diversity level

(between products): different families have different aesthetic preferences and the dimensions of the primary user vary (this can also be considered dynamic product level since these dimensions change over the years).

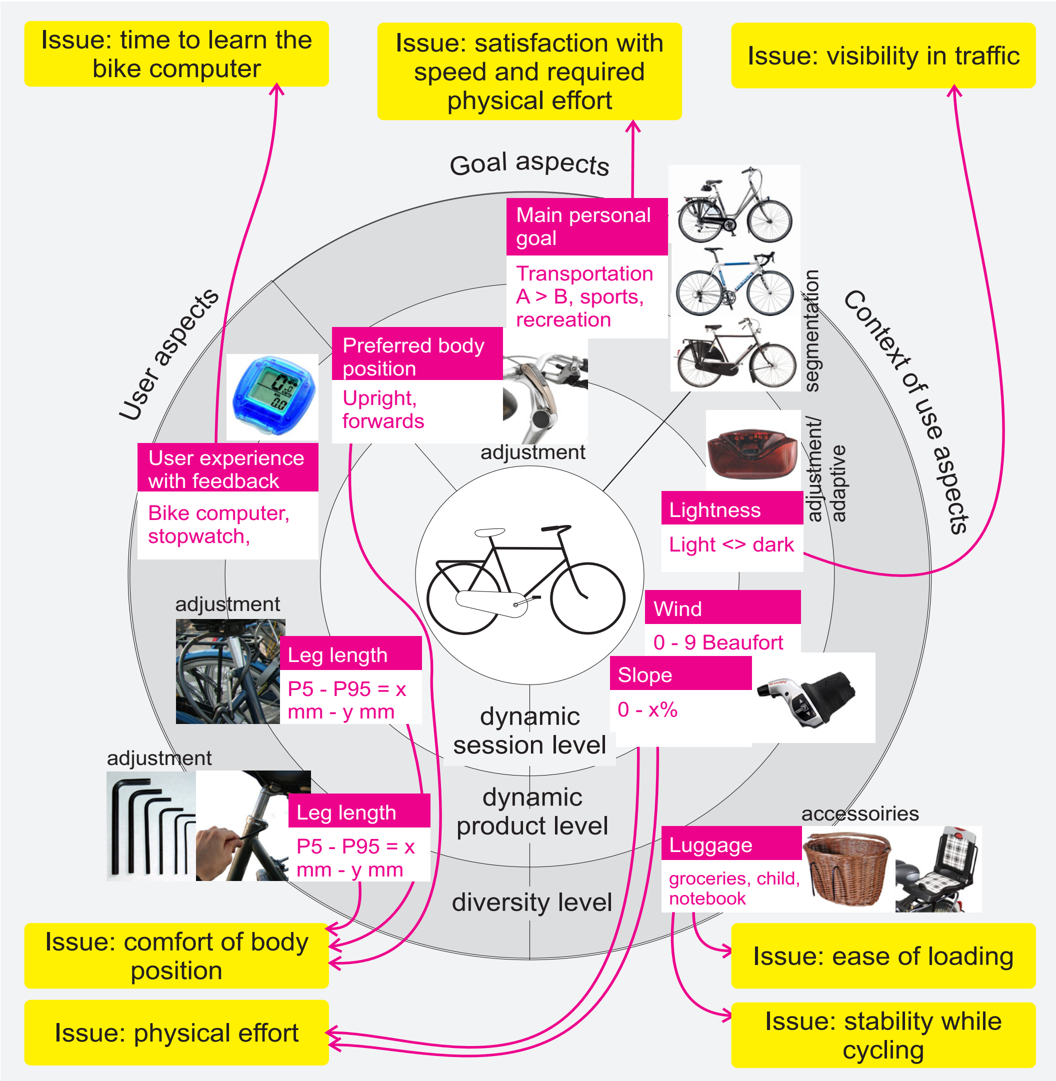
The chair is available in different colours. Furthermore, the chair can be adjusted to the dimensions of its primary user, by means of a cushion, adjusted seat and foot plate height, and high back and rail support for baby's.

2.1.5 The complexity of identifying relevant DDUS aspects

Figure 2.6 shows a couple of relevant user, environment and goal aspects for a bicycle and their dynamics and diversity on different levels and a specific solution to accommodate the concerning aspect or combination of aspects. The case of the bicycle is here used to show how use situation aspects relate to usability issues and to the solution (van der Bijl-Brouwer and van der Voort, 2008).

Section 2.1.2 already described that in order to identify the most relevant use situation aspects it should be clear how a certain use situation influences a specific usability issue which is indicated as being of importance. When we look at a bicycle and at the issue 'comfort of body position' there are several varying user and context aspects that influence this comfort, for instance leg length between users and preferred body position between

Figure 2.6: example of how use situation aspects of different type and variety level influence usability issues of a bicycle.



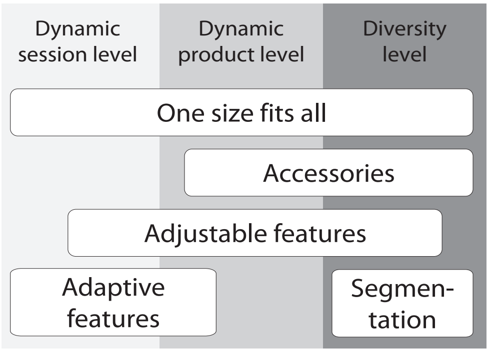


Figure 2.7: different means to accommodate a product to the different levels of variety of use situations

users or use sessions. The issue 'physical effort' is influenced by wind conditions and slopes which can vary on dynamic session level. A bike design can be accommodated to these aspects in different ways. The gear can often be adjusted to wind, slope and the user's physical condition, the seat height may be adjusted to the leg length and the steer height or position may be adjusted to the preferred body position. Note that in case of a personal bicycle, adjustment of seat height is usually not so easy. You need an extra tool for the adjustment. In case of a rented bicycle, adjustment is much easier, usually by means of a fixed lever. In the last case the aspect 'leg length' varies frequently on dynamic product level while with a personal bicycle it varies on diversity level. Thus, the means by which a product feature accommodates variations of use aspects seems to depend on the variety level of the aspect. For instance, on diversity level, one can decide to segment to accommodate different use situations. Different bicycles can be developed for different personal goals. On dynamic product level a product can be tuned to its use situation by means of adjustable features and accessories. A customer can for example purchase accessories to be able to transport different types of luggage. On dynamic session level products could apart from easy adjustable features like gears also include more or less dynamically adaptive features, for example a bicycle light that automatically adapts to light conditions. On all levels the cheapest solution is usually 'one size fits all'. This is one solution which attempts (more or less deliberately) to accommodate all variations of an aspect. For instance, a bicycle computer can be designed for people with the least experience with these kind of devices while all persons with more experience will be able to use it as well.. Figure 2.7 shows how products in general can accommodate variation of use situation aspects on the three levels.

One of the difficulties of identifying relevant use situation aspects is that their relevancy with regard to usability depends on the type of solution. This is consistent with the general notion that designers explore and define problem and solution together (Dorst and Cross, 2001; Lawson, 2006; Cross, 2007). As an example consider the issues comfort and safety and using the breaks of a bicycle. When we choose a solution in which the breaks are controlled by hand, the user aspects 'hand power' and some anthropometric hand data are relevant. However, when we choose a solution in which the breaks are controlled by feet, the hand aspects are no longer relevant. Instead the aspects 'experience with pedal breaks' and 'available learning time' might become more relevant. This issue of interdependency was discussed by Dourish (2004) who states that contextuality is a relational property that holds between objects and activities. A similar statement was made earlier by Johnson (1998) with regard to mobile systems: "To contribute to the design of mobile systems we need to understand what the design problems of mobile systems are. This may sound circular or tautological but it is not. There are extensive psychological, sociological, organisational and environmental phenomena to be studied when we start to investigate the "worlds" in which mobile computing might take place. However, whether or not these phenomena have any relevance to system design has to be considered." This means that use situation aspects cannot be investigated independently of solutions. For each product and interaction other use situation aspects can be relevant.

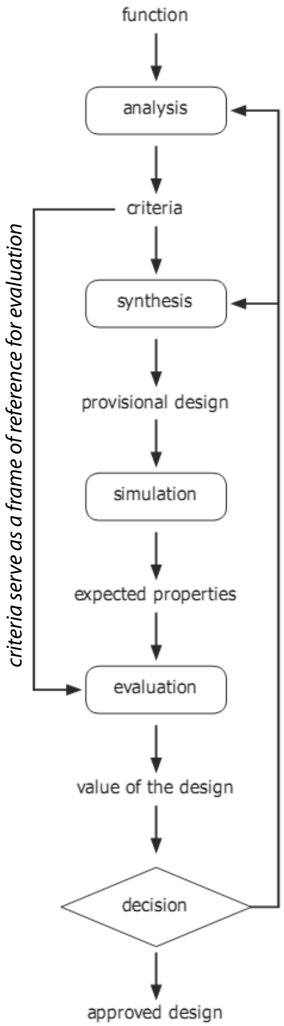


Figure 2.8: the basic design cycle of Roozenburg and Eekels (1995). The frame of reference for evaluations is presented as a number of criteria.

This section on the design problem for DDUS has shown that the diversity and dynamics of use situations can lead to conflicting requirements for solutions as was illustrated by the example of the light system in the lecture room. Many different aspects and variations of the user, goal and context can influence usability. For specific domains, such as software design, research has given insight on what the most important varying use situation aspects are such as the difference between novice and expert users. However, for the type of products considered in this research, product development teams need to identify relevant use situation aspects and usability issues themselves. The example of the bicycle shows the complexity of this task. Many use situation aspects can influence different usability issues and thereby the suitability of the solution. The relevancy of use situation aspects depends in return on the solution. This means that the design problem of DDUS evolves together with the evolution of the solution. The next section describes a further exploration of designing for DDUS with regard to the design *process*.

2.2 Dynamic and diverse use situations in the design process

This section describes the exploration of the design process of designing for DDUS by means of comparing the characteristics of designing for DDUS to design methodology. This results in a list of criteria for assessing design approaches and methods on their suitability in designing for DDUS. Subsequently, the section describes a comparison of several user centred design methods and techniques with regard to these criteria, based on a review of literature on user-centred design and usability engineering.

2.2.1 Criteria for design methods aimed at designing for DDUS

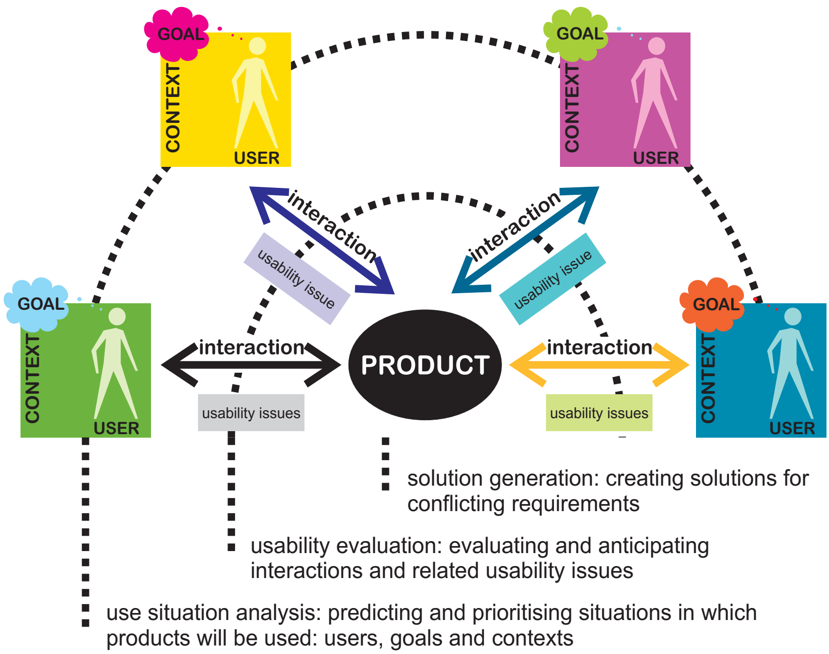
Awareness of DDUS

A first precondition of designing for DDUS is that product developers should be aware of the fact that their designed product will be used in this variety of use situations. A usable design requires that the designer is motivated to acknowledge the importance of use situation factors that influence usability. In other words, they should be able to focus on future use. The importance of awareness was shown in a study of Harkema, Luyk-de Visser, Dorst and Brombacher (2011) which showed that unawareness of decision makers of a lack of information with regard to usability, led to usability problems of the developed product. If this requirement of making product developers aware of dynamic and diverse use situations is met, the following question is *how* they can take this issue into account in their design process. General design methodology can give insight into this issue.

Activities in designing for DDUS

General design methodology distinguishes activities aimed at creating a frame of reference, creating solutions and evaluating those solutions with regard to the frame of reference. This is reflected in for example the basic design cycle of Roozenburg and Eekels (1995, see figure 2.8) in which the frame of reference is represented as a number of criteria to which solutions are compared in evaluations. When designing for DDUS we can therefore distinguish similar activities. Firstly, building a frame of reference could be based on 'use situation analysis' aimed at predicting and prioritising the situations in which products will be used. Secondly, solution generation includes creating solutions for conflicting requirements from different use situations. Finally, evaluation could be aimed at anticipating usability issues based on evaluating the interaction between solutions and the variety of use situations. These elements are indicated in figure 2.9. For example, for the design of the Stokke Tripp Trapp chair, use situation analysis would probably have included gaining insight in the type and dimensions of children that would use the chair and the purposes for which the chair would be used such as eating or playing.

Figure 2.9: the basic design activities in design for DDUS. Use situation analysis can assumingly lead to a fourth activity: the generation of a frame of reference for usability evaluations.



Usability evaluations would have been aimed at gathering insights in the consequences of these child dimensions and goals for the usability of the chair such as the extent to which children should be able to reach over. This would have led to conflicting requirements for the use by baby's who need protection from falling off the chair and older children who should be able to reach over the table. In solution generation this was dealt with by means of providing accessories and adjustable features for the chair.

Without presupposing a specific order in the aforementioned activities, it is assumed that each activity can influence the usability of products that are used in DDUS. This section now further discusses initial criteria for each of the activities to positively influence design for DDUS. These criteria are used in the following section to discuss the appropriateness of existing methods and approaches for design for DDUS.

Use situation analysis

The previous section has shown that identifying relevant use situation aspects depends on the solution and on usability issues that are considered to be important. Design approaches aimed at gathering these insights should therefore allow the exploration of the variety of use situations as well as the relation of these use situations to usability issues. To be able to use the thus gathered insights of use situations and issues, it is furthermore necessary to prioritise them. This is reflected in the recommendation of ISO to give particular attention in the selection of contexts for usability evaluations, to those attributes which are judged to have a significant impact on the usability of the product (ISO, 1998, page 8). Prioritising use situations is necessary because it is practically not feasible to evaluate each possible use situation and usability issue in usability tests.

A frame of reference of use situation aspects and related usability issues

The gathered use situations and issues need to be made explicit to be able to communicate them and take them into the design process. At the start of a design project, analysis of current use could give insight in use situation aspects and usability issues that might be relevant for future use as well. The frame of reference would then reflect this current use. However, as concluded in the previous section, relevant use situations are dependent on the type of solution. A generally acknowledged principle to design usable solutions is iterative design (e.g.(Gould and Lewis, 1985; Nielsen, 1993)), which means solutions are created, evaluated and adjusted continuously during the design process. Therefore, later in the design process, new information is necessary with regard to relevant use situations and issues for new solution proposals. This was reflected in the example of the bicycle breaks in section 2.1.5. Therefore a flexible frame of reference is needed which represents the variety of relevant use situation aspects and usability issues and which can easily be adjusted to changing opportunities and limitations of new solutions.

Solution generation

In the previous section several types of solutions were mentioned to accommodate solutions to conflicting requirements such as accessories and 'one size fits all'. Although these solution types give some suggestions on the *content* of possible successful solutions, they do not give any insight in the solution generation *process*. This process of generating solutions is a creative activity. Dealing with DDUS in solution generation does essentially not differ from other types of designing for broad and 'ill-defined' problems. Apart from a 'creative leap' from problem to solution, creative design includes 'problem framing', 'co-evolution' and conceptual bridging between problem space and solution space (Cross, 2007). This means that it is not a matter of first fixing the problem and then searching for a satisfactory solution concept. It seems more to be a matter of developing and refining together both the formulation of a problem and ideas for solution (Dorst and Cross, 2001, page 11). The success of individual creative design seems most of all a result of design expertise (Akin and Akin, 1996). For group creativity, many techniques are available that support the generation of a wide range of ideas, such as brainstorming and synectics (see Pahl and Beitz (1995) for an overview), although there is no consensus yet on whether generating many alternative designs leads to better end results (Cross, 2007, page 92). Little guidance could be found on approaches for solution generation with regard to user centred design, other than recent attempts at increasing designers empathy to inform and inspire designers to create products that fit the user's needs. (Kouprie and Sleeswijk Visser, 2009).

It is acknowledged that solution generation is an essential part of designing for DDUS. However, since the creation of solutions for DDUS does not differ from general approaches of creating design solutions, it was decided that a further study of this activity is outside the scope of this research.

Usability evaluation

Finally, solutions should be evaluated with regard to the created frame of reference. Evaluations are particularly important because they support improving a product as part of an iterative design process: a formative evaluation. They can also be used to assess the overall quality of the solution, for example for use in deciding between alternatives: a summative evaluation (Nielsen, 1993, page 170). Since formative evaluations form the basis of iterative design, I focussed on these type of evaluations in this research. Usability evaluations should be aimed at considering the implications for usability of important interrelated use situation aspects at the same time. In other words, solutions should be evaluated in integrated use situations. For example, in case of the bicycle, it makes sense to consider environmental aspects as wind, slope and the user's physical condition at the same time. Furthermore, designing for dynamic and diverse use situations obviously requires that multiple use situations are taken into account. This is also acknowledged in the ISO-standard, which states that "for a general-purpose product, it will generally be necessary to specify or measure usability in several different representative contexts, which will be a subset of the possible contexts and of the tasks which can be performed" (ISO, 1998).

Concluding, the criteria of a design approach aimed at taking DDUS into account include that:

- Designers should be made aware of DDUS
- Designers should be supported in analysing the dynamics and diversity of use situations and exploring the relation to usability issues
- Designers should be supported in prioritising these use situations
- Designers should be supported in building an explicit and flexible frame of reference of those use situations
- Designers should be supported in evaluating solutions with regard to integrated and multiple use situations.

In the remainder of this section each above mentioned criterion is further explored by means of a comparison of the criteria to existing design approaches and methods. This will give insight in if and what kind of design support is needed to design for DDUS.

2.2.2 Making designers aware of the diversity of future use situations

The first criterion concerns making designers aware of the dynamics and diversity of use situations and make them focus on possible future use. A method which is often employed to deal with user needs in the design process is specifying user requirements by means of technical and functional specifications (see for example, Cushman and Rosenberg (1991)). However, translating desired use into technical and functional specifications risks losing the grounds of these specifications (Miedema, van der Voort et al., 2007). A designer might forcedly create solutions that fit the specifications instead of accommodating the future use situation. This is further discussed by Rosson and Carroll (1990) when they argue that functional specifications in user interface design might *abstract away* from what people might want to do with the system and the contexts within which they might want to do it. Therefore specification analysis does not meet the criterion of focus on possible future use. This focus can be better achieved by means of methods that make different usages explicit and present them to designers. Prototyping and usability evaluations (see for example Rubin (1994); Jordan, Thomas et al. (1996)) are a useful means to achieve this goal. When solutions are generated, these kind of tests can be exploited to make designers aware of possible future use. Earlier in the design process, designers can be made aware of future use by means of scenario based design (Rosson and Carroll, 2002). In scenario based design descriptions of people using technology are used in discussing and analysing how technology could be reshaping their activities. These 'scenarios' thus are a means to present and communicate possible and desired future use and keep a focus on future use. The methods have the potential to have designers focus on *variety* in future use when they are stimulated to explore various scenarios.

From this can be concluded that in methods which have the potential of making designers aware of the dynamics and diversity of future use, use is made explicit in integrated representations of use, instead of a translation in more narrow specifications.

2.2.3 Analysing use situations

The second criterion concerns supporting designers in analysing the diversity of use situations relevant for usability issues that are considered important. ISO 9241-11 (1998, page 3) mentions that a description of the use situations may include a description of the existing use situation and/ or a specification of the intended use situations. The section firstly describes methods to analyse real-world use in which information is gathered about this existing use situations in the field. Analysis of these existing use situations could give insight in use situation aspects and usability issues that might be relevant for future use as well. This is true for both the design of a new version of an existing product, as for the design of 'something new' (Moggridge, 2007, page 726). Secondly it describes the more experimental approach of usability evaluations of current solutions which allows an exploration of the intended use situations which differ from existing situations.

Real world studies of the current situation

In literature, many methods are described which give insight in current use situations and relevant usability issues. For specific use situation aspects, data may already be available because it has been researched before by others. For example, anthropometric information is largely available through the work of Henry Dreyfuss (1968) and of later researchers such as the TU Delft ergonomics group (Daanen, Krul et al., 2004). In all other cases, product developers should conduct 'user research' themselves to collect this information. This type of user research includes user observation, interviews and focus groups (Sharp, Rogers et al., 2007). Each technique can give insight in one or more use situation aspects and related usability issues, for example interviews can give insight in user goals, while observations are more appropriate to analyse the context of use (see for examples van der Bijl - Brouwer and van der Voort (2009)). The structure of the chosen method influences the extent to which use situations can be explored. For example, unstructured interviewing can provide a larger breadth of data than more structured types of interviewing (Fontana and Frey, 2000). A specific type of combination of these activities is the ethnographic study. Ethnography is aimed at understanding people's everyday activities by gathering information in the settings in which the activities of interest normally occur (Blomberg, Burrell et al., 2003). It's main distinguishing feature compared to other approaches of data gathering is that it aims to observe a situation without imposing any a priori structure or framework upon it, and to view everything as 'strange' (Sharp, Rogers et al., 2007, page 331). As such they allow the exploration of both relevant use situation aspects and usability issues. An ethnography-like approach aimed at gathering customer data for computer-supported cooperative work systems is contextual inquiry (Beyer and Holtzblatt, 1998). The core premise of contextual inquiry is: go where the customer works, observe the customer as he or she works and talk to the customer about the work. These type of approaches can provide rich data on current use in the sense that they result in a detailed and accurate description of a specific instance of current use. However, exploring variety of use situation aspects and usability issues simply means conducting more studies. Thus, these type of studies can become very time-consuming. Moreover, they will be less successful in revealing usability issues that do not occur while the researcher is present.

Approaches that have a larger chance of giving insight in the broadness of use situations and issues are those that are based on self-reports in which users report their use experiences themselves. Examples of these kind of self-reporting techniques are retrospective interviews, probing and after sales feedback. In retrospective interviews people are asked to recall use episodes that they remember as particularly successful or unsuccessful. However, according to Rosson and Carroll (2002, page 240), self-reported critical incidents should never be taken at face value, because users are often mistaken about what happened and what caused what. This tendency becomes stronger as time elapses. In probing, potential users are given probe packages (see figure 2.10) which they can use to capture their use experiences by means of materials such as a diary, disposable photographic camera, audio recorder and question cards (Gaver, Dunne et al., 1999; Wensveen, 1999). The results of probes are

Figure 2.10: example of a probe developed by Biemans (2011) to investigate 'bathing experiences', including a disposable camera, exercise booklet, diary and thermometer. By distributing the probes to 18 people, valuable insights could be gathered on the diversity of bathing experiences.

aimed at inspiring design rather than giving an accurate picture of current use or the current situation. A downside of the probing approach is that researchers depend to a large extent on the willingness of users to capture and share their experiences. However, they do allow for a longer term exploration of use situations and related usability issues, thus having the potential to give more insight in the dynamics of use situations. This benefit can be exploited even more by distributing the probes to different places around the world which allows for an exploration of the diversity of use situations. A final category of approaches that is mentioned here is making use of after sales feedback. This kind of data can be used to gather insight in the use of a predecessor product. After sales feedback seems to offer a large potential for gaining insight in real world product use (van Kuijk, Kanis et al., 2007). It is based on the idea that when customers encounter a problem they report it at a helpdesk or on internet. Thus, it has the potential of gathering insight in a large amount of usability issues and related use situation aspects. Indeed, Den Ouden, Yuan, Sonnemans and Brombacher (2006) found that sources such as helpdesks, online customer surveys and internet forums provided more information on consumer dissatisfaction – including usability problems and relevant context information - than the information sources that were normally used for this purpose: the service centres with a focus solely on technical product failure. Like probing, a limitation of after sales feedback is that it completely depends on the initiative of the customer to report a problem. Furthermore, it can only be used for the design of a new version of a product that already exists, such as the bicycle mentioned in the first part of this chapter.

Experimental approach: evaluations of current solutions for new use situations

As opposed to the above mentioned real-world studies of gathering insight in the relation between use situations and usability issues surrounding current use, a more experimental approach is observing the issues that occur during the evaluation of current solutions in usability evaluations. These type of evaluations do not completely reflect real-world use, because the evaluator decides upon the test conditions. This means that test persons might be asked to use products which they would not have used in the real-world. However, they do allow a further exploration of the relation between use situations and usability issues, which gives the opportunity to explore new use situations for which currently no comparable product is available. Theory based evaluations test predefined assumed usability issues, reflected in the research questions. According to Carroll (2000, page 41), they should be complemented with 'discovery-oriented' evaluations which allow the discovery – and thus exploration - of unexpected usability issues. The exploration of relevant use situations is reflected in the test conditions. This includes the respondents, test task and test environment (Rubin, 1994). Users and tasks can quite easily be varied in the test plan. The variation of the context of use depends on the type of test environment. Classical usability evaluations often take place in specially equipped usability laboratories (Nielsen, 1993, page 200), which should simulate the real use environment, but leave little room for varying the context of use. For field tests (see for example Rowley, 1994; Nielsen, Overgaard et al., 2006) it seems easier to vary and consequently explore those contexts of use, although this depends on the practical feasibility of visiting different use situations. From this can be concluded that the extent to which usability evaluations allow the exploration of usability issues and relevant use situations, depends on the one hand on the realism and variability of test conditions, and on the other hand on the extent to which the evaluation is oriented towards the discovery of new usability issues.

Concluding, insight in use situations and related usability issues can firstly be gathered by conducting real-world studies of the current use situation by means of actively gathering information in the field or collecting self-reports. These insights in the current use situation and related usability issues can then be used as a basis for generating a view on intended future use situations. With regard to the extent to which the real-world studies allow the exploration of usability issues and relevant use situations, we can distinguish methods that study the use situations and issues in *depth* and methods which have the potential to provide more *breadth* of information on use situations and issues. Secondly, usability evaluations of current solutions can provide a further exploration of relevant future use situations and usability issues by varying the different conditions under which those solutions are evaluated.

2.2.4 Prioritising use situation aspects

When there is a coherent view of the relevant use situations connected to usability issues, it is necessary to prioritise those aspects to be able to take them into account in the design process. Since use situations and design together define future use, the ranking of use situations is basically a strategic decision. As mentioned before, designers explore and define problem and solution together. When designing for DDUS one should make a decision on the breadth of use situations that a product should accommodate. This is often referred to as the target group of use situations, although these targets often only refer to the target *user* group. As mentioned before, Cooper proposes to define a narrow target by arguing that facilities that please some users can interfere with the enjoyment and satisfaction of others (Cooper, 1999, page 125). The first part of this chapter showed that 'segmentation' can be used to achieve this goal. The example mentioned there was to design distinct bicycles for different personal goals such as sports or recreation. This segmenting is also of importance when it comes to the appropriate aesthetics of solutions. When the target group is defined more narrowly and homogenously, there is also more room for aesthetic preference (Van der Bijl - Brouwer and Eggink, 2010). A well-known principle of product marketing is that market segmentation and selecting a corresponding product differentiation strategy can give a firm a commercial advantage (see for example Kotler and Craven, 2003). Prioritising use situations thus seems more a matter of product marketing, than of usability only. However, products like ticket vending machines or ATM's by nature have a very broad spectrum of users. Around the turn of the century, different movements came into existence that were aimed at stimulating designing for user diversity for these kinds of products, given names such as 'universal design' (Shneiderman, 2000), inclusive design and design for all (EIDD, 2008). This general philosophy is aimed at enabling all people to have equal opportunities to participate in every aspect of society and is rooted in the ideal of equalising opportunities for persons with disabilities. The ideal breadth of target use situations thus seems to be either a commercial or ideological trade-off.

Independent of choosing an 'inclusive' approach or a more specific target group of use situations, there is still a need to decide which are the most important use situations within this target to take into account in evaluations. One means to distinguish and prioritise different groups of users to take into account into design is the use of so-called personas. Personas are descriptions of hypothetical users who represent a homogeneous group of actual users (Cooper, 1999). Cooper proposes to define at least one 'primary persona', which is someone who must be satisfied, but who cannot be satisfied with an interface designed for any other persona. The definition of this most important group of users thus completely depends on the expected satisfaction of those users with regard to the designed product. How to rank user characteristics can also be derived from studying the recommendations for the selection of test persons in usability evaluations. In general, literature about how to conduct usability evaluations, recommends to select test users who are representative of the target users (Nielsen, 1993, page 175; Rosson and Carroll, 2002, pag 241) and most authors propose to distinguish novice and expert users. Rubin (1994) describes to select typical users of the product for usability evaluations. Within this user group he proposes to identify entire groups of end users who share many of the same characteristics. These groups, identified by occupation or roles, use the product in different ways. He also suggest to incorporate the expertise level for these groups. This implies that expertise and role are important characteristics to take into account in general. Although these sources all acknowledge the importance of ranking user characteristics, no support could be found on *how* to get insight in what the most relevant user characteristics are.

With regard to the prioritisation of goals and related tasks, Cooper (1999, page 180) proposes to distinguish daily use scenarios, necessary use scenarios, and edge case scenarios. Daily use scenarios are the primary actions that the user will perform, typically with the greatest frequency. Necessary use scenarios include all actions that must be performed, but that are not performed frequently. Edge cases scenarios are those actions that are neither frequent nor necessary and therefore do not require a careful design. For the creation of scenarios, Rosson and Carrol (2002, page 230) furthermore propose to describe work activities that are typical, critical or novel. A similar prioritisation is proposed by Rubin (1994, page 85) who suggests to prioritise tasks for usability evaluations by frequency of tasks, criticality (tasks which can have serious consequences) and vulnerability (expected problems).

With regard to the context of use, little recommendations could be found on the prioritisation of these type of aspects of the use situation. Although ISO 9241-11 mentions that it is important to specify the contexts of use with the most significant impact (ISO, 1998, page 8), it does not include recommendations on how this can be achieved. Cushman and Rosenberg (1991, page 53) propose to include 'extremes' as well as typical conditions in usability evaluations, but do not give any suggestions on what these extremes should be and if these typical conditions consider for example frequent or 'necessary' use.

The work of Beyer and Holtzblatt (1998) on their field interviewing method called 'contextual inquiry' shows that for specific types of products or systems (in their case computer-supported cooperative work systems) it is possible to explore the most important use situation aspects and create a general framework or checklist that can be used for various projects. Another example is a study by De Sa and Carrico (2008) who proposed a general framework for the selection of scenarios for mobile design which describes the 'determinant' factors that influence possible usability issues for these type of products including environmental conditions as light and noise and user characteristics, such as the movement and posture of the user. The dependency of prioritising use situation aspects on the solution also accounts for the fact that the level of experience is often mentioned as the most important user characteristic. This is caused by the fact that user-centred design is rooted in human-*computer* interaction in which usability issues like learnability are strongly influenced by the level of experience of the user. General priority lists of use situation aspects can therefore only be constructed for specific types of products or usability issues. No support is available for the design of products which do not fall in these categories of products.

Unintended use

All above mentioned approaches are based on the idea that to get insight into the future use situations, one should analyse the current use situation and make decisions on the most important target use situations. However, this 'intended' use that is defined during the design process is not always reflected in the actual use that can be seen after the introduction of the product to the market. This phenomenon of unintended use is well-known and many examples can be found. For instance, the significance of the World Wide Web was initially thought to be its improved user interface for transferring files over the network (Rosson and Carroll, 2002). Text messages were originally developed by cell phone carriers to send customers network notifications and no one anticipated that people would discover them and then use them to send messages to each other.

Bag balm, a salve developed initially to soothe irritated cows' udders after milking, has been used as a treatment on humans for trapped and irritated skin, when wives of farmers began to notice the softness of their husbands' hands and took to using the product themselves (Curran, 2010). Many amusing examples of products that are used 'differently' can furthermore be found in for example the book 'non intentional design' (Brandes and Erlhoff, 2006) and the weblog 'museum of unintended use' (Kuiper, 2012). This shows that different people use the product for different purposes in different contexts than the product developers might have intended. The question is if these product developers could have anticipated those uses. As Redström (2006) has argued there will always be a difference between intended use and actual use. Designing is not about determining the use of objects in detail and this use cannot be predicted completely. Although an iterative approach including usability evaluations of early solutions will give insight in to be expected usability *issues*, they will never be able to completely predict future use *situations*. These usability evaluations are executed in use situations chosen by the development team, so unintended use situations will often not become apparent until after the product is introduced to the market.

With regard to the prioritisation of use situation aspects it can thus be concluded that the higher level target can be defined based on commercial or ideological argument. With regard to the lower level of target, general rankings of use situation aspects can be found for specific products or systems and specific usability issues. With regard to the lower level target use situations, little guidance can be found on *how* to define the most important user and context characteristics independently. A general tendency in defining the target tasks or goals is to rank with regard to frequency and criticality and with regard to 'novelty' for the created solution. Finally, it can be concluded that although it is possible to a certain extent to anticipate future use situations, development teams need to accept that creating a complete picture of future use is essentially impossible.

2.2.5 Building an explicit and flexible frame of reference

A traditional approach for creating a frame of reference which reflects the desired level of usability is the use of requirements. User requirements are presented as a means to integrate or align user-centred design to the more matured method of requirement engineering. In this way user centred design was expected to get a better accepted role in system development (Lindgaard, Dillon et al., 2004). In early methods of user-centred design, those kind of requirements did not reflect the use situation. For example, Nielsen's usability engineering lifecycle (Nielsen, 1993) only includes a 'goal setting' step, which is aimed at operationalising usability parameters (the usability requirements) -,such as the maximum acceptable user errors per hour using the system. Although this specification of measures of effectiveness, efficiency and satisfaction can indeed be useful (ISO, 1998), they should be accompanied by a specification of the related user, goal and context of use. User requirements can further specify the constraints related to user characteristics. Generally, constraints should be established so that the limitations of the least capable user are not exceeded (Cushman and Rosenberg, 1991, page 25), such as the minimum body length that should be supported by the design. For that reason they can only be used to represent quantifiable use situation aspects. To make different types of use situation aspects explicit, more recent attempts of user-centred design include using user requirements in combination with other types of representations such as persona's and scenario's (see for example Don and Petrick, 2003; Sharp, Rogers et al., 2007; Anggreeni and Van der Voort, 2008). Scenarios express requirements only implicitly by describing the needs and opportunities in the current situation instead of specifying what a new system should do (Rosson and Carroll, 2002, page 75).

A less abstracted means to make information about varying use situations and related usability issues explicit is the use of models which represent commonalities in information about specific categories of use situation aspects. The collection of attributes for a typical user is called a user profile (Rubin, 1994; Sharp, Rogers et al., 2007). Persona's (Cooper, 1999) are a well- known means to represent user profiles. They represent the target users as a hypothetical person with specific characteristics, a name and an image. Beyer and Holtzblatt (1998) developed five types of consolidated work models for computer-supported cooperative work systems in their contextual inquiry approach. These models show the common structure in the work different people do. For example, the flow model represents the communication and coordination necessary to do the work and the physical model shows the physical structure of the work environment as it affects the work. Thus, each category of use situation aspects can be captured in a specific type of model. The models are particularly useful for computer-supported cooperative work systems because they deal with the complexities of cooperative work, although they might be applicable to other types of products as well. Both persona's and the contextual inquiry models are based on large quantities of verified data about users and other use situation aspects, which are translated into models by a thorough interpretation step to reveal the similarities (see for example, Pruitt and Grudin (2003)). Although both persona's and the contextual models seem easy to adjust, doing so without an additional interpretation step will decrease the strong value of the models of giving an accurate view on commonalities in actual information on use situations. This makes them less flexible to adjust.

While persona's and contextual models represent use situation aspects in separate categories, a more integrative approach is the work of Lim and Sato (2006) who proposed the Design Information Framework (DIF), which allows the integration of multiple models of use situation aspects, such as user profiles and work flows, and translates them in scenarios. Anggreeni (2010, page 35) argued that although DIF addresses the multiple use situation aspects in product design, its prescriptiveness is very demanding and not realistic in practice. Indeed its extremely specified mechanism for generating scenarios would only allow the identification of requirements, but does not provide the necessary flexible representation that can be updated and adjusted throughout the design process. However, scenarios in general are a good means to represent use situations in an integrated way and are flexible themselves. They are deliberately incomplete and easily revised or elaborated: in a few minutes, a piece of the scenario could be rewritten or elaborated (Carroll, 2000). Scenarios can be expressed by means of different media such as narratives, storyboards and video (Nielsen, 1990; Rosson and Carroll, 2002). As opposed to the matured application of scenarios in human-computer interaction, the optimisation of the use of scenarios in product design is still in development (see for example, Anggreeni, 2010).

From this can be concluded that currently used frames of reference vary from abstract to more realistic representations of the use situations and issues and from decomposed in individual use situation aspects to more integrated representations. Scenarios seem the most appropriate type of representation in terms of their flexibility and the extent to which they represent the diversity of use situations in an integrated way.

2.2.6 Evaluating solutions

The last criterion for designing for DDUS concerns applying integrated and multiple use situations as a frame of reference in usability evaluations of solutions. For some aspects of use, insight in the use situation aspects by itself can be used to predict the fit of a particular solution accurately. For example, insight in the variety of body length can quite easily give insight in the percentage of people that will fit through a doorway. However, based on these data it is not possible to make predictions about what users will *do* in a certain use situation, for example, whether a tall person will bend in that doorway to prevent bumping his head. The information gathered about user and context characteristics will therefore by itself not give any insight in the actual actions that the user will perform with a product. This is shown for example in a study of Kanis (1998) who showed that user characteristics can set boundary conditions by indicating what users will *not* do, but they do not give insight in what users *will* do. He concludes that usability evaluations are an obvious way of getting such insight into variations of actions. This is also reflected in the work of Suchman (1987) on the 'situatedness' of human action in which she critiqued the general view adopted in cognitive science that the course of an action could be prescribed based on user's intentions or predefined plans. Instead she introduced the term 'situated action' which underscores the view that every course of action depends in essential ways on its material and social circumstances (Suchman, 2007, page 70). Since those circumstances are never fully anticipated and are continuously changing around us, user's behaviour cannot be predicted from one situation to the next. Therefore usability tests are necessary to get insight in the consequences of certain design solutions.

Usability evaluations score well on the criterion of the integration of relevant use situation aspects in evaluations when those relevant users, goals and contexts are reflected in the test conditions. Therefore, an evaluation conducted in a usability lab does not meet this criterion when the lab is just an empty room with camera's and a one-way mirror. The importance of reflecting the context of use in the test conditions is acknowledged in most literature about user-centred design (Cushman and Rosenberg, 1991, page 53; Bevan and Macleod, 1994; ISO, 1998, page 8). However, for designing for DDUS it is not only necessary that test conditions represent the use situations, but that *multiple* varying use situations are evaluated as well. This issue receives only limited attention in literature. The focus of handbooks of usability testing is on the specification and variation of the user and the task. It is generally advised to select users from different relevant user groups and to select different sets of tasks [which reflect the user goals] to evaluate (Nielsen, 1993, page 175; Rubin, 1994, page 125). However, little guidance is given on the variation of the context of use. As I argued in the previous section, field tests seem to offer more opportunities for reflecting on multiple contexts of use than lab tests. Rubin advises that when the context of one type of users is significantly different from the context of another type of users in a way that will impact your product, you should try to go into those different contexts to test (Rubin, 1994, page 97). However, laboratories are often favoured over field studies for reasons of control of the experiment (Jordan, Thomas et al., 1996, page 240), because a field study introduces all kinds of uncontrollable influences, which makes it impossible to conclude on the causality of emerging usability issues. Therefore, to be able to meet the criterion of evaluating multiple use situations, it seems necessary to sacrifice control of the experiment. However, the principle of control is particularly important to obtain quantitative proof of research hypotheses and not very relevant when obtaining qualitative information on how to fix problems and redesign products as in a formative evaluation (Rubin, 1994, page 25). It therefore seems more valuable to execute usability evaluations for DDUS in less controlled, but easier to vary, field evaluations than in controlled evaluations based on a classical experimental approach.

Another means to integrate multiple use situation aspects in evaluations, without the need of a usability evaluation with prototypes, is the use of scenarios. According to Carroll scenarios evoke reflection about design issues. He argues that the scenario can function much like a "soft prototype" (Carroll, 2000, page 47). This makes it possible to reflect on a solution without building a mock-up or prototype. Although the reliability of these kind of 'evaluations' is low, they do allow easy variation of use situations.

A final category of methods which can be used to evaluate solutions are analytical evaluations where users are not directly involved (Sharp, Rogers et al., 2007). These evaluations investigate usability problems that can generally occur, based on an analysis of the solution characteristics.

They include techniques in which solution proposals are evaluated on their conformance to a set of qualitative guidelines (Reed, Holdaway et al., 1999) such as Norman's seven principles for transforming difficult tasks into simple ones (Norman, 1998) and heuristic evaluations in which experts, guided by a set of usability principles known as heuristics, evaluate whether user-interface elements such as dialog boxes, menus and navigation structures conform to the principles (Nielsen, 1994); These techniques consider usability independently of use situations. For example the guideline 'visibility of system status' – about the need for good feedback – is applicable in any use situation. They can be useful because they are relatively quick to apply, can reveal unexpected issues or can compare solution proposals which stimulates continuation of the design process. However, since they do not comply with the criteria for integrating multiple use situations they are not relevant in designing for DDUS.

From this can be concluded that both usability evaluations with prototypes and scenario analysis allow for evaluating and reflecting on multiple and integrated use situations. Particularly formative field evaluations are useful for gathering reliable results, although it is practically not possible to achieve the reliability of a classical controlled experiment. Scenario evaluations lead to even lower reliable results, but their advantage is that they allow easier variation of use situation aspects.

2.2.7 Conclusion design process for DDUS

In this section it was argued that to be able to design for DDUS, designers should follow a design approach which makes them aware of DDUS and supports them in analysing and exploring the variety of use situations and related usability issues, identifying the most important use situations and related usability issues, generating a flexible frame of reference which represents this variety and priority of use situations and related usability issues, and evaluating solutions with regard to multiple use situations. Although valuable methods and techniques could be found in literature for most of the formulated criteria, none of these approaches conformed to the complete set of criteria. A combination of methods and techniques could therefore possibly lead to a design approach which meets most of these criteria. However, no insight could be gained in how to identify the most important use situation aspects for what ISO 9241 calls 'general purpose products' (which are developed in product design) and there is little guidance on the creation of a flexible frame of reference which reflects the variety of important use situation aspects. Therefore, for these type of products there is a gap between the analysis and exploration of DDUS and translating the outcome into a frame of reference which can be used for usability evaluations.

2.3 Design for DDUS in design practice

Until now I have discussed which factors of the *content* of the design problem of design for DDUS influence usability and which factors of the design *process* seem to influence the usability of products that are used in DDUS. The last elements of the design activity which could potentially influence design for DDUS are the *designer* and the *design context*. As mentioned in chapter 1, a critique of scientific literature on user centred design is that there is a misfit with its application in design practice (Wixon, 2003; Stolterman, 2008). Only recently there is more attention for the 'practice-factor' in the user centred design field (see for example van Kuijk, 2010; Dul, Bruder et al., 2012). Therefore, factors of this design practice which are expected to influence design for DDUS are discussed in this section.

The most important aspect of design practice is the practitioner him- or herself: the designer. A designer characteristic which was already considered in the previous section is the designer's awareness of DDUS. In section 2.2.2 it was discussed which approaches could potentially make designers aware of DDUS. However, a preceding question should be if designers are aware of DDUS in the first place. Since this question could not be answered by means of literature, additional empirical research is needed to investigate this issue. Furthermore, in the section on solution generation (2.2.1) the expertise level of the designer was indicated as a factor that could influence the success of creative design, and thus the generation of solutions for DDUS. Lawson and Dorst (2009) distinguish several expertise levels for designers. In section 2.2.1 it was concluded to not further investigate the expertise level of designers in relation to DDUS, since essentially the skill of creating solutions for DDUS does not differ from creating solutions for other types of design problems. However, designer expertise and learning design does not just involve skill acquisition, it also involves the learning of declarative knowledge (knowing 'that', as opposed to procedural knowledge: knowing 'how'), and the building up of a set of experiences that can be directly used in new projects (Lawson and Dorst, 2009, page 100). The latter types of knowledge and experience might be interesting to consider in design for DDUS. In a study on the factors in product development practice which influence usability, van Kuijk (2010) found several types of knowledge that influence usability. The knowledge types that are expected to be of particular value for design for DDUS are 'knowledge of the user group' and 'knowledge of potential usability issues'. If designers have more knowledge of the variety of the user group (and other use situation aspects) and related usability issues, this will probably positively influence design for DDUS. This type of knowledge can be acquired within a project, but also across projects. Apart from this individual 'store' of DDUS knowledge, it might furthermore be interesting to consider the knowledge available in the team. As van Kuijk concluded, the generation of *shared* knowledge of usability in product development teams also influenced the usability of the developed products. It is therefore interesting to further study how knowledge of DDUS is communicated within design teams.

Apart from the characteristics of the designer and design team, other factors in the design context might influence design for DDUS as well. In addition to the earlier mentioned knowledge factors, van Kuijk (2010) identified factors in product development projects which influence usability, such as if upper management prioritises usability, if there is a user-centered company culture, and available and allocated resources. For example, the project budget influences what can be spent on development activities with regard to usability. It is not expected that these factors will influence design for DDUS differently than design for usability in general.

Concluding, the designer and design context factors that seem interesting to further investigate for design for DDUS are the awareness of the designer of DDUS and the means by which knowledge of DDUS and usability is shared and built up in design teams. Although the latter would need a study of the design activity across projects, as advocated by Dorst (2009), it was chosen to firstly focus on the communication and knowledge gathering process within a project.

2.4 Conclusion

In this chapter I investigated the different factors that influence the usability of products with DDUS. With regard to the content of the design problem, literature analysis and product reviews revealed that the diversity and dynamics of use situations can lead to conflicting requirements for solutions. Many different aspects and variations of the user, goal and context can influence usability. The relevancy of use situation aspects depends in return on the solution. This interdependency of use situations, usability and solutions, complicates the identification of which of these use situation aspects are relevant to consider in the design problem.

With regard to the design process, I motivated that when designing products for DDUS, designers should firstly be aware of this issue. Then they should be able to analyse the use situations for important usability issues, rank them on their importance and translate them in an explicit and flexible frame of reference which reflects this variety and priority of use situations. Finally they should be able to apply the frame of reference in evaluations of solutions. Literature on user-centred design was consulted to investigate how current approaches and methods comply with these criteria. None of the found approaches conformed to the complete set of criteria and no insight could be gained in how to identify the most important use situation aspects for product design. Furthermore little guidance could be found on the creation of a flexible frame of reference which reflects the variety of important use situation aspects.

Finally a discussion of the aspects of the designer and design context that might influence DDUS led to the conclusion that the factors that need a further investigation are the awareness of the designer of DDUS and the means by which knowledge of DDUS and usability is communicated within design teams. The gathered insights lead to the following problem definition:

> **Problem definition**
>
> The dynamics and diversity of use situations in which products are used influences their level of usability. To design products with a certain level of usability in intended use situations, it is therefore necessary to evaluate solutions with regard to these intended use situations. However, the interdependency of use situations, usability issues and solutions, makes the identification of use situations and their application as a frame of reference inherently difficult. It is generally acknowledged in user-centred design that it is important to describe and specify the intended use situations. It is also often mentioned that the test conditions of usability evaluations should represent the actual user, goal and environment. However, in spite of these acknowledgements, little guidance could be found on how a specification of intended use situations can lead to a frame of reference for those usability evaluations. No support was found aimed at translating the insights from analysing intended use situations and related usability issues in a flexible frame of reference which reflects the variety of prioritised use situation aspects and related usability issues, and which can be used to set the varying test conditions for formative usability evaluations in an iterative design approach. For specific types of products such as software design and mobile devices, general frameworks are available to build a frame of reference of use situations and usability issues. However, they only consider the use situation aspects that are important for that specific type of products and systems, such as the level of experience of the user, and do not indicate how to define the most important variable use situation aspects for intended use situations for products that do not fit in these categories. Other frameworks, such as persona's and contextual models, do provide opportunities for defining a frame of reference for specific types of use situation aspects, but are not flexible enough to apply in an iterative design process. This research is therefore aimed at developing a support for product design teams, aimed at generating a flexible frame of reference which reflects the variety of intended use situations and the consequences for usability, and applying it in usability evaluations.

Before exploring solutions that solve the above mentioned problems with regard to designing for dynamic and diverse use situations, more insight is needed in how this problem is currently tackled in design practice. For this purpose, a retrospective study of three real design projects was conducted. This study is described in the following chapter.

3 Design For Ddus In Practice

3 Design for DDUS in practice

Chapter 2 explored the topic of design for DDUS with regard to the content of the design problem, the design process and the designer and design context. The literature review gave insight in the complexity of the design problem and in if and how existing design approaches and methods could possibly be used in designing for DDUS. The study led to the identification of both potentially useful methods for parts of a DDUS approach as well as a gap with regard to the creation and application of an explicit frame of reference of DDUS. Furthermore the study led to the formulation of questions with regard to the awareness of designers of DDUS and the way in which knowledge of DDUS is communicated within design teams. Before exploring new support tools which are aimed at bridging this gap, it is firstly necessary to answer these questions and study design for DDUS in design practice to investigate if the insights found in theory are reflected in design practice. Section 3.1 describes the objectives of this study and the research questions. The study is divided in a part which is aimed at investigating designer's awareness of DDUS and a part aimed at investigating how designers currently deal with DDUS in their solutions and their design process, by means of a retrospective study of three design projects of different companies. The method for the awareness study is described in section 3.2 and its results are described in section 3.3. Section 3.4 describes the method for the retrospective study. The insights that were gained in this study are described in section 3.5. Finally, section 3.6 concludes this chapter by comparing the results of both studies to the insights gained in chapter 2.

3.1 Objectives

3.1.1 General objective of studying DDUS in design practice

The main objective of the research described in this thesis is to support designers in dealing with DDUS. Since the success of this support depends on the extent to which it fulfils the needs of practitioners (Wixon, 2003), this chapter describes an exploration of the issue in the context of product development practice. As Blessing and Chakrabarti state: "Designing is a complex activity, and failure of support can be expensive in terms of time, people and money and can have a large effect on practice. Descriptive studies help understand this complex activity and should provide a sound basis on which to develop support" (Blessing and Chakrabarti, 2009, page 75). The studies described in this chapter therefore further complete the literature review described in the previous chapter. Together they constitute a 'comprehensive descriptive study I' which provides insight in the current design situation by combining a literature review with a study in which the results are produced by the researcher (Blessing and Chakrabarti, 2009, page 60).

3.1.2 Research questions

The first objective of this study is to answer the questions for which no evidence was found in literature. Firstly, in theory there is support available which could potentially make designers more aware of DDUS. However, before employing this support for this purpose, it was concluded in chapter 2 that it is firstly necessary to get insight in what the current level of 'DDUS awareness' of designers is.

Another open question is related to the means by which knowledge of DDUS and usability is communicated within the design team. This question is part of the main question how designers deal with DDUS in their design process. This question is therefore connected to the second objective of this study which is to investigate if the insights found in theory with regard to the design *process* are reflected in design practice. A study of design approaches and methods in literature showed that in theory there is support available for gaining insight in the variety of use situations which products can encounter and for making designers aware of DDUS. However, there is a gap between the results of such 'use situation analyses' and the use situations that are reflected in test conditions of usability evaluations. It is not clear how an explicit frame of reference can be created which represents the results from use situation analysis and which can be applied as a reference in usability evaluations. This issue therefore needs a further investigation of the design process in practice.

A third objective is to investigate if the insights found in theory with regard to the design *problem* are reflected in design practice. Based on the literature review it was concluded that the dynamics and diversity of use situations can lead to conflicting requirements. Different types of solutions were proposed to deal with these conflicts. Furthermore a model of three variety levels of use situation aspects was proposed, as well as a list of possibly influencing use situation aspects. A study in design practice could give insight in the value of these models in the identification of relevant use situation aspects, and in what the relevancy of the variation level is in creating a solution that accommodates the aspect.

Since *how* something is designed (the design process) can better be understood when insight is gathered into *what* is designed (the solution), the question with regard to the solutions was investigated before the question with regard to the design process. The main research questions are therefore:

1. Are designers aware of DDUS?
2. How do designers deal with DDUS in their solutions?
3. How do designers deal with DDUS in their design process?

Another objective of the study is to investigate what designers needs are with regard to development of a support for designing for DDUS, since they are the future users of this support. The related research question is:

4. What are the needs of designers with regard to the new support?

3.1.3 Method

To answer research question one, practising designers were asked to participate in a design experiment in which their awareness of the different types and variety levels of DDUS could be investigated. The set-up of this research is described in section 3.2. To answer research questions 2 and 3 a retrospective case study approach was chosen to analyse three real design projects in design practice. The respondents of this retrospective research were also shortly interviewed about their needs for a DDUS support, to answer research question 4. The set-up of the retrospective study is described in section 3.4.

3.2 Set-up study on DDUS awareness

3.2.1 Research questions DDUS awareness study

The main research question that needs to be answered in this study is if designers are aware of the dynamics and diversity of use situations. Furthermore the study was used to evaluate the usefulness of the categorisation in variety levels and types of use situation aspects. The sub research questions are:

1. Which type and variety level of use situation aspects that influence usability are designers aware of?
2. Is the presented level and type categorisation accessible for designers?
3. Does the presented categorisation help designers in identifying relevant dynamic and diverse use situation aspects?

3.2.2 Method DDUS awareness study

Question 1 was answered by means of an exercise in which designers were given a design assignment and asked which use situation aspects they would take into account when designing a particular product.

Question 2 and 3 were answered by means of firstly providing designers in the exercise with a checklist of use situation aspect types and an explanation of the variety levels, such as described in chapter 2. Secondly it was analysed how this supported the identification of DDUS aspects.

Influencing factors

To be able to compare results of different designers it is necessary to identify the factors which could influence these results. Firstly participants were asked to work on a subject with predefined desired usability issues and a given solution direction. This compensates the influences of usability issues and solution on the relevancy of use situation aspects. Other factors that would assumingly influence the results were the level of design expertise with attention for usability and the level of personal and professional experience with the problem domain. Therefore only participants were invited with at least one year of experience with designing products for which usability was considered important. A case was chosen of which all participants were expected to have a similar amount of domain knowledge. Finally, participants were also expected to influence each other. Since this research is aimed at supporting design teams, all sessions were therefore executed in couples.

3.2.3 Case and exercise DDUS awareness study

The design assignment should consider a case which covers use situation aspects on as much as possible levels and types. Furthermore the subject should be something of which the participants already have some knowledge by means of choosing a topic that everyone is familiar with. Therefore participants were asked to identify use situation aspects for the case of a 'grocery barcode-scanner' for mobile self-scanning in supermarkets.

Exercise

The instruction for the assignment and necessary timing was explored in a pilot session with colleagues. Participants were firstly posed an open-ended question about the aspects of the use situations that they would take into account in their design process, to test their general awareness of DDUS. Subsequently 'clues' were given step by step about other possible relevant aspects of the use situation by means of successively providing a 'checklist' of possible use situation aspect types and an explanation of the different variety levels. The checklist was based on the literature review described in section 2.1.3 (see appendix 1). Table 3.1 shows the resulting tasks and timing for the session. To prevent influences of the phrasing of the questions, participants were given written instructions for each task. Only if they did not understand the subtask, they would get additional explanation from the researcher.

3.2.4 Participants DDUS awareness study

Apart from the pilot session, three sessions were executed with designers who had minimum 1 year of experience in design practice with designing for usability. Session one was held with two academics who also worked or had worked as practicing designers (1 and 10 years of experience). Session two and three were each held with two team members of the retrospectively studied cases A and B (see section 3.4.3, 3 to 15 years of

Table 3.1: tasks and timing for the exercise on DDUS awareness

Task	Time
Welcome and explanation assignment	5
Assignment 1: write down on a flip chart which aspects of the use situation have to be taken into account when designing a mobile shopping scanner that is easy to learn, efficient and comfortable.	45
Assignment 2: complete the mentioned use situation aspects by means of the provided checklist	10
Assignment 3: indicate which type and amount of variation can be expected for the mentioned aspects on yellow sticky notes	20
Introduction to variety levels	15
Assignment 4: assign variety levels to aspects by means of coloured notes	10
Assignment 5: prioritise aspects with regard to learnability, efficiency and comfort in the categories 'very important', 'less important' and 'least important', by means of coloured stickers.	15

experience). None of them had ever designed or used a barcode-scanner before. Since the three sessions showed very similar results, it was chosen not to conduct additional studies.

3.2.5 Data gathering and analysis DDUS awareness study

The sessions were recorded on video and observation notes were generated by the researcher during the session. The relevant parts of the recordings of the sessions were transcribed. To answer question 1 and 3, the written results and transcripts of the different sub-assignments were compared. Designers were considered to be aware of DDUS if they could identify all different types and levels of use situation aspects in assignment 1. The added value of the categorisation could be defined by analysing which additional aspects were added after offering participant the categorisation. Question 2 was answered by means of analysing the observation notes and transcripts of how participants reacted on the categorisation.

3.3 Results DDUS awareness study

All three sessions were executed successfully (see figure 3.1 for an example). In some of the sessions, more use situation aspects were discussed orally than actually written down. Therefore the audio recordings were needed to complete the results. Although the participants were asked to focus on learnability, comfort and efficiency, they all questioned to a certain degree the initial problem statement and also discussed additional issues like acceptance and safety (fraud). Furthermore they all mentioned other possible concepts than the predefined solution direction. Based on the observation of the pilot session the latter was foreseen, and participants were allowed to draw and write these ideas on separate sheets of paper. However, both the discussion of the problem statement and the generation of ideas made the comparison of results difficult, since the time participants actually spent on the identification of use situation aspects strongly differed per couple.

3.3.1 Which type and level of DDUS aspects are designers aware of?

In the first part of the exercise, all participants mentioned use situation aspects with regard to users, goals and context, as well as aspects on the three different variety levels. The least use situation aspects were found by participants in the third session, because they spent most time on discussing the usability issues and the needed design process, instead of on identifying use situation aspects. Participants also explicitly indicated the importance of taking into account the variety of use situation aspects during assignment one, as can be illustrated by the following comment:

> *Participant (2): "What I would need as a design tool is a reference set. A reference set of types of grocery trolleys, connected to archetypical personas including variety of age, physical characteristics, shops and typical types of groceries"*

From this can be concluded that the participants all were aware of the dynamics and diversity of use situations. However, participants indicated that they found it difficult to define and identify use situation aspects 'in advance' in the exercise. They either indicated that they first wanted to explore the problem statement and explore and test possible solutions or first wanted to gather insights externally, before doing this kind of exercise.

> *Participant (session 2): "I miss the step of going shopping yourself. That's what we do here. First visit the customer without precise questions. And after that you do have the questions."*

> *Participant (session 2): "I have the feeling we are looking for things that you don't know yet"*

> *Participant (session 1): "You only want to know specific use situation aspects when you have generated some solutions."*

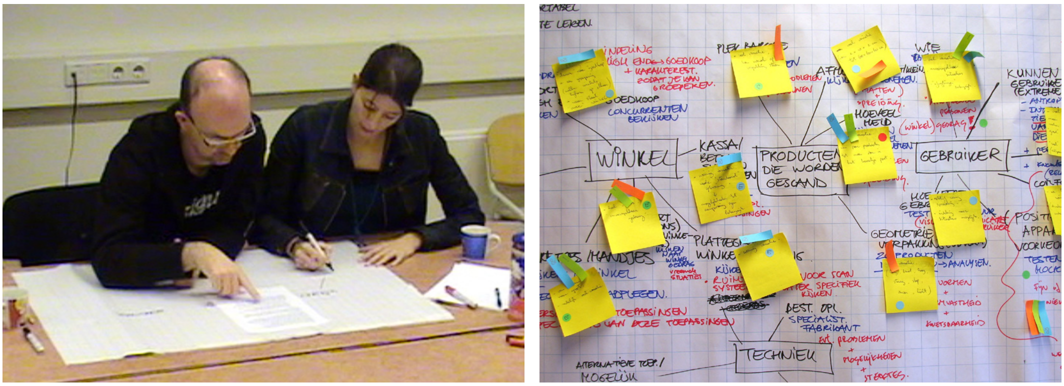


Figure 3.1: participants working on the DDUS awareness exercise and example of the result.

Thus, the artificiality in the exercise of prescribing a solution and important usability issues does not give insight in how use situation aspects are identified in design practice. The comments furthermore confirm the conclusion in chapter 2 that the interdependency of use situations, usability issues and solutions makes it difficult to identify use situation aspects before any other design activity is executed.

3.3.2 Accessibility and added value of type and variety categorisation

All participants understood the checklist of use situation aspects, although they sometimes asked the researcher about particular definitions of types of use situation aspects. The model of variety levels seemed less easy to understand since all participants needed some time and additional explanation to understand it. Eventually they all managed to apply the categorisation to the gathered use situation aspects.

Both the checklist and the model of variety levels led to the addition of some new use situation aspects in all three sessions. However, these were use situation aspects that were considered of less importance. Some participants questioned the general value of these kind of checklists and models:

Participant (session 2): "It is just another way of categorising the world. I don't see how that would help you."

Participant (session 3) "You know what it is, all these aspects [points at checklist] are to a certain degree interesting to look at. The problem is that if you have to instruct people, you cannot give them this kind of long list. You have to identify the key aspects."

3.3.3 Conclusion study on DDUS awareness

From the results of the exercise it became clear that designers are aware of the dynamics and diversity of use situations and that they find it important to take them into account in the design process. Since the exercise was executed in limited time, it cannot be concluded if the checklist and model of variety levels would have led to new insights in a real project. Considering the limited addition of use situation aspects based on these models within the time frame of the exercise, and the comments of participants that they expect to find more relevant use situation aspects after solution generation and external analyses of product use, it can be concluded that the checklist and model of variety levels have no or only minor additional value in identifying use situation aspects. Therefore they were not included in the developed support for design for DDUS.

3.4 Set-up retrospective study

3.4.1 Research questions retrospective study

The main questions that need to be answered in this study are how designers deal with DDUS in their solutions and how designers deal with DDUS in their design process. The sub questions are:

2. How do designers deal with DDUS in their solutions?
    a. What are the dynamics and diversity of the studied design problem?
    b. What kind of solutions are generated to deal with this variety?
3. How do designers deal with DDUS in their design process?
    a. How are DDUS aspects analysed in design practice?
    b. How are DDUS aspects prioritised in design practice?
    c. How is the usability of solutions evaluated with regard to DDUS?
    d. How are use situations and usability issues made explicit and communicated?

Furthermore, as an addition to the retrospective study, participating designers were also interviewed about their needs with regard to the development of a support for designing for DDUS. The related research question is:

4. What are designers needs with regard to learning and applying a new support?

3.4.2 Method for the retrospective study

To answer the research questions a retrospective case study approach was conducted (van der Bijl - Brouwer and van der Voort, 2009). Since the research questions are open-ended, they require an exploratory research approach. A *case study* approach was found appropriate, because it allows the study of real-world contemporary events which do not require control over behavioural events (Yin, 2009, page 8). The objects of this case study are design projects. Since the studied design projects had a throughput time from one to five years, it was chosen to study the projects retrospectively.

3.4.3 Cases for the retrospective study

The cases that were selected for the retrospective study had to meet the following requirements:

Figure 3.2: case C concerned the design of a bicycle carrier. This is a product that can be placed on a car's towing hook to transport one or two bicycles

- They should concern design projects in which usability was an important issue so the focus could be on the importance of the dynamics and diversity of use situation aspects instead of on usability in general
- The projects should be finished recently so interviewees could easily recall project issues.
- The cases should concern design problems with different expected levels and types of DDUS, as described in chapter 2.

Based on these requirements three cases were selected. Case A concerns the design of a colour toner wide format printer by a multinational company that provides digital document management technology and services. Case B concerns the design and evaluation of the installation features of a health monitoring system at home for elderly by a multinational company. The system consists of one or more devices which measure a physiological parameter, such as blood pressure, connected to the user's own television which displays the graphical user interface. Case C concerns the design of a bicycle carrier by a product design and consultancy agency. A bicycle carrier is a product that can be placed on a car's towing hook to transport one or two bicycles (figure 3.2). In all cases usability had a high priority. The DDUS variety levels of the cases are indicated in table 3.2.

Table 3.2. use situation dynamics and diversity of the selected cases

Cases	Goals vary on	User characteristics vary on	Context characteristics vary on
Case A wide format printer	Dynamic product level	Dynamic product level	Diversity level
Case B health monitoring system	Diversity level	Diversity level	Diversity level
Case C bicycle carrier	Dynamic product level	Diversity level	Dynamic session level

3.4.4 Data gathering retrospective study

For each project two or three (depending on availability) actors that played an important role in the usability research and design of the project were involved. The respondents had considerable knowledge about the design decisions that were made with regard to usability. The following roles are distinguished: designers, usability experts and project managers. Designers can make decisions with regard to the product design and in all cases were more or less involved in testing the design. Usability experts evaluate the usability of the product, but only have an advisory role with regard to changes to the product design. Project managers coordinate the project and set priorities.

Role end-user (incl. knowledge and skills)

Source: *client visits, survey,*
Communication: *personas*

Variation: *end-user, key operator, IT manager*

Influences:
Use phase: *end-use*
Product feature: *GUI*
Usability issue: *learnability*

Solution: *different layers based on login*

Figure 3.3: example of a use situation aspect card

The respondents were firstly introduced to the concept of DDUS. In case A and B this was done by means of the exercise on DDUS awareness. In case C this was done by means of a PowerPoint presentation. Then, in a group interview, they were asked to discuss and write down on a flip chart the use situation aspects that played a role in their design project. Based on an analysis of this discussion, the researcher created 'use situation aspect cards', which each described an aspect of the use situation, the information source for the aspect, how it influenced usability, and the way it was dealt with in the design solution (see figure 3.3). These use situation aspect cards were then used in individual interviews with the involved participants to confirm the interpreted results. For each card, the relevance of the listed use situation aspect with regard to usability was shortly discussed. Subsequently the respondents were asked to select the most relevant cards with regard to usability, see figure 3.4. These aspects were discussed in more detail including a confirmation of the information source, variance of the aspect and solution that was implemented to accommodate to the use situation aspect. In some cases also other possible solutions were discussed. Furthermore general questions were asked in the individual interviews with regard to the design process. The main topics that were discussed in that part of the interview were the role of the respondent in the project and the role of usability, and techniques that were applied to improve usability in this project. The complete list of interview questions can be found in appendix 2.

3.4.5 Data analysis retrospective study

The group interviews were recorded on a digital voice recorder. The transcripts of these interviews and the overview of use situation aspects that the respondents had created during the group interview were used to create the use situation aspect cards. The recordings of the individual interviews were transcribed as well. Subsequently relevant sections of the transcripts were identified and assigned to either a specific use situation aspect or a general process issue. For each use situation aspect, sheets were created in which all quotes with regard to that aspect from the different actors came together. In an iterative process a general solution strategy for each use situation aspect was assigned based on these sheets. Similar solution strategies and process strategies of the three projects were then clustered and from this clustering more general principles and strategies with regard to designing for DDUS were formulated.

3.5 Results retrospective study of design projects

Before answering the research questions for the retrospective study, this section firstly describes the general characteristics of the three studied projects.

Case A concerned the development of a colour toner wide-format printer. Although it was a high-tech project with a focus on engineering, usability was considered important from the start of the project. The main usability issues were learnability of both the graphical user interface (GUI) as well as paper-handling and cartridge-handling. Furthermore physical effort and accessibility were important issues for the latter mentioned goals. The user-centred approach of this five year project (>100 man-years) included work place visits and iterative user testing from in company lab tests to full scale 3-month in situ beta-tests.

Case B concerned the development of a health care portal at home for elderly people. The project studied was a subproject of one year (1,5 man-year) in which the installation process was optimised with regard to usability. This included both hardware, software and a manual. The main usability issue was effectiveness: are people able to install the product by themselves? Other issues were acceptability (do people start) and subjective efficiency (do people feel it does not take too long). The approach consisted of expert tests, internal tests (with colleagues) and in situ user testing with 9 persons/ households of the target group.

Case C concerned the redesign of a bicycle carrier by a design studio. The case was originally only a re-styling assignment. However, first confrontations of the design proposals with experts showed that usability was indeed a crucial issue. The design studio had developed a similar product years before and is regularly involved in design projects that concern products related to bicycles. The main usability issues were effectiveness, prevention of errors (that cause damage) and comfort. The approach included internal testing (personal and with colleagues) and expert testing. The complete project took about one year (3 man-years).

Figure 3.4: respondent of the retrospective study analysing and prioritising the created use situation aspect cards

The next sections will firstly describe the results with regard to the DDUS of the studied design problem (research question 2a, section 3.5.1) and corresponding solutions (research question 2b, section 3.5.2). Secondly, the research questions with regard to how designers deal with DDUS in their design process (research question 3a-3d) are answered in section 3.5.3-3.5.6. Finally, section 3.5.7 describes the answer to the question what designers' needs are with regard to learning and applying a new support (research question 4).

3.5.1 DDUS problem

The first question considered the dynamics and diversity of the different design problems. This question was aimed at getting insight in the variety levels and types of use situation aspects that played a role in the studied projects.

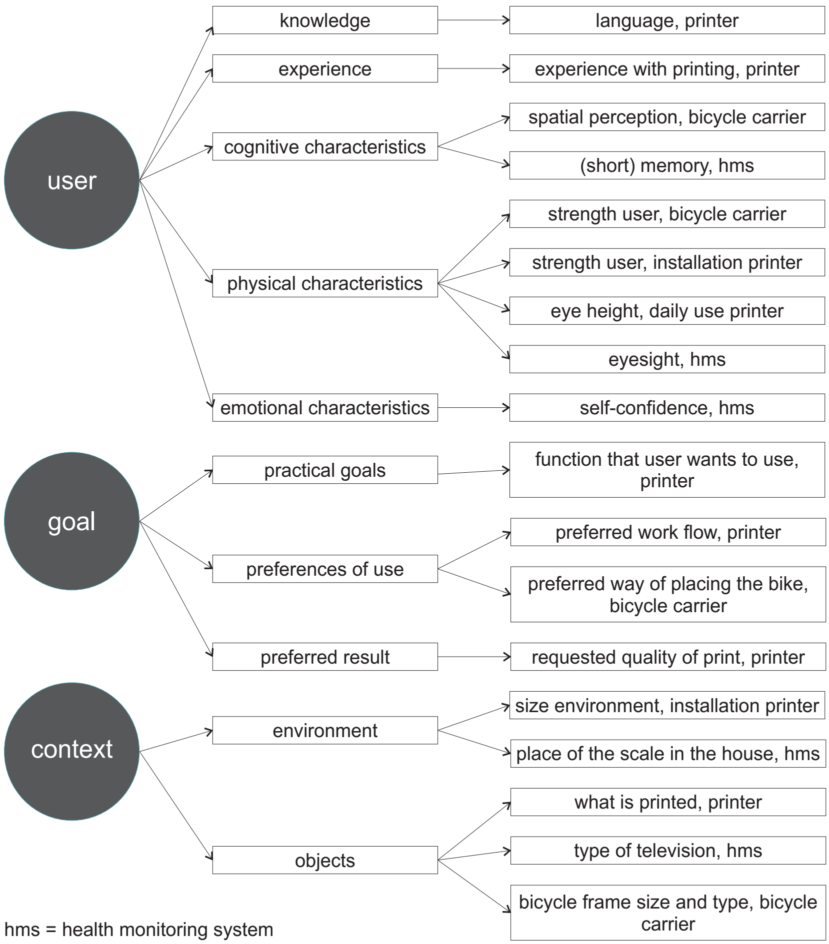
Aspect types: user, goal and context

In chapter 2, use situation aspects were distinguished with regard to user, goal and context. The results found in the studied projects are comparable to the aspects introduced in chapter 2. With regard to the user, the following characteristics were of influence to use: knowledge, experience, cognitive characteristics, emotional characteristics and physical characteristics. The goal aspects considered things like preference with regard to the way of use, the functions users want to control and the expectations of the result. The context of use aspects included environmental conditions and other objects which had the role of tool or subject. Figure 3.5 shows some examples of relevant use situation aspects for each project.

Variety levels of the use situation aspects

In chapter 2, different 'variety levels' of use situation aspects were distinguished. Use situation aspects can vary dynamically on session level (within a use session), and on product level (between use sessions of one instance of a product) and can vary on diversity level (between products). The selection of cases was aimed at covering all three levels. However, the research gave little insight in aspects which varied on session level. Only the bicycle carrier case included a dynamic part on session level which considered the context, but the context aspects (road conditions) were of little influence to usability. Examples of varying use situation aspects between sessions include the different user characteristics of the printer users and different bikes that users want to transport on their bicycle carrier. Between sessions other aspects could play a role depending on the use phase. For example with the installation of the printer other aspects played a role than during daily use. From this can be concluded that when identifying use situation aspects, it is important to consider the different use phases. The next section further describes which type of solutions were created to accommodate the different types of varying use situation aspects treated in this section.

Figure 3.5: examples of relevant use situation aspects for the three projects



3.5.2 DDUS solutions

In chapter 2 general solution principles were presented to accommodate products to varying use situations, based on the level of variety of use situations. Examples of the principles of 'one size fits all', 'accessories' and 'adjustable features' were found in the different cases. However, other principles to adjust products to DDUS were found as well.

One size fits all

The 'one size fits all' principle is revealed in the projects in two different forms. Firstly, product characteristics can be designed for extreme use situation aspects, so the less extreme use situations will be accommodated as well. Secondly, versatile solutions can be developed that allow multiple ways of use. The solutions for extreme situation characteristics are widely applied for physical characteristics such as described by Dreyfuss (1968), but also for other types of aspects. For example in the case of the bicycle carrier the product was designed to accommodate the most 'extreme' types of bikes, electronic bikes, which are the most heavy and have a different kind of frame (context aspect). In the health monitoring system case the installation procedure was designed to fit the extreme cognitive characteristic of short memory by including enough reminders and hints to the manual. Versatile solutions were found in for example the design of the manual of the health monitoring system which allowed multiple ways of use and the bicycle carrier which contained a strap with an eye that users could pull tight with any tool they wanted. The following quotes illustrate these solutions:

Usability expert (case B): "You should make the manual easy to find and invite people to read it. Actually you should design it [the manual] double, firstly if you do follow the manual and secondly if you do not follow it."

Project manager (case C): "We also had this trick. You have to pull tight this strap if there is a bike here and if users could not pull hard enough we made an eye so people could use a tool if they wanted to, for example a hook [...] We also thought it would be handy if people could attach a string if they liked it."

Researcher: "So people are allowed to think up a solution themselves?"

Project manager (case C): "Yes, we facilitate something, but we don't know what."

Accessories

A nice example of the principle of accessories to accommodate a product to varying use situations is the ramp that can be purchased with the bicycle carrier which allows another way of putting a bike on the carrier.

Usability expert (case C): "There are all kinds of ways to put your bike on the carrier, for example one wheel first and then lift the other one on it. Therefore we made a ramp, so you can also drive your bike on the carrier."

Here the varying user characteristic is the user's preference with regard to placing a bike on the carrier. Users that prefer not to lift their bike but who like to drive their bike on the carrier can buy the ramp.

Adjustable features

Also different types of adjustable features were found. For example the bicycle carrier had adjustable frame holders to adjust the carrier to the bike frame. An aspect that is of influence in many products is the different languages of users as illustrated by the following quote:

Designer (case A): "On all GUI's [graphical user interfaces] you can choose from about twelve languages, but of these twelve you can also indicate two which are preferred languages. This means that on the local control panel you can switch between those languages. [...] In Belgium maybe French and Dutch."

So for the language variation between printers (diversity level) the language can be adjusted in an installation menu and for the more frequent variation of languages between sessions an easier accessible adjustment solution was chosen.

Make situation aspect irrelevant

In the presented model of solution principles it was assumed that the use situation aspects would be independent of the solution. However, some principles we found in the cases showed that another principle of dealing with DDUS aspects is to make the aspect irrelevant. An example that illustrates this principle is the way that was dealt in the health monitoring system with limited knowledge of the use of computers and related terms like 'usb' and 'modem'. This was solved by not using those terms but referring to parts as 'the white box' and 'the blue cable' and using labels. In this way the knowledge about these terms was made irrelevant.

Use situation aspects can furthermore be made irrelevant by 'redefining' the context, or the form-context boundary. According to Alexander (1964) the form is a part of the world over which we have control, and which we decide to shape while leaving the rest of the world as it is. The context is that part of the world which puts demands on this form (Alexander, 1964, page 18). In case of DDUS the context is made up of all user and environmental characteristics that put demands on the product. In some cases these demands are so contradicting that designers think up solutions to redefine the context. A good illustration of this principle is the varying context aspect of the type of TV with the health monitoring system. Users could use their own TV to install the system. However, the variation in types of TV's was so large that it was impossible to explain users in the manual how to install the system. This caused large usability problems. A solution would be to integrate a display in the system itself, so the display becomes part of the 'form' instead of the context. This redefinition of the context can be illustrated by the following comment of the involved designer:

> *Designer (case B): "We approached the borders of the system. […] Look, inside you can solve things, there you have control. But on the borders you have a given thing. And you have to accept that and take care of it or if that does not work there is only one thing left and that is to pull it into your product. That's the structural solution"*

Redefine the target use situations

A final category of strategies is to try to change use situation aspects, in order to achieve a better fit with the designed product. This can be done redefining the target intended use situations, as happened in case A. The initial target use situation included that the printer could be used by inexperienced users. However, solutions to accommodate that part of the target group were too expensive. Therefore the target was redefined to a decentralised environment in which the printer would be used by a trained operator who would not need the additional expensive features.

Conclusions solution types

With regard to the dynamics and diversity of the use situation aspects and solutions that were generated to accommodate to these use situations, it can be concluded that the in chapter 2 proposed solution types are reflected in the design projects, except for the type 'adaptive features'.

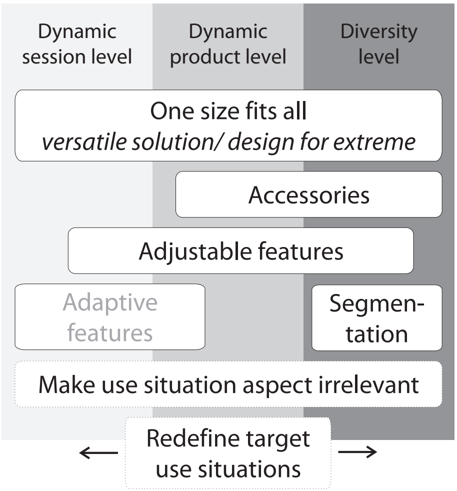


Figure 3.6: different solution principles for dealing with the levels of variety of use situations found in the retrospective studies.

This might be due to the fact that there were no use situation aspects on dynamic session level which were relevant for usability. Additional insights were gathered with regard to the one-size-fits-all principle which could be either a versatile solution or a design proposal aimed at an extreme instance of a variable use situation aspect. Another strategy to deal with the variety of use situation aspects is to make the use situation aspect irrelevant or redefine the target use situations. The complete set of found solution principles is indicated in figure 3.6.

The variety level was expected to be relevant in choosing a solution that accommodates the aspect. The variety of the use situation aspects for the generated solutions indeed corresponds to the variety levels as indicated in figure 3.6. There did not seem to be a difference in difficulty of designing solutions for the different levels, since there were no conflicting requirements for which the development teams could not think up solutions. Furthermore, the design teams did not indicate having any difficulties with creating solutions for DDUS. Instead, there were often other constraints that prevented the implementation of a solution, such as the marketing requirement in the health monitoring system case that the system should be connected to the user's television. Since it was expected that thinking up solutions for the different variety levels of DDUS would in general not be a problem for experienced designers, it was chosen not to further consider this aspect in this research and focus on the design process aspects of DDUS as discussed in the following sections.

3.5.3 Design process: analysis of DDUS

Question 3a was 'how are DDUS aspects analysed in design practice?'. The different means to get insight in use situations, as described in chapter 2, are real-world studies – including self-reports by users – and usability evaluations of current solutions. The real-world studies and usability evaluations of current solutions were reflected in the studied cases. However, in addition to 'direct' studies of use situations and self-reports of users, other sources were used to gain insight in use situations as well, including personal and organisational domain knowledge, experts and standards and legal requirements.

Direct study of users and use situations

The real-world studies and usability evaluations of current solutions were all reflected in the analysed projects. In all the projects that were studied, end-users and contexts of use were studied or involved directly to get insight in several use situation aspects. The techniques applied to get to this information ranged from observations during in situ user testing and interviews to field visits and cultural probes. On-line information sources were consulted as well.

Self-reports of users: after sales feed back

As mentioned in chapter 2, a specific type of real world studies is the use of self-reports in after sales feedback. Since the future use situation can never completely be predicted - we cannot *design* the user experience (Redström, 2006)) - after sales feedback gives new insight in unforeseen use situation aspects. Therefore, it can be a very valuable source of information in the development process (van Kuijk, Kanis et al., 2007). With participants of project A and C the use of after sales feedback as a source of information was shortly discussed.

Two means were mentioned to use this information. A designer from company A claimed that they know that they do not know everything when the product is introduced to the market, but that they can use after sales information to improve a next version of the product. This corresponds with the findings of van Kuijk, Kanis, Christiaans and van Eijk (2007) who state that much of the information that is collected can be re-used in a next version of the product. Another goal of this information source emerged in the discussions with company C who said that the first signs from the market were now used to adjust the manual of the product without actually changing the design. The manual shows how users should deal with a certain use situation aspect, in this case an irregular size of the tow hook to which the bicycle carrier should be attached. Depending on the product characteristics, after sales feedback can therefore be used to either make real-time adjustments to the current design (such as with software updates) or use the information as a source for a successor product.

Personal domain knowledge

While the literature review in chapter 2 focused on studies with actual end-users in actual contexts, this study revealed that other sources from the 'real world' were used as well to get insight in DDUS. The first source is personal domain knowledge. Most participants indicated to often make use of their own knowledge about the use situation, either from personal experience with the domain or from previous projects they had worked on. For example, one of the respondents of case B indicated that he knew that the variety of physical condition influenced the concentration level and consequently the learnability of the system, because he personally experienced that himself in his life when using other products. This corresponds to the proposition of Poelman (2005, page 109) which states that (personal) experience is often a more important source to define product functions than market research.

Organisational domain knowledge

Another source is the knowledge available in an organisation. This was reflected in company A, which has been developing the same kind of products for years, and which keeps records of relevant use situation aspects, for example the sizes of environments and the types of documents that are printed. An intermediate information source was found in case C. Because that case is about a product that is used in a common environment, the design team could make use of information sources close to the company. For example they used their own 'fleet' of cars and bicycles in usability evaluations of their own and of competitor products.

Experts

Although end-users and environments are the most direct source to gather use situation information, it seemed more efficient to consult experts that have insight in the variations between use situations. For example the design team of the bicycle carrier gathered many insights from the consultation of bicycle dealers. Not only did they have a wide knowledge of types of bicycles that should fit the bicycle carrier, they also knew a lot about the different needs of users with regard to using the bicycle carrier. For example, as mentioned earlier users have different preferences with regard to lifting the bike on the carrier. Just consulting end-users might have given a biased view on these issues. An interesting type of expert is the client of the project. Although in this study no use situation aspects were found that came from the client, designers indicated that often the clients have knowledge about use situation aspects when they have developed products for similar use situations previously.

Standards and legal requirements

Chapter 2 already mentioned that for specific use situation aspects, data may already be available because it has been researched before by others. A specific category of this information are standards. Some standards prescribe which types of users the product should accommodate, for example the American section 508 law (Section508.gov, 1998) which describes accessibility to people with disabilities, that was used in the printer case. Others describe the test conditions for certification, for example, in the case of the bicycle carrier, the RDW (Dutch governmental road safety council, (RDW, 2012)) conducts a certification test that reflects various road and driving conditions.

Conclusion use situation analysis

Question 3a concerned how DDUS aspects are analysed in design practice. The methods and approaches to analyse DDUS which came forward in the literature review in chapter 2 were reflected in the studied projects. However, while the literature review only gave insight in direct studies of use situations and the use of self-reports, much information on use situation aspects was gathered from additional sources, including personal and organisational domain knowledge, experts and standards and legal requirements. Particularly experts were an efficient source to give insight in the dynamics and diversity of use situations and related usability issues. As discussed in chapter 2, when designers have more knowledge of variety of use situations and related usability issues, this will probably positively influence design for DDUS. Therefore, a support to design for DDUS should stimulate designers to efficiently employ aforementioned sources of information.

The sources of information that can be used to gather information about use situation aspects seem to depend to a large extent on the context in which the project takes place and the nature of the project. . When the product is developed in a context in which the project is preceded with projects for similar use situations, a designer can rely on organisational knowledge such as was described for case A. When the project concerns use situations that are common, for example in the case of many consumer products, a designer can rely to a certain extent on his personal domain knowledge. Therefore, design for DDUS is most difficult, when the use situations are unfamiliar to the design team. For this reason it was decided to develop a support for the latter type of design contexts. This is further discussed in section 3.5.6.

3.5.4 Design process: prioritising use situation aspects

The second research question with regard to the design process was how DDUS aspects are prioritised in design practice. When asked to order situation aspects with regard to importance, participants from the same team often used different categorisations. This suggests that prioritising use situation aspects was not an explicit activity in the studied design projects. In chapter 2 it was concluded that the relevancy of use situation aspects depends on the extent to which it influences usability, based on severity (criticality) and the extent to which the use situations will occur (frequency). Most critical aspects that were mentioned in this study were the ones that resulted in mistakes, made use impossible or made users lose their confidence in the product. To get insight in the extent to which a use situation aspect influences usability, it needs to be explored what the relation between use situations and usability is. A study of the use situation aspects that were considered in the three design projects gave more insight in this aspect. While some connections between use situations and usability issues can be predicted, most influences are uncertain.

Preconditions: predicting what will not be effective

For some usability issues it was possible for the teams to predict their occurrence for certain use situation aspects. For example for the user characteristic ‘knowledge of a certain language’, the printer team could ’predict’ if persons would be able to read the instructions on the product or in the manual. Not knowing the right language would make it impossible for the user to achieve that goal. Another example is the context aspect ’bicycle frame size’ for the bicycle carrier. Information on bicycle frame sizes and combinations of bicycles that should fit the carrier, could be used to predict if the bicycles would fit on the carrier. In this case it influenced the adjustability of frame arms and the length of attachment straps. These aspects can all be considered *boundary conditions*: if they are not taken into account it will definitely deliver unsatisfying results.

Difficult to predict relations between use situation aspects and usability issues

For some user characteristics it was less obvious what their consequences were in relation to a product. For example in the bicycle carrier case the user characteristic spatial perception seemed to influence people’s understanding of the movement of the frame arms, but it was not very clear how. In the health monitoring system it seemed that the self-esteem of users influenced their acceptance of the system, but it was not obvious which solution was needed to overcome this problem. Context characteristics could also have a difficult to predict influence on use. In the case of the health monitoring system the different types of television that people have had a large influence on the installation process, but the effect was larger than the developers thought in advance, as is illustrated by the following quote:

Usability expert (case B): “The type of television was very important; it turned out to give a lot of issues. […]

Researcher: “Did you know in advance that it was going to give problems? […].

Usability expert: no, but we knew that, we had written the manual and you have to write there how to put it on its channel. You know from experience that it will be different everywhere. So we mentioned a couple of solutions, but people often just looked at the top one.”

Analysing relations between use situation aspects and usability issues was further complicated by the fact that many aspects and issues were interrelated. For example in the bicycle carrier case, the comfort of putting the bike on the carrier relates to the weight of the bike, but also to the strength of the user. The way of folding down left and right carrier arms is probably related to experience with other carriers and understanding of technical matters. In the printer case the role of the user relates to the frequency of use and the experience with printing. These aspects all have influence on the learnability of the system. In the case of the health monitoring system, learnability is related to experience with other types of products, particularly a computer and knowledge of terms. In all cases it was difficult to derive which use situation aspects led to which usability issues. In some cases it was not clear at all which use situation aspect caused differences in usability issues. For example in the case of the health monitoring system the point in the installation procedure at which problems occurred seemed not related to a specific user or context characteristic.

These difficulties in anticipating use are also demonstrated in a study of Kanis (1998) who showed that user characteristics can set boundary conditions by indicating what users will not do, but they do not give insight in what users will do. Therefore the relevancy of use situation aspects cannot be defined completely at the start of a design project, and will become more clear after the first usability evaluations. This was already reflected in the study of the awareness of designers of DDUS and it was again acknowledged by the participants of this study:

> *Designer (case B): What surprised me [...] was that the concept of a computer was unfamiliar to them. [...] and maybe you know that, but it is a surprise how it impacts use. That stays surprising, because if you understand that you would not have to do user tests.*

Usability testing is thus not only useful to get insight in usability issues, but also in relevant use situation aspects. How usability was evaluated is further described in the following section.

3.5.5 Design process: evaluating usability for DDUS

The third research question with regard to the design process was: 'how is the usability of solutions evaluated with regard to DDUS?'. In chapter 2 it was argued that usability testing with end-users is necessary to get insight in usability issues. All participants in this study acknowledged the importance of early usability evaluation and each project involved one or more cycles of formative usability evaluations. One design team specifically indicated that summative evaluations to compare alternatives were not considered useful.:

> *Usability expert (case A): "We never test to make a choice between alternatives […] If we want to choose between A and B, we discuss until we agree on a choice. Than we decide what we want to know about that solution and then we test that and adjust it. That is our principle belief. If two people agree, we are not going to test, because you can interpret that tests in different ways. Then you can better do that interpretation before a test and proceed with that."*

This suggests that effort can better be put into formative evaluations than into summative evaluations. Different means to get insight in future usability issues were discussed. Prototypes or mock-ups can be tested inside the company with colleagues who are outside the project, or by self-tests of the designer in which he or she can build models to test the design him- or herself quickly. Prototypes can furthermore be tested externally with domain experts or intended users.

Internal usability evaluation

About testing yourself an interviewee indicated the following:

Designer (case C): "Just doing things yourself with the design can give you a lot of information. It is important to quickly make prototypes and models so you can have something in your hands and work with it. For example the grip, make foam models and look what it means. […] It is important to have it in your hands as soon as possible.[…] I think for that matter that if you design a product for a professional market, for example doctors, you would use other techniques, but when the product is so close to you, you can learn from testing yourself."

Obviously testing yourself does not give insight in variations in use and it can only be applied to domains that are well known to the designer personally. Furthermore it seems to be limited to testing physical actions. In early design phases more insight in variations in actions can be gathered by testing early prototypes with users inside the company. Interviewees gave the following remarks about this means:

Usability expert (case B): "Before going outside we did some early tests with secretaries to be able to remove the basic problems. So you usually firstly test inside."

Designer (case C): "Well, we did user tests with people here about carrying the product and how it is placed on the tow hook. So we tested with a colleague who is female and small and we tested with a colleague who is a typical user of bicycle carriers."

Designer (case A): "I organised a test with people from the R&D department, because it was very difficult to show it to people outside for reasons of confidentiality. But we invited colleagues who did not know the project at all and did not work in the business unit."

External usability evaluation with experts

In project B and C the developers deliberately chose different types of users to test the product with to get insight in variations of use. In tests with experts these variations of use can be revealed as well, because apart from their personal preference of performing an action they also can have a broad view on types of use. For example:

Usability expert (case C): "Another fact that came forward during evaluation with bicycle dealers was how people place their bike on the carrier. We thought, well, you just lift the bike and put it on the carrier, but the dealers showed that there are various ways to do it for example put one wheel in first and then lift the other wheel."

External usability evaluation with intended end-users

Finally, tests with different types of end-users can reveal variations of use. In project B tests with nine elderly persons and couples were conducted in their home. In project A, apart from earlier internal user tests, extensive user tests were conducted in situ with five representative clients who could use the printer for three months. In project C no extra tests were conducted with end-users because they indicated they had gathered enough information from the evaluations with colleagues and the experts (bicycle dealers) and the client. In the other projects tests with end-users were applied in later design phases when working prototypes were available and the first problems with the design had been removed based on internal tests.

Test conditions

In chapter 2 it was discussed that in design for DDUS, multiple use situations should be integrated in usability evaluations. It was concluded that particularly formative field evaluations are useful for gathering reliable results on varying use situations and related usability issues. This was reflected in the studied cases. Both project A and B included extensive tests in the field. Project C included a mixed approach. The product was not evaluated in a lab, but in the near environment of the company.

For the different formal usability evaluations, one or more use situation aspects were consciously varied. Often, extreme use situation aspects were taken as test conditions. For example, in the bicycle carrier project, a short inexperienced female user and an experienced male user were included in the internal test. For the 'pre-beta-test' of the printer project 'extreme clients' were invited to participate.

For the beta-test of the printer project, they selected different types of clients based on what they thought would reveal the most interesting results. Important characteristics that were mentioned were workflow, level of education and 'context'. Also for internal tests, user characteristics were consciously varied, for example participants of different length were invited to see how that would influence paper handling. In the health monitoring system project random situations within the chosen target group (elderly at their own home) were chosen to test the product, because they had no insight yet in what relevant varying use situation aspects would be. Since the health monitoring system was a completely new product with no comparable competitors, it seems that the variation of certain use situation aspects in test conditions depends on the extent to which the designers are familiar with the use of comparable products. This can also be concluded from the following remark of the printer designer:

> *Designer (case A): "With regard to physical comfort, we could draw on our knowledge from existing products. For example, we had made products with drawers before, and products in which you sometimes have to solve failures. We tried to use that as background knowledge."*

Usability tests can have a more or less formal character depending on the conscious choice for an evaluation approach. The informal tests, such as the self-tests or undocumented tests with colleagues, have a larger chance of not revealing issues for variable use situation aspects, because of their opportunistic character. However, as mentioned by the usability expert of case B, they are useful for revealing 'the basic problems'. These are usability issues that seem independent of use situation aspects. Another benefit is that since they do not need a lot of time, they can be easily applied to proceed in an iterative design process.

A limitation of internal tests was the constraints it puts on available test persons and test environments. For example, in the bicycle carrier case, the usability expert indicated that a critical user would have been an elderly person with limited technical knowledge. However, such a person was not included in the test, because there was no colleague available who met this requirement. In other cases the internal tests limited the exploration of relevant use situation aspects. For example, the influence of the levelness of the floor on the stability of the bicycle carrier while being stored, was only found out when it was tested outside.

Conclusion usability evaluations

The research question discussed in this section concerned how usability of solutions is evaluated with regard to DDUS. Chapter 2 described that usability evaluations with prototypes allow for evaluating and reflecting on multiple and integrated use situations. All projects involved such usability evaluations with more or less variations of user, goal and context. Apart from usability tests with end-users, these evaluations also included evaluations with experts and internal evaluations such as tests with colleagues and self-tests.

In the formal tests a conscious choice was made for varying use situation aspects in test conditions when it was clear what these relevant use situation aspects were. Often 'extremes' were chosen to include in the evaluations. In the project which concerned a totally new product, it was not clear in advance what distinguishing use situation aspects would be, so these tests were executed under random test conditions. Informal tests such as self-tests have an opportunistic character and are therefore often not sufficiently contextualised. From this can be concluded that knowledge of the relevancy of use situation aspects is needed to be able to carry out useful variations of this use situation aspect in evaluations. Usability evaluations could therefore assumingly lead to more useful results when designers are supported in gathering this knowledge of use situation aspects. Furthermore designers could assumingly take more advantage of informal tests when they are stimulated to better contextualise these tests.

The literature review in chapter 2 furthermore showed the opportunities to reflect on usability issues in DDUS by means of scenarios. The results gave no insights in the use of these type of evaluations in the studied design projects.

3.5.6 Design process: communicating DDUS

The last question with regard to the design process was how knowledge of DDUS and usability is made explicit and communicated. In this section the results with regard to communication are divided in communication about usability insights and communication about use situations.

Communicating usability insights

All teams made reports of the analyses and usability evaluations and additionally presented the results orally in (PowerPoint) presentations, although respondents of case B and C indicated that their documentation process could be done better. The designer of case C indicated there was not enough time for good documentation during the project. He mentioned one case where he made the report only weeks after a certain observation while he had communicated the results already orally right away.

The use of the reports as a means of communication is low. Some designers indicated that they don't like to read the reports or that they only read the conclusions, while usability experts questioned if the designers read the reports. To make sure results of analyses and usability evaluations would give input to the design process, results were communicated orally in team meetings or face to face, and/ or visually by means of video. Furthermore most respondents indicated that it is better to do the observations and evaluations yourself, as can be illustrated by the following comments.

Project leader (case C): "We used to have the usability evaluations done by someone who was not the designer, because then we had someone who would critically assess the design. However, since the designer was not present at the test, he would not know what to improve. Therefore we quit that approach. Now, if we do usability evaluations, we bring the engineers and the principle designer."

Designer (case B): "If you look at PowerPoint as a means of communication, you sometimes read a comment, but there's a complete story behind it. […] But we have videos of people who are using the system, if you see that, the comment comes to life."

However, in none of the cases were the designers involved in all the observations and evaluations. From this fact and the earlier insight that team members often relied on personal knowledge of product use, it can be concluded that there still is a need to communicate usability issues and related use situation aspects otherwise.

Communicating use situation aspects

Some specific use situation aspects were well documented. For example in case A a complete reference set of possible types of prints was documented and in case C different bicycle sizes were documented. These aspects consider the earlier mentioned 'boundary conditions'. In case A important user characteristics were documented in persona's. In case B and C, some issues were made explicit in a start document or critical scenarios, but were not kept up to date. It could not be analysed to which extent the reports and presentations included information about the use situation aspects. However, it was clear that some usability issues and related use situation aspects were not made explicit at all, as can be concluded from the following comments:

Researcher: "Did you analyse the user or the use context?

> *Usability expert (case C): "The designer did that. I don't think we really created clear critical scenario's in this project. It was more in our heads."*

Usability expert (case A): "Experience with technology is a user aspect that I know from previous projects".

> *Designer (case A): "That is also knowledge you gain in your personal life. If I look at my parents and see how much problems they have with relatively simple things, then you know that will occur frequently. The funny thing is, we hardly communicated this aspect."*

An interesting way of communication was a workshop executed at the start of case B. In that project, the usability expert could bring in his expert knowledge of elderly, because he had done projects for elderly before. In the workshop the development team went through possible workflows of the product and explored the most important expected usability issues for each step.

Conclusion communication

The last question with regard to the design process was how use situations and usability issues are made explicit and communicated. The documentation of knowledge of product use seems to depend on the time and budget available for the project and the extent to which the project can build on knowledge of previous projects. The company of case A develops products that are very similar to each other. They also had the largest budget with regard to usability. In chapter 2 it was already discussed that persona's rely on a lot of data of user insights and need a large interpretation step. It is therefore not surprising that they were only applied in case A. They had the budget to create the persona and could apply them to several projects. However, as concluded in section 3.5.3, for unfamiliar use situations, knowledge of use situations and related usability issues needs to be built from scratch, which also means it can only be made explicit during the design process. However, in case B and C, knowledge of use situations was only made explicit and communicated at the start of the project and not regularly updated. Communication during the design process relied on oral communication, since the generated reports were not read or created too late. Therefore, it can be concluded that for cases in which knowledge is gathered during the design project, there is a need for a more flexible and less time-consuming frame of reference, which can be used to communicate knowledge of product use during the design process.

3.5.7 User constraints for the support development

The respondents of the retrospective study were furthermore asked what they find a pleasant way to learn and apply new techniques or approaches. These insights can be used as input for the development of a support. Most participants indicated that they learn most from doing and less from for example reading a book. This could be either in a workshop format or learning from colleagues. They furthermore indicated that they appreciate the theoretical background of what they are doing.

> *"I want to do it myself, but I am not motivated if I don't know what it's place is in the whole"*

Furthermore all participants indicated that it is very important that it is clear what the goal is of the technique and how it fits in their design context, and that the invested learning time is in the right proportion to the expected effect.

3.6 Conclusions regarding design practice

The study on designers' awareness of DDUS and the retrospective study of three design projects in practice, gave insight in the current situation in design practice with regard to DDUS. Conclusions were made with regard to DDUS awareness and solution generation, the difficulties of analysing relevant use situation aspects, the need for a flexible frame of reference for usability evaluations and the lack of sharing knowledge of product use.

3.6.1 DDUS awareness and solution generation

The participating designers in this study were all aware of the dynamics and the diversity of use situations. The generated checklist of possibly influencing use situation aspects and model of variety levels of use situation aspects did not increase their awareness level. Furthermore, it was concluded that the model and checklist have no or only minor additional value in identifying use situation aspects. The model and checklist were therefore not further considered in the development of the support and it was decided to not further focus on designer's awareness of DDUS.

Furthermore, the retrospective study showed that generating solutions for known relevant varying use situation aspects did not lead to any observable problems. Therefore it was decided to focus neither on the generation of solutions in the development of a support.

3.6.2 Analysing relevant use situation aspects

The literature review in chapter 2 revealed different methods and approaches to analyse relevant use situation aspects by means of direct studies of use situations and the use of self-reports. These approaches were applied in the studied design projects as well. Additional information sources were personal domain knowledge and organisational domain

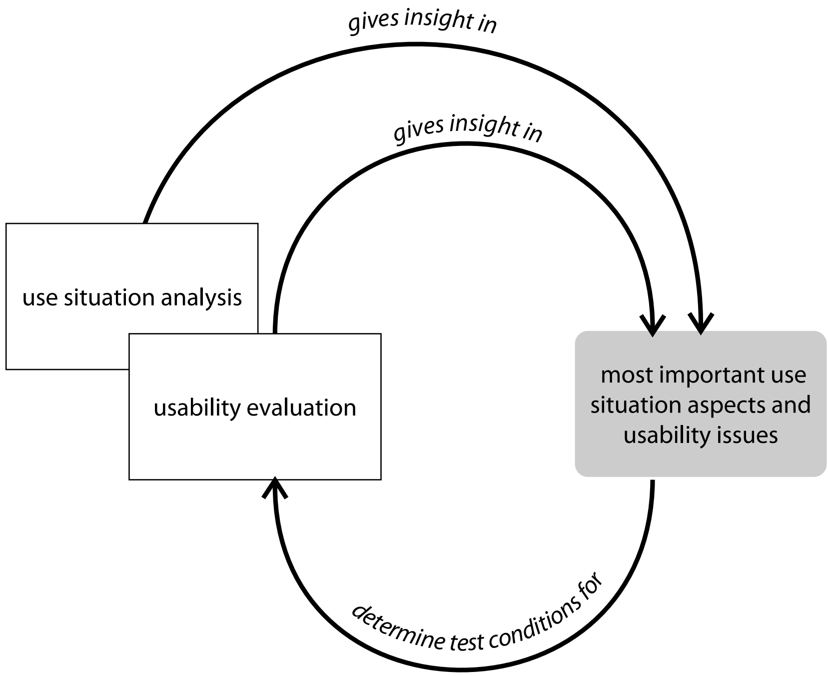


Figure 3.7: building a frame of reference of most important use situation aspects and usability issues is an iterative process, since they both depend on as well as influence usability evaluations.

knowledge, experts and standards and legal requirements. Particularly experts were an efficient source to give insight in the dynamics and diversity of use situations and related usability issues. A support to design for DDUS could stimulate designers to efficiently employ aforementioned sources of information to gather insight in relevant varying use situation aspects.

What designers did indicate as being difficult in designing for DDUS is that relevant use situation aspects cannot always be defined 'in advance'. Both the study of awareness of DDUS, as well as the retrospective study, showed that use situation aspects that are not 'boundary conditions', can only become clear in evaluations of prototypes or of comparable products. After sales feedback can also be used for this purpose. However, to be able to take these varying use situation aspects into account during the design process, it is necessary to conduct usability evaluations early in the design process. Therefore the support should encourage these early evaluations.

3.6.3 Frame of reference for usability evaluations

In chapter 2 it was argued based on literature that more valid results can be retrieved in usability evaluations when test conditions reflect the most important use situations. Therefore a frame of reference which reflects these most important use situation aspects is needed. As mentioned before, these use situation aspects can often only be retrieved from these same usability evaluations. Building such a frame of reference can therefore only be done iteratively, such as illustrated in figure 3.7.

In the studied design projects, the use situation aspects that were made explicit in such a frame of reference mostly considered constraints or boundary conditions (extreme frame sizes for example) and were reflected in requirements. Less predictable use situation aspects were only made explicit in the case in which the company continuously designed similar products and could invest in for example building persona's. In other cases, these use situation aspects were sometimes made explicit in the beginning of the design project, such as the critical scenarios which were created in case C, but not adjusted during the design project.

The study showed that the informal types of usability evaluations often lacked sufficient contextualisation of the evaluation, because the solution was only tested by the designer him or herself or only in the direct company environment, thus ignoring other types of users or contexts of use. The external validity of the formal usability evaluations could not be tested here since the products were not or only recently introduced to the market. Therefore it could not be concluded to what extent the test conditions represented the current or future real-world use situations of the product in the market. However, the lack of an up to date and explicit frame of reference of most relevant use situation aspects, makes it difficult to set relevant test conditions, which negatively influences the external validity of usability evaluations. This issue is further discussed in the following chapter, section 4.1.1.

It was therefore concluded that there is a need for a support which stimulates building and updating an explicit and flexible frame of reference of the most important use situation aspects and usability issues, particularly for cases where this frame of reference cannot be reused from previous projects. Furthermore the support should support the application of this frame of reference in both formal and informal usability evaluations.

3.6.4 Sharing knowledge of use situations and related usability issues

A final issue that came forward in the retrospective study was the difficulty of communicating use situation aspects and related usability issues. The test and observation reports which were created in all the studied projects, were often not read at all. Communication thus depended on oral communication, the use of video or having designers do the tests themselves. It was already mentioned that designers used personal knowledge in identifying relevant use situation aspects. Thus both knowledge of use situation aspects as well as of usability issues can remain implicit in the heads of the designer. In case A persona's and contextual models were used to align thoughts of designers. As mentioned before this was possible because of the consistency between projects and length of projects. It was therefore concluded that for projects which cannot rely on the reuse of a frame of reference of product use of previous projects, there is a need for a support to share knowledge of product use.

The above mentioned problems of designing for DDUS are further discussed in chapter 4. There, the complete comprehensive descriptive study 1, based on the literature review in chapter 2 and the retrospective study described in this chapter, are used to make a so-called reference model of the existing situation. This is the reference – hence its name – against which the intended improvements are benchmarked (Blessing and Chakrabarti, 2009, page 20). This reference model was used as a basis for the development of a support for designing for DDUS.

4 Objectives Of The Design Support

4 Objectives of the design support

In this chapter, the results of the literature review described in chapter 2 and the retrospective case study described in chapter 3 are compared to additional literature on the most relevant related topics, to create a description of the existing design situation with regard to designing for DDUS (section 4.1). Based on the representation of the existing situation in a reference model, the desired design situation is formulated and represented in an initial impact model. While the reference model represents the existing situation, an impact model represents the desired situation and shows the assumed impact of the support to be developed (Blessing and Chakrabarti 2009, page 20). An analysis of these models and an analysis of existing support tools and of contextual prerequisites leads to a list of requirements for the to be developed tool (section 4.2). Based on these requirements a concept for a support is proposed in section 4.3. The chapter concludes with an overview of how this concept was further developed and described in the following chapters.

4.1 Analysis existing situation

The case studies have shown that all participating product developers are aware of the dynamics and diversity of use situations. In some cases knowledge about use situations is captured explicitly in personas, scenarios or other types of documentation to capture a specific use situation aspect. However, knowledge about users, contexts and goals often remained implicit in the heads of team members and was often not shared. This was particularly true for teams which dealt with unfamiliar design problems. These teams could not make use of a 'frame of reference' which explicitly represents knowledge of product use which could have been gathered in previous projects. A lack of such a frame of reference makes it difficult to contextualise usability evaluations. Moreover, when there is no clear shared frame of reference of use situations, communication about the quality of proposed solutions and the intended use situations in design decisions might be difficult. Therefore, it was chosen to focus the remainder of this research project on gaining and using knowledge of DDUS in the design process. To further explore this problem, a short literature study was conducted to gain insight in the role of this knowledge in usability evaluations and in communication processes.

4.1.1 Knowledge of product use in usability evaluations

Chapter 2 described that when designing for DDUS, the most important varying use situations should be reflected in usability evaluations. The importance of reflecting the context of use in test conditions is acknowledged in most literature on user centred design (Cushman and Rosenberg 1991, page 53; Bevan and Macleod 1994; ISO 1998, page 8) and is called the *ecological validity* of the evaluation (Jordan, Thomas et al. 1996, page 241). The goal of reflecting realistic test conditions is to improve the *external validity* of the usability evaluations. In experimental research this refers to the populations, settings, and variables to which the measured effect can be generalised (Campbell 1957) and is therefore also called *representativeness* or *generalisability*. When the results of usability evaluations would not be representative of the variety of real-world intended use situations, they would not lead to useful recommendations to adjust the evaluated solution to better accommodate those use situations.

The retrospective case studies in chapter 3 showed that informal evaluations were often not sufficiently contextualised. Furthermore, for formal evaluations for unfamiliar design problems, knowledge of intended use situations and connected usability issues was often not communicated and made explicit during the design process. Both insights suggest that the external validity of usability evaluations in design practice is not optimal.

Since chapter 2 and 3 showed that the relevancy of use situation aspects and usability issues are strongly interrelated, an externally valid evaluation can only contribute to more useful results, when the evaluation is focussed on the expected related usability issues. This is particularly true for theory based (focussed) evaluations that test predefined assumed usability issues, reflected in the research questions (Carroll 2000, page 41). For example, one might expect that or question if users of a prototype of a new design coffee machine can comfortably fill the water reservoir under their tap. An evaluation of the prototype should then include a task in which users are asked to do this, and users should be asked if they can do this comfortably. The theory of comfortably filling the water reservoir under the tap can then be verified in this evaluation. Carroll defines such a theory as 'not the single factor variety that often form the core of academic discussion. Rather they are comprehensive theories of everything that occurs within a situation of use and every causal implication for what happens subsequent to that situation' (Carroll 2000, page 40). The 'theory' in design for DDUS concerns the frame of reference of use situations and how they relate to usability issues, including for example different kinds of taps and sinks and how they influence the ease of use of filling the water reservoir of a certain coffee machine As opposed to theory-based evaluations, 'discovery-oriented' evaluations allow the discovery of unexpected usability issues. In case of the coffee machine, users would be asked to make coffee with the machine while evaluators would ask open questions on the usability of the machine and be open to observe whatever would happen. Since usability evaluations both contribute to, as well as can be designed based on the frame of reference, the evaluations will have a more discovery oriented character in early design phases and a more focussed, theory-based character in later design phases.

Since such a frame of reference is often not created in projects in which products are designed with use situations and usability issues that are unfamiliar to the design team at the start of a design project, the results of the retrospective study suggest that both the external validity of usability evaluations as well as their focus on expected usability issues are not optimal.

4.1.2 Sharing knowledge of product use

The retrospective study revealed that knowledge about use situations and related usability issues often remained unshared in the design teams. The importance of sharing knowledge with regard to usability was shown in the research of van Kuijk (2010) who concluded that the communication of usability issues was a critical step in the establishment of shared knowledge about a usability weakness. The chance of usability weaknesses being dealt with effectively increases if teams do not only know about a usability weakness, but also understand and empathise with it (van Kuijk 2010, page 252). The need for shared knowledge or a shared vision in design was furthermore discussed by Buchenau and Fulton Suri (2000, page 425) who state in their work on user experiences, that to work effectively as a design team, it is important to develop a common vision of what the team is trying to bring into being. This section further explores the influences of sharing knowledge of product use by means of a literature review.

The influence of shared knowledge on team performance

The influence of sharing knowledge and information in teams on team performance has been studied in several disciplines, but the research is still in its formative stage (Mohammed and Dumville 2001). From 1985 the influence has been studied by social psychologists in so called 'hidden profile tasks' (i.e. murder mystery, or select the best candidate) where information that supports a superior option is unshared, whereas information that supports an inferior option is predominantly shared (Stasser and Titus 1985). Hidden profile groups (where the optimal decision choice is hidden to the group as a whole) are eight times less likely to find the solution than groups having full information (Lu, Yuan et al. 2012). However, hidden profile studies only focus on the *mentioning* of information during team discussions, so called information pooling. This information should also be actively considered to create a 'team mental model' (Mohammed and Dumville 2001, page 92). Team mental models have been investigated primarily by industrial/ organisational psychologists from the nineties, and are defined as team members' shared, organised understanding and mental representation of knowledge about key elements of the team's relevant environment (Klimoski and Mohammed 1994). The general thesis of the shared mental model literature is that team effectiveness will improve if team members have an adequate shared understanding of the task, team, equipment and situation (Mohammed and Dumville 2001).

The influence of shared knowledge on team performance in design

Very few studies have been conducted on team mental models in design-related areas. Badke-Schaub, Neumann, Lauche and Mohammed (2007) discuss the implications of team mental models for design. They assume that mental models for design can relate to knowledge about the task, the process, the group, the competence, and the context. Knowledge on the variety of use situations and usability issues would fall in the category of task models which relates to a person's stored knowledge regarding the particular task, including product knowledge such as information about the problem, the goal and the solution. They furthermore discuss the possible influence of sharedness of team mental models on team performance. If team members have to arrive at a common solution, task mental models would have to be shared up to a certain level to make collective decisions. Information exchange is necessary to share team members' mental models about the problem, the goal and the solution. On the other hand, when creativity is needed to come up with new solutions to a given design problem, diversity (and thus diverse mental models) is needed. Furthermore a too high level of sharedness of team mental models might result in an effect known as 'groupthink' (Janis 1972) which means that when there is too much cohesion, team members tend to develop a mindset where unanimity in the team overrides the motivation of team members to realistically evaluate alternative decisions, resulting in suboptimal solutions.

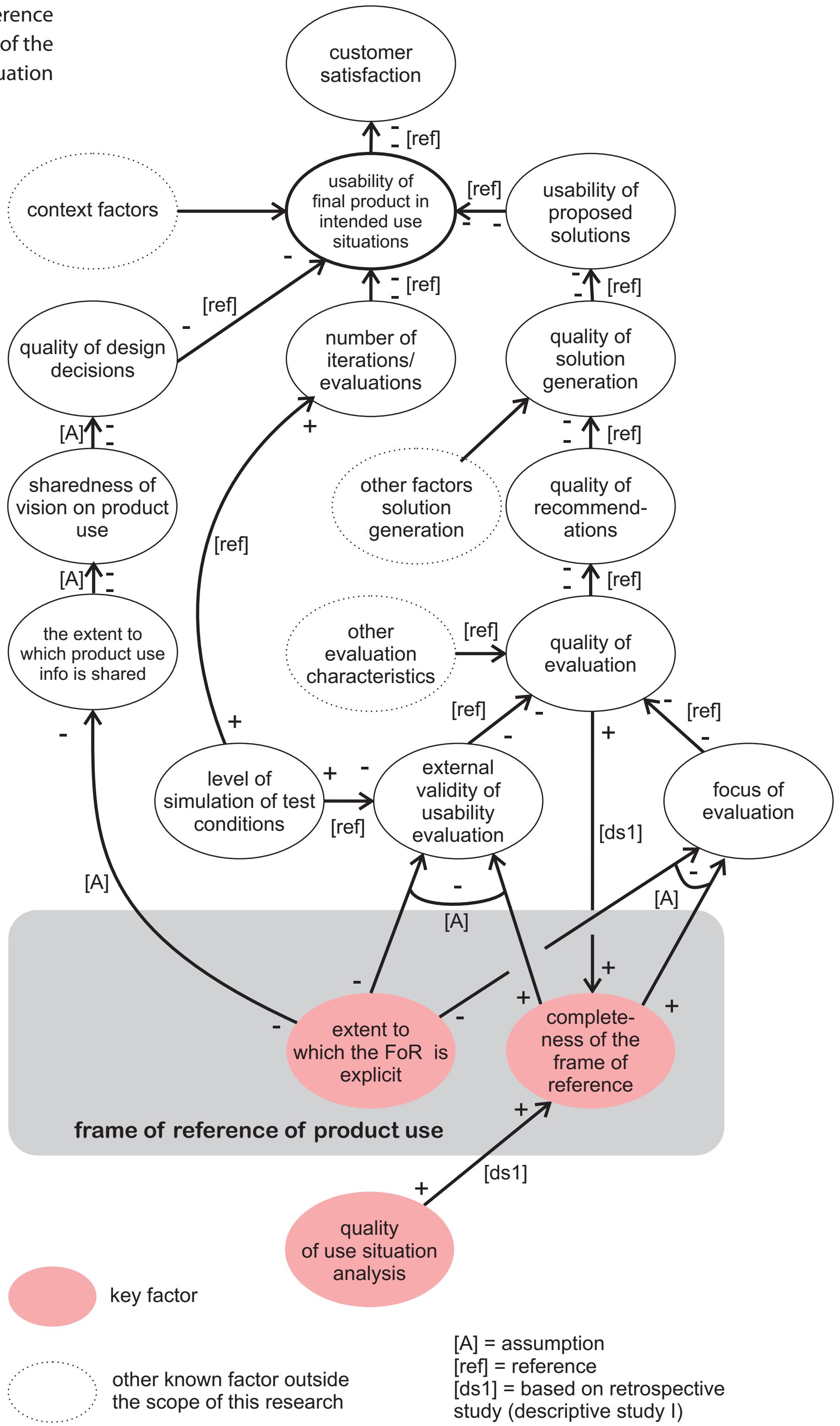
The influence of shared knowledge in designing for DDUS

Based on above mentioned discussion, it is assumed in this research that a lack of sharing of information of product use can negatively influence a shared team mental model of use situations and usability issues. Sharing information involves all activities aimed at this goal including group discussion, e-mail and other communication means. In this thesis, the created team mental model is further referred to as a 'shared vision on product use'. A lack of sharedness of a vision on product use is expected to negatively influence decision making with regard to choosing solutions and defining intended use situations. There is a possible negative influence of a high level of sharedness of a vision on product use, on group thinking and creativity in the early phases of the design process. However, it is assumed that the current level of sharedness of product use is so far below the optimum level, that it is expected that there is still room for improvement.

4.1.3 Representing the existing situation

To define the objective of the to be developed design support, it is useful to make the existing design situation and the desired design situation explicit. The objectives of the support can then be derived from comparing the existing to the desired situation. Blessing and Chakrabarti (2009, page 20) propose a graphical representation that was developed specifically for design research studies, such as the research described in

Figure 4.1: reference model of the existing situation



this thesis. It was therefore chosen to use this representation to model the existing and desired design situation. The model to represent the existing situation is called the reference model, because it is the reference against which the intended improvements can be benchmarked.

The representation concerns a network of influencing factors and is shortly introduced here to clarify the model. The nodes in the reference model represent influencing factors, which are aspects of the existing situation that influence other aspects of that situation (Blessing and Chakrabarti 2009, page 20). An influencing factor is formulated as an attribute of an element that is considered relevant and that can be observed, measured, or assessed, for example the external validity (attribute) of usability evaluations (element). The links between factors show how the factors influence each other. The sets of '+, '-' and/ or '0' signs at the ends of a link describe how the value of the factor at one end relates to the value of the factor at the other end. Every link is labelled with the source of the statement it represents, such as if the statement is an assumption, published in a reference or based on own investigations. Key factors are those influencing factors that are identified as the most useful factors to address in order to improve an existing situation.

Explanation of reference model

The conclusions of the retrospective study and the literature analysis were used to create a reference model which represents the existing design situation for design for DDUS (figure 4.1). The final objective of this research is to improve the usability of products in their intended use situations. This is the success factor indicated in the top of the reference model (figure 4.2). The success factor is the ultimate goal of the research project. Although there are exceptions, the level of usability of products is in general still far from optimal. Section 1.1.1 already described how a lack of usability can negatively affect customer satisfaction and company profit. Usability of products in intended use situations can be limited because firstly, the usability of design solutions is low, secondly the number of iterations in which solutions are evaluated and adjusted is low and

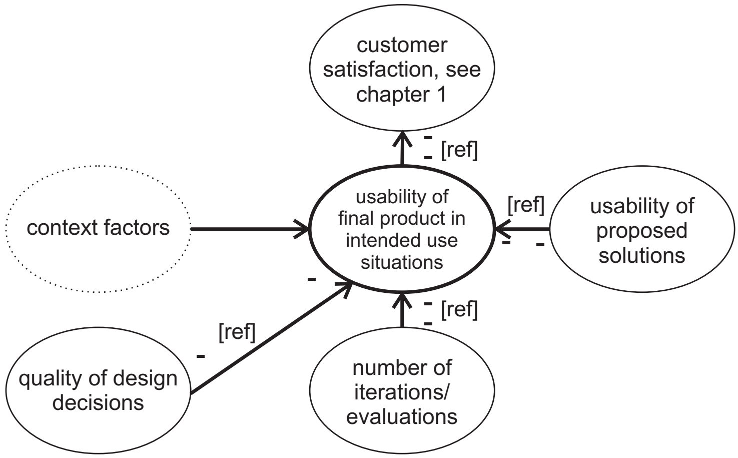


Figure 4.2: influencing factors in the top of the reference model.

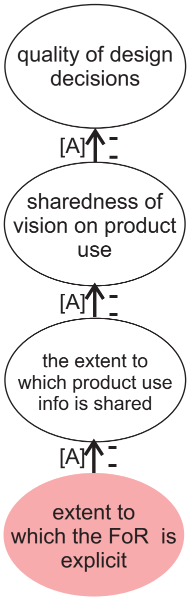


Figure 4.3: existing influencing factors on the quality of design decisions

thirdly because of an inappropriate choice for use situations that the product is aimed at and solutions that fit these use situations best. This inappropriate choice can be caused by the quality of the related decision making process with regard to choosing solutions and target use situations. The quality of decision-making can improve the usability of the product (Harkema, Luyk-de Visser et al. 2011). Factors in the design context that influence the usability of the final product were mentioned in chapter 2 and consider for example a user-centred company culture and upper management that prioritises usability (van Kuijk 2010). Since the context factors were not further considered in this research, they are indicated in dotted lines. The remainder of this section describes firstly the factors that influence the quality of design decisions, and secondly the factors that influence the usability of proposed solutions and number of iterations.

Quality of design decisions

As mentioned above, decisions need to be made about which use situations to target, and which proposed solutions fit this target best. From the literature described in section 4.1.2, we can conclude that this decision making process benefits from a shared vision on product use (the mental model) which in turn is influenced by sharing information on product use (the activity of sharing, see figure 4.3). Therefore 'sharedness of the vision on product use' and 'the extent to which product use information is shared' are added as factors that influence the factor 'quality of decision making'. Since the retrospective study showed that knowledge about use situations is not always shared, this factor needs to be improved. It is assumed that the lack of sharing is caused by the fact that knowledge of use situations and related usability issues is often not made explicit. This explicit knowledge is defined as a 'frame of reference of product use'. Therefore the factor 'extent to which the frame of reference is explicit' is added to the reference model.

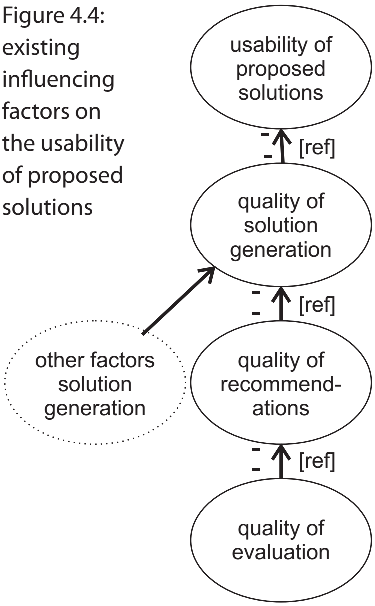


Figure 4.4: existing influencing factors on the usability of proposed solutions

Usability of proposed solutions

The usability of proposed solutions is directly influenced by the process in which these solutions are created (figure 4.4). The quality of solution generation is positively influenced by the quality of recommendations that result from formative usability evaluations of preceding solution proposals such as mock-ups (see for example Nielsen 1993; Hartson, Andre et al. 2001). As discussed in chapter 2, the quality of solution generation furthermore depends on designer factors such as the expertise level of the designer (Lawson and Dorst 2009) and the experience of the designer with designing comparable products (van Kuijk 2010). These factors set conditions for the extent to which the other factors influence the usability of proposed solutions. For example, the quality of usability evaluations and resulting recommendations is more likely to influence the usability of solution proposals when the expertise level of the designer is high, than when the expertise level of the designer is low. As discussed in chapter 2, these designer factors are left outside the scope of this research.

Quality of the usability evaluation

In order to get to good recommendations, the quality of the evaluation needs to be high. This quality depends on the external validity and focus of the evaluation and other evaluation characteristics (figure 4.5). The latter characteristics include reliability, thoroughness and other types of validity (see Hartson, Andre and Willeges (2001) for an explanation of these terms). As mentioned before, the external validity refers to the generalisability of the results, while the focus of the evaluation refers to the extent to which predefined assumed usability issues are reflected in the research questions. Since in this study, the main objective is to take the dynamics and diversity of (real world) use situations into account in usability evaluations, the external validity and focus of the evaluation are crucial for the evaluation to lead to relevant recommendations for solution generation. The other evaluation characteristics are outside the scope of this research.

The external validity of the usability evaluation depends on the one hand on the appropriateness of the situations that are chosen to be set as test conditions and on the other hand on the extent to which these situations are simulated. A higher level of use situation simulation, for example by means of testing in a lab, will lead to a lower external validity of the evaluation compared to real-life use situations (see for example Jordan (1998)). It is assumed that more appropriate use situations can be chosen to set test conditions, when enough insight is gathered in what these situations are and when these situations are made explicit. Likewise, it is

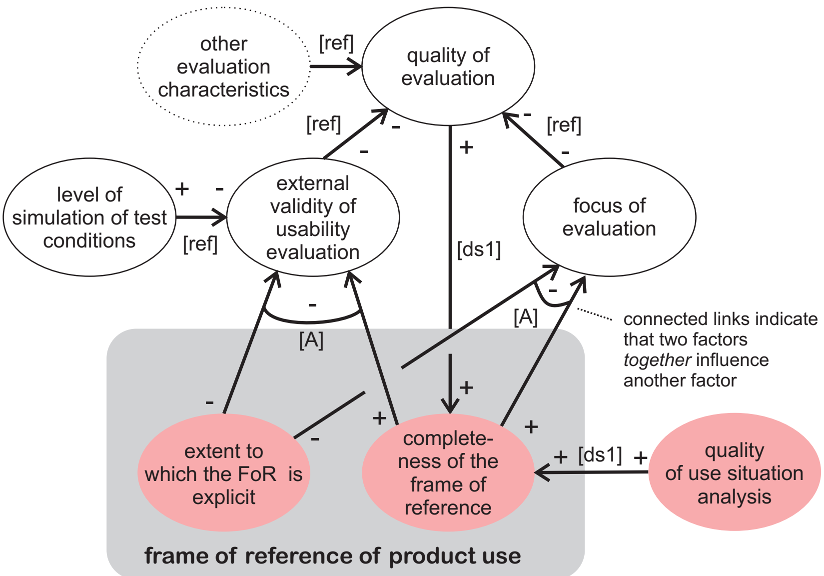


Figure 4.5: factors which influence the quality of the usability evaluation

assumed that the focus of evaluations will be better, when enough insight is gathered in what use situations are and which usability issues are relevant in these situations. Enough insight in relevant use situations and relevant usability issues is indicated in the reference model as 'the completeness of the frame of reference of product use'. Making the frame of reference explicit was already introduced in the previous section. Since an explicit frame of reference of product use will assumingly not have an effect on the external validity and focus of the evaluation when it is not complete, the factor completeness is added as a precondition for those influences (see the connection of the related links in the reference model). The literature review in chapter 2 and the retrospective analysis of the current situation, described in chapter 3, described several techniques to gather insight in use situations. Better analysis of use situations will lead to better insights, and thus a more complete frame of reference of use situations. Furthermore, this research also showed that evaluations can lead to better insights in use situations. Therefore a link is added which shows the positive influence of the quality of the evaluation on the completeness of the frame of reference.

Number of iterations

Design is an iterative process, which means that solutions are generated, evaluated, adjusted, evaluated and so on. Although revised designs might introduce new usability problems, executing multiple iterations increases the chance for a more usable final product. Measured usability will normally go up for each additional iteration, until the design potentially reaches an optimum (Nielsen 1993). Therefore, the more iterations are being conducted with regard to usability evaluations, the higher the chance that the final product will have a high level of usability, until a certain optimum. Less iterations will reversely reduce the chance that products are created with a high level of usability. The number of iterations that can be executed in a design process, depends on the available time in a project and the amount of time needed for an iteration. Fast evaluations can be conducted by simulating use situations in which products will be used. For example, instead of real users, a designer can test a product himself by quickly making a prototype and trying it out. Although these evaluations with a high level of simulation lead to a lower validity of the evaluation, they need little preparation time and are therefore easy to integrate in iterative design (Van der Bijl-Brouwer and Boess 2010). This influence of the level of simulation of test conditions is added as a link in the reference model to the number of iterations (see figure 4.1).

4.1.4 Problem statement

The reference model represents the insights gained by combining the retrospective study and related literature. Based on the reference model the problem statement for this research can now be formulated as:

Problem statement

In current design practice, knowledge about the dynamics and diversity of users, contexts and goals often remains implicit and is mostly not shared. When it is not known what probable use situations are and what relevant usability issues in these situations are, the external validity and focus of evaluations will be low. Moreover, when there is no clear shared 'frame of reference' of use situations and issues, communication about the quality of proposed solutions and appropriate intended use situations in design decisions will be difficult. Since both the external validity and focus of the evaluation as well as the quality of decisions on the usability of design solutions will influence the usability of the final product, incomplete explicit knowledge and a lack of shared knowledge of use situations negatively influence the usability of the final product in intended use situations.

The factors in the reference model that seem to be the most useful factors to address in order to improve the problem stated above, are the quality of use situation analysis, completeness of the frame of reference and the extent to which the frame of reference is made explicit. It was chosen to address these key factors through the development of a support. The following section describes the objectives of this support.

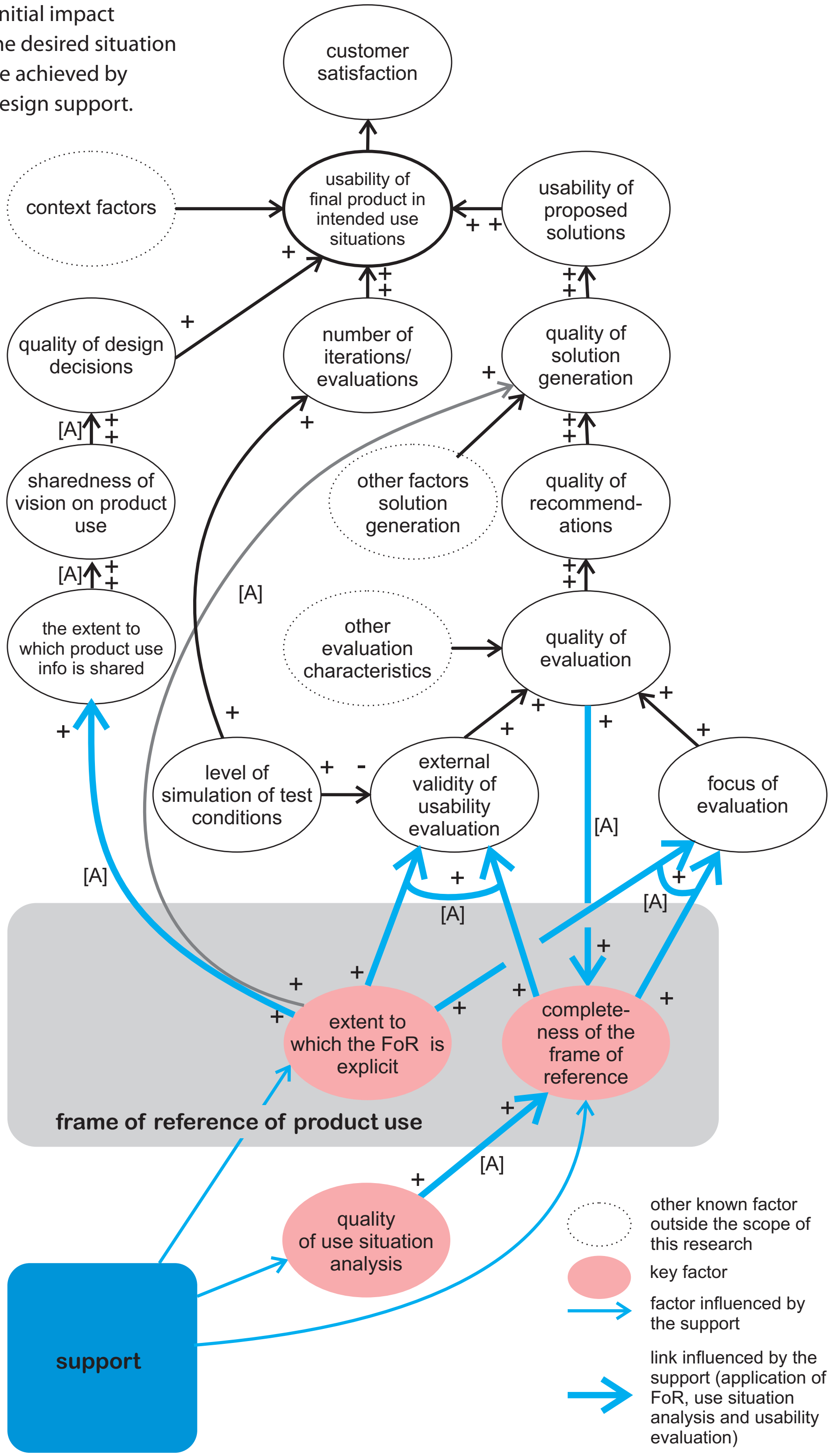
4.2 Objectives of the design support

In the remaining part of this research, a support will be developed, aimed at improving the existing situation described in the previous section. The development of a design support is defined as a 'prescriptive study' by Blessing and Chakrabarti (2009). In accordance with their methodology, this research stage will start with a task clarification, aimed at describing the desired situation at which the support will be aimed.

4.2.1 Desired situation

In the desired situation (i.e. to improve the problem stated above), a more complete and explicit frame of reference of use situations and related usability issues is created than in the current situation. This frame of reference is applied to improve the external validity and focus of evaluations. Furthermore, the frame of reference can be used to improve the quality of design decisions because it assumingly improves the extent to which information on product use is shared. This assumed positive influence of the explicit frame of reference is shown in the initial impact model (figure 4.6). In the impact model, the links between factors show how the factors are desired to influence each other after the introduction of a support. The support is desired to both directly influence the complete explicit frame of reference, as well as indirectly through the application of use situation analysis and usability evaluations for this purpose. Furthermore it is desired to support the application of the complete explicit frame of reference in usability evaluations and sharing

Figure 4.6: the initial impact model shows the desired situation which should be achieved by introducing a design support.



information of product use. These influences of the support with regard to the *application* of the frame of reference, use situation analysis and usability evaluations are indicated in the bold blue lines in the impact model.

Although the retrospective study did not indicate that there were any problems in generating solutions for DDUS, it is expected that a more explicit frame of reference will also positively contribute to the quality of solution generation, by functioning as a source of inspiration. Therefore an additional link is added which shows this assumed influence of the explicitness of the frame of reference of product use on the quality of solution generation.

Existing support tools to analyse and improve the explicitness of DDUS

Before a support is developed that is aimed at the creation of a complete and explicit frame of reference, insight needs to be gathered in existing support tools that are aimed at the same goal. Chapter 2 already mentioned different techniques and frameworks for the creation of explicit frames of reference of use situations and related usability issues, and for analysing use situations. It was concluded that existing techniques and tools for the creation of frames of reference lack the flexibility required in iterative projects. This is particularly important for projects which cannot rely on reuse of frames of reference of previous projects.

To analyse use situations the literature review gave insight in many potentially useful approaches including literature of existing user research, real-world studies such as observations and interviews, self-reports and evaluations of current solutions. The retrospective study showed that personal knowledge and experts were also useful sources to get insight in use situations. Therefore there is no need to develop a new technique to analyse DDUS aspects. However, designers could be supported in the selection of appropriate techniques. This is further discussed in section 4.3.1.

Definition of target design domain

In accordance with general user centred design approaches, the development of a design support should include the definition of the target users of this support. The support developed in this research is aimed at designers and product developers of companies who consider the usability of their products an important issue in product development and who already employ general user centred design approaches such as described in chapter 2. The to be developed support is expected to be more effective, when companies are familiar with general design for usability approaches and have already built a usability oriented organisation (see e.g. van Kuijk (2010).

The support is expected to have most added value for projects that do not possess complete representations of use situations yet. The studied cases showed that the company in which a product was developed which was familiar to the development team and also had a familiar range of use situations, kept most advanced representations of use situations. To make these advanced representations also available for other types of projects, the design support is therefore initially aimed at projects with unfamiliar use situations for the development team.

Contextual pre-requisites

The small study of designers needs with regard to a to be developed support, described in section 3.5.7 showed that it should be easy to learn and preferably have an 'active' character, while still giving enough background information. Another pre-requisite of the to be developed support is the flexibility of its application. This can be illustrated by a study of Fricke (1996) who observed designers and analysed their abilities and design processes. He showed that designers following a 'flexible-methodical procedure' tended to produce better results than designers with too rigid adherence to a methodical procedure or with very un-systematic approaches. Therefore 'engineering design methodology' should be flexible to apply. This is also true for supports aimed at product design. According to Stolterman (2008, page 61) it is important for those who produce support for design practitioners to make the 'incorporation' into the designer's own approach possible. The necessary flexibility of the design support is furthermore reflected in the comments of the respondents in the retrospective study who indicated that the support should fit in their design process. Since every design process is unique, a flexible support is needed.

4.2.2 List of requirements

Based on its discussed intended impact and its contextual prerequisites, a list of requirements can be formulated which the to be developed support should meet.

1. The support should be able to support the design of products for which usability is considered an important issue and the use situations are diverse and dynamic
2. The support should improve the extent to which knowledge of product use is shared
3. The support should improve the external validity and focus of usability evaluations
4. The support should be easy to integrate in existing design processes
5. The support should be easy to learn

The following section describes the conceptualisation of a support that is expected to meet above mentioned requirements.

4.3 Conceptualisation

The key factors that are addressed to achieve the desired situation described in the previous section are the quality of use situation analysis, the completeness of the frame of reference and the extent to which the frame of reference is made explicit. These key factors are the factors in the reference model that seem to be the most useful factors to address in order to improve the existing design situation. The support should improve the quality of use situation analysis and the translation of the results of these analyses in the frame of reference of product use. The completeness of the frame of reference can thus be increased by means of a better quality of use situation analysis. However, a further completeness of the frame of reference is expected to result from supporting the gathering of implicit knowledge which is already available in a development team. Furthermore the support should improve the extent to which the frame of reference is explicit. Since it is not expected that the explicit frame of reference will lead to better usable products when nothing is done with it, the support should also be aimed at stimulating the application of the frame of reference. To increase the influence of the explicitness of the frame of reference on the validity and focus of usability evaluations, the support should stimulate the application of the frame of reference in evaluations. Likewise it should support the application of the explicit frame of reference in communication. The following section describes the support concepts that were generated to achieve those goals.

4.3.1 Quality of use situation analysis

The retrospective study showed that different techniques are used to get insight in different use situations and how those situations relate to usability issues. These techniques seemed appropriate to gain the needed insights. Therefore it seems not useful to develop a novel technique that supports the analysis of use situations. However, many techniques are available and it is not always clear which technique should be applied in which case. For example, in a study by Weevers (2011) on the selection of user centred design methods by practitioners, the involved companies stated that it is difficult to choose such a method when you do not know how much it will improve your design. Development teams could therefore benefit from a 'catalogue' of existing techniques aimed at gathering insight in use situations, which supports them in choosing the appropriate technique. This catalogue was part of the intended support.

4.3.2 Extent to which the frame of reference is complete

The improvement of the quality of use situation analysis by means of providing a catalogue of existing techniques will assumingly increase the completeness of the frame of reference of product use. However, it is expected that the frame of reference can be further completed by gathering the implicit knowledge of product use which is already available in development teams. Therefore, it was decided to develop a technique aimed at gathering this implicit knowledge and bring it together in an explicit frame of reference.

Based on the results of the retrospective case study, it was concluded that usability evaluations can also positively influence the completeness of the frame of reference. Since the frame of reference is therefore both output of and input to usability evaluations, the frame of reference will have an evolving character. The support should therefore stimulate this evolution of the frame of reference.

4.3.3 Extent to which the frame of reference is explicit

As mentioned above, a knowledge gathering technique was developed which was aimed at bringing together knowledge of product use. Additional support is needed to further support the application of the frame of reference in usability evaluations and decision making, and the application of use situation analysis and usability evaluations to update the frame of reference. With regard to creating an explicit frame of reference basically three directions can be chosen. The first direction is to develop a software tool which can be used to manage and record information on use situations and issues and represent it in an explicit way. The second direction is to develop a step-by-step method by means of which product developers can create an explicit frame of reference themselves. The third direction is to develop a set of guidelines by means of which product developers are guided in creating their explicit frame of reference themselves.

A benefit of a method or guidelines compared to a tool is that they can not only be used to support the creation of the frame of reference, but also to support its *application* in usability evaluations and communication. Since the application of the frame of reference is crucial for its success, it was decided not to develop a software tool in this stage of the development process.

The advantage of guidelines above a step-by-step method is that they can easily be applied to multiple design activities. According to Stolterman (2008), support tools which demand a specific step-by-step sequence of activities would impact the designer's own way of doing things. Thus, they do not meet the requirement with regard to the flexible integration of the support in current design approaches. For this reason, developing guidelines seems the best direction to follow. By means of the guidelines, designers could *adjust* their own approach to design for DDUS instead of completely *replacing* their approach. However, the downside of guidelines is that by their heuristic nature they can easily be overruled by other factors that influence the design process. As Blessing and Chakrabarti (2009, p160) state: "the higher the degree of freedom for the user as to how the support can be used and the more the support allows different interpretations, the more difficult it will be to ensure that the support will be effective and efficient". Therefore it is particularly important to consider the introduction of the guidelines to its users in the development of the support.

It should be noted that the set of guidelines is not intended to alter current methods of user testing, solution generation or decision making. Instead, it is aimed at providing a better frame of reference of DDUS for these activities, to improve the effectiveness of the techniques.

4.3.4 Complete intended support description

Combining the sub solutions for the support mentioned in the preceding section can be used to describe the intended support which is aimed at achieving the described desired situation. The intended support consists of a catalogue of use situation analysis techniques to gain insight in DDUS, a technique to create an explicit frame of reference of DDUS and related usability issues and a set of guidelines. The design guidelines are on the one hand aimed at guiding use situation analysis and usability

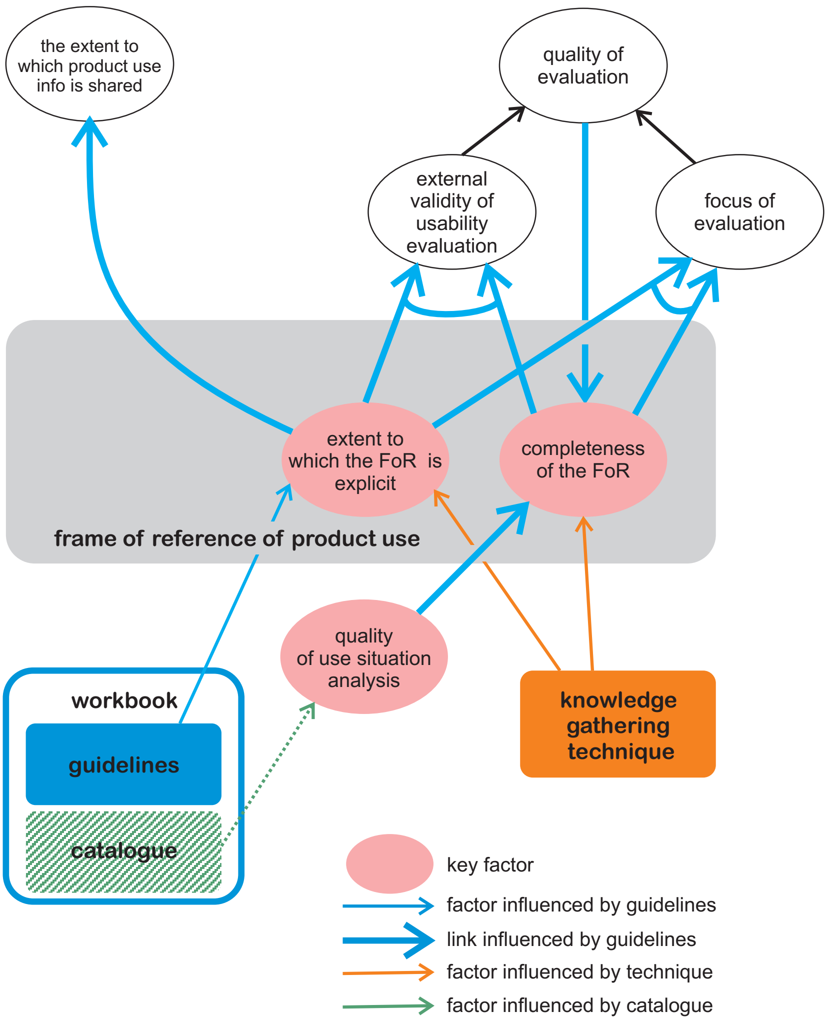


Figure 4.7: impact model of the intended support

evaluation in such a way that the dynamics and diversity of use situations are considered explicitly and can be used to create the frame of reference of use situations and issues. On the other hand they are aimed at applying the frame of reference in usability evaluations and communication.

Because the guidelines are aimed at supporting the design *process*, it was chosen to give the guidelines the format of a workbook. This workbook can then be combined with the catalogue of use situation analysis techniques. Guidance for the execution of the knowledge gathering technique was developed separately, to allow design teams to apply the technique independently of the guidelines. The desired situation for the thus defined intended support is represented in the intended impact model in figure 4.7. Compared to the reference model, this model includes the support and its desired effects. For reasons of overview, only a part of the intended impact model is shown. The knowledge gathering technique is expected to support the gathering of all implicit and explicit knowledge available in a product development team and translating it in an explicit frame of reference. The technique therefore is expected to positively influence both the extent to which the frame of reference is explicit as well as the completeness of the frame of reference. The guidelines in the workbook are firstly expected to support the creation of an explicit frame of reference, secondly to support the application of use situation analysis and usability evaluations to create a complete frame of reference and thirdly to support the application of the frame of reference in evaluation and communication. The latter expected influences of the guidelines are indicated in the impact model in the links represented by means of bold blue arrows.

4.3.5 The actual support

Blessing and Chakrabarti (2009, page 145) distinguish an intended support and an actual support. The Intended Support is a description of the complete support, such as mentioned in the previous section. The Actual Support is a realisation of the Intended Support that may cover only a part of the functionality of the intended support and may be implemented in a different way, but can still be used as a proof-of-concept for the purpose of evaluation.

In this case it is not possible to develop all three support types mentioned in the intended support within the time frame of this research project. It was therefore chosen to develop those parts of the support that represent the core functionality of the support. The core functionality of the support is the creation and application of the explicit frame of reference of DDUS. The success of the application of the frame of reference can be assessed without a complete catalogue of techniques for use situation analysis, as long as some suggestions are given on how this can be done. Therefore it was chosen not to integrate a catalogue in the actual support, but to firstly focus on the guidelines and the knowledge gathering technique.

4.4 Overview of the development process of the design support

The following chapters describe the development and evaluation of the guidelines and the knowledge gathering technique. This section gives an introduction to this development process. The topics that need to be explored are:

- Organisation of the frame of reference of product use: before the frame of reference can be applied in the design process, it needs to be explored what the organisation of this frame of reference could be.
- Gathering knowledge of product use: to fill the frame of reference with relevant information, a technique needs to be developed to gather knowledge of product use and bring it together in a frame of reference.
- Guiding the creation and application of the frame of reference: to further update the created frame of reference in the design process by means of use situation analysis and usability evaluations and to apply the frame of reference in evaluation and communication, a workbook needs to be developed which gives guidance on how this could be integrated in the design process.

4.4.1 Approach

The knowledge gathering technique was developed in an iterative approach. Multiple versions of the technique were executed with experienced designers and the technique was evaluated and adjusted accordingly after each execution. The technique at the same time allowed the exploration of the organisation of the frame of reference. The iterative development of the technique and the organisation of the frame of reference is described in chapter 5.

The development of the workbook also benefits from an iterative approach. However, since its application can only be evaluated in a complete design process, only two iterations could be executed within the time span of this research. The first iteration concerned the exploration of the use of the frame of reference and the application of the knowledge gathering technique in a complete design process executed by students, supported by a simple initial workbook. A complete workbook was created based on the first iteration. Chapter 6 and 7 describe the development, evaluation and adjustment of the initial workbook.

Both support tools needed to be evaluated on their success with regard to the higher level goals. The knowledge gathering technique was therefore evaluated in three real design projects in practice. The evaluation was aimed at measuring if the technique improved the extent to which a vision on product use was shared. The evaluation of the technique in design practice is described in chapter 8. Based on the evaluation in practice a manual for the technique was developed which supports product developers in executing the technique.

The application of the technique, as part of the application of the guidelines, described in chapter 6 and 7 revealed that it had additional value at different stages of the design process. The evaluation of the technique in practice only gave insight in the influences of the technique on one

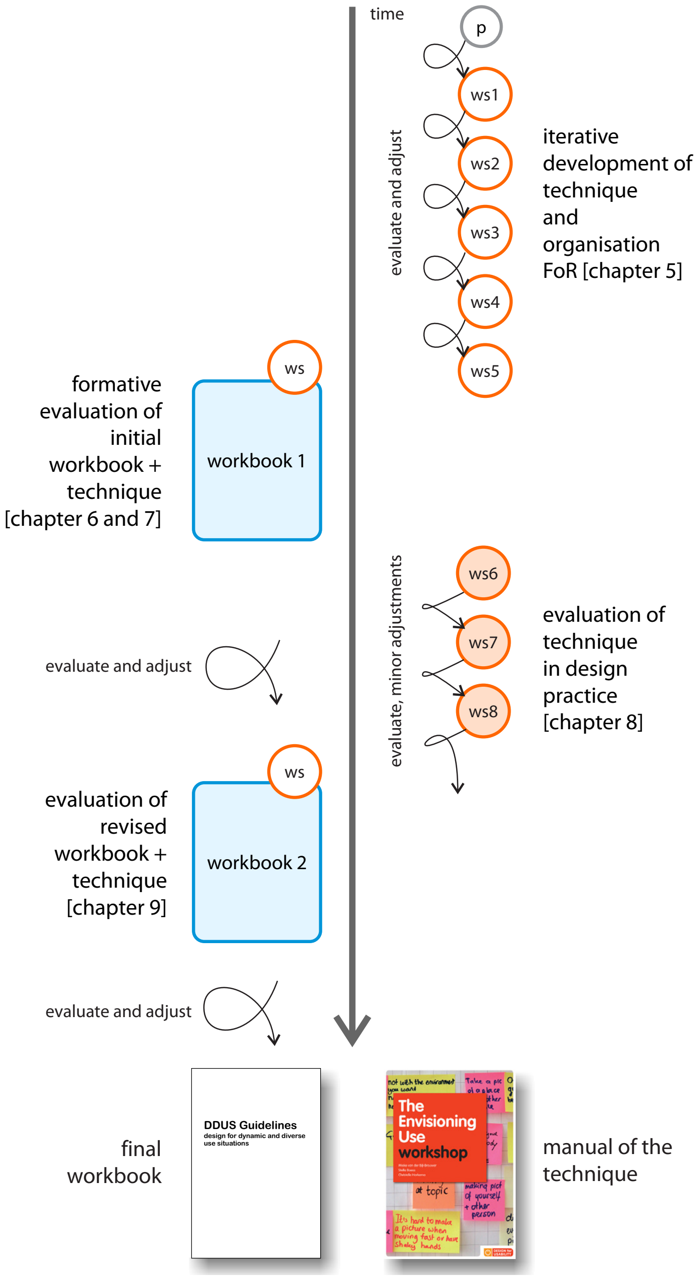


Figure 4.8: the development process of the support tools.

stage of the design process. The application and effects of the technique on a complete design process were therefore evaluated in another design project executed by students, as part of the evaluation of the revised workbook. The result of this evaluation was a 'final' workbook and a set of recommendations for its introduction and further development. The evaluation is described in chapter 9. Figure 4.8 illustrates the development process and how the individual studies were planned in time.

4.5 Conclusions

This chapter showed the development of a concept for a support for designing for DDUS, based on the conclusions of the retrospective study and literature studies. The objectives of the support are firstly to improve the external validity and focus of usability evaluations by means of the creation and application of an explicit frame of reference of product use, which reflects the dynamics and diversity of use situations. Secondly, the support is aimed at improving the sharedness of a vision on product use: the team mental model of DDUS and related usability issues by means of increasing the extent to which information on product use is shared by making it explicit in the frame of reference. The concept of the actual support consists of a set of guidelines to create and apply the frame of reference and a technique that supports gathering knowledge of product use. The further development of the support is described in the following chapters, beginning with the development of the knowledge gathering technique in chapter 5.

5 A Technique To Gather Knowledge Of Product Use

5 A technique to gather knowledge of product use

Chapter 4 specified the problem that needs to be solved by means of the to be developed support. This chapter describes the development of a technique to gather all available implicit and explicit knowledge in a product development team and bring it together in an explicit frame of reference. It was chosen to give this technique the format of a workshop, which will be motivated in the first section of this chapter. The questions that were addressed in the development of this workshop was firstly how to elicit and gather the available knowledge of product use and secondly how to record and organise the gathered knowledge in a frame of reference. An iterative approach was chosen to develop the workshop. Five workshops were executed with experienced designers, evaluated and adjusted accordingly. This chapter firstly describes the objectives (section 5.1) and the research method (section 5.2). Then the results are described with regard to the workshop steps, organisation of the frame of reference and other practical workshop characteristics (section 5.3). Section 5.4 gives a summary of the complete workshop technique. Finally, the results with regard to the evaluation of the workshop technique in the different iterations are described and discussed in section 5.5.

The workshop was developed in collaboration with two other researchers: Stella Boess from Delft University of Technology and Christelle Harkema from the Technical University of Eindhoven. Where needed, the chapter will give insight in which researcher was responsible for which part of the development.

The research described in this chapter has a prescriptive and iterative character. In several iterations, the workshop is developed, executed and adjusted. In the Design Research Methodology of Blessing and Chakrabarti this concerns the realisation and evaluation step of what they define as a ‘comprehensive prescriptive study’ (Blessing and Chakrabarti 2009, page 144). Although the workshop development in this stage is more ‘explorative’ than ‘comprehensive’, the methodology was found a useful framework to describe this part of the research. A comprehensive study covers all the steps of the systematic prescriptive study process: task clarification, conceptualisation, elaboration, realisation and support evaluation. Support evaluation is also the start of the next stage in the framework, the ‘descriptive study II’ (see chapter 1). Task clarification and conceptualisation were already described in chapter 4. This study will further elaborate and realise the design for the workshop technique. Since an iterative approach was chosen to develop the workshop, the steps elaboration, realisation and evaluation are executed several times. For reasons of overview they are here described in one section.

5.1 The existing and the desired situation

Chapter 4 described the task clarification and an initial conceptualisation of the complete support. The aim of task clarification is to establish the problem to be solved by the support, to clarify its requirements and to better define the desired situation. Conceptualisation is aimed at identifying the functions of the support, generating concepts and an introduction plan. Those steps are further elaborated here to show the objectives of the workshop. Furthermore, additional motivations to develop the workshop in collaboration with the other researchers are included in the description of the existing and desired situation.

5.1.1 Existing situation

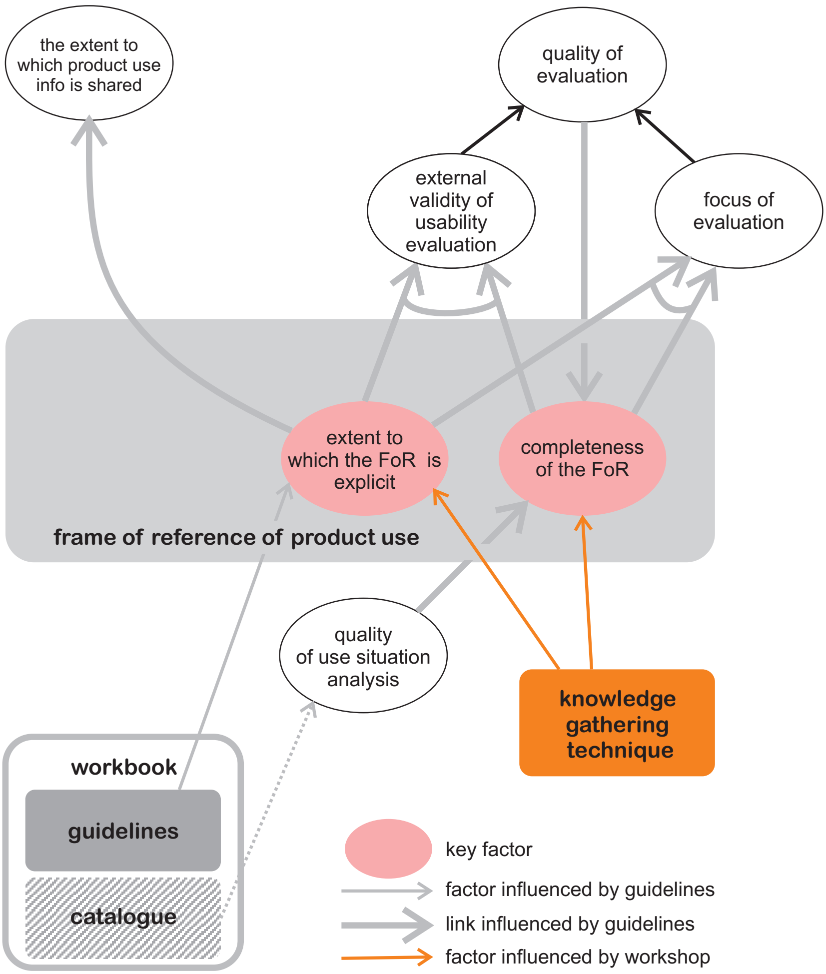
Chapter 4 described that in current design practice, knowledge about the diversity of users, contexts and goals often remains implicit and is mostly not shared. This lack of an explicit and shared frame of reference can negatively influence decision making with regard to choosing appropriate solutions and target use situations and can negatively influence the external validity of usability evaluations. For this reason, it was decided to develop a technique aimed at bringing together this knowledge. The to be gathered knowledge concerns both explicit knowledge of product use available in for example reports of usability evaluations as well as implicit knowledge in the heads of the members of a product development team.

Another aspect of the existing situation that led to the development of the technique, was the insights gathered by the researchers with regard to how designers deal with usability in general in design practice. A study of Stella Boess (2009), based on in-depth interviews with ten practicing designers, showed that most designers in that study were seldom closely involved in a formal usability test or user research, because they might inadvertently try to influence the test and it takes special training to conduct proper testing. Instead, most of them mention informal ways of testing that they conduct themselves: with colleagues, or themselves and with their family. Designers mentioned that they did not think of this informal testing specifically as usability testing. The retrospective study described in chapter 3 showed similar results with regard to informal testing (van der Bijl - Brouwer and van der Voort 2009). These informal tests need little preparation time, which means results of the test can easily be integrated in solution generation. This is shown in the work of for example Buchenau and Fulton Suri (2000) who proposed such an informal technique which allowed easy exploration and evaluation of early design ideas. However, informal techniques incur the risk that the testing is not sufficiently contextualised (Van der Bijl-Brouwer and Boess 2010). This corresponds to a lower external validity of usability evaluations. Furthermore, their informal character incurs the risk of not being integrated with the rest of the development process (Boess 2009). We therefore developed the workshop technique which on the one hand makes these informal steps explicit and allows integrating them in the design process, and stimulates designers and design teams to better contextualise those steps. On the other hand it brings together the knowledge which is available implicitly in the heads of team members and explicitly in different kinds of representations of product use.

5.1.2 Desired situation

The desired situation at which the workshop is aimed is reflected in the intended impact model which was developed in chapter 4. Figure 5.1 shows the contribution of the knowledge gathering workshop to this desired situation. It is aimed at improving the extent to which the frame of reference of use situations and issues is made explicit, by directly making implicit knowledge in the heads of team members explicit and merging it with knowledge that is already explicitly available about product use. At the same time it is expected that this will lead to a more *complete* explicit frame of reference. These are the goals of the workshop with regard to the explicit frame of reference and its contribution to the research topic described in this thesis.

Figure 5.1: lower part of the intended impact model for the workshop technique



5.1.3 Conceptualisation of the support

A first step in the conceptualisation of the support is to investigate current methods and techniques which have similar goals as the ones described in the aforementioned desired situation.

In current design practice, formal reports are often used to communicate user information. These reports tend to provide abstracted conclusions in which a lot of the richness of the data is lost. Moreover, research results are often formulated for a research audience instead of a design audience (Bruseberg and Deana 2002; Sleeswijk Visser, van der Lugt et al. 2007). They therefore make it difficult to connect usability evaluations to design, which Hornbaek (2010) identified as being one of the dogmas prevailing in research on usability evaluation methods.

Other ways of gathering and communicating user insights are aimed at having designers actively experience and work with this information. For example, Buchenau and Fulton Suri (2000) advocate to have designers experience interactions subjectively to understand its experiential qualities. In these experiences, important aspects of the real user experience can be simulated by means of gathering insights from personal experiences of team members or researches of the more conventional kind. Role-playing is a well-known technique to achieve this subjective experiencing (Iacucci, Kuutti et al. 2000; Simsarian 2003; Svanaes and Seland 2004). It allows the exploration of both current as well as future scenarios. Another technique to further elicit implicit knowledge of product use is storytelling. Stories are memorable and have particularly strong powers as communications catalysts (Erickson 1996).

To overcome the limitations of communication through formal reports and to allow the additional gathering of implicit knowledge, a workshop format was chosen as a support means. This workshop could combine the benefits of the aforementioned role-playing and storytelling techniques. A workshop is a group of people engaged in study or work on a creative project or subject (The Collins Dictionary 2012). The advantage of a team technique over an individual technique, is that members of a development team can bring the knowledge together without creating redundant data. When each team member would individually make his or her knowledge explicit by means of the technique, an additional technique would be needed to integrate this knowledge.

Within such a workshop technique, it should be possible to record the knowledge to allow taking it further into the design process as a frame of reference. A technique which has a similar goal is affinity diagramming, which can be used to organise ideas and data into groupings (Brassard 1989). Beyer and Holtzblatt use this technique to bring together individual notes, captured during interpretation sessions of user interviews. It results in a wall-sized, hierarchical diagram (Beyer and Holtzblatt 1998), which in their case shows how individual examples of work practice are instances of overarching patterns that define the whole population. The technique is also used by the innovation and design firm IDEO to identify connections between issues and reveal innovation opportunities (IDEO 2003). In the workshop development we explored if a representation similar to an affinity diagram was appropriate to achieve the workshop goals.

List of requirements

Based on the description of the desired situation a short list of requirements is created as input to the workshop development process. The technique should:

1. gather implicit knowledge of product use and knowledge explicitly available in other sources
2. support recording and organising the knowledge
3. result in an explicit frame of reference of product use which is usable within the workshop
4. result in an explicit frame of reference of product use which is usable in the rest of the design process
5. be efficient (executable within a time frame that product development teams consider reasonable)

Introduction of the workshop

According to Blessing and Chakrabarti's framework of design research methodology, it is useful to consider the different life-cycle phases of the support (Blessing and Chakrabarti 2009, page 160). In case of a workshop technique, the most important life cycles are the introduction stage and the use stage. The exploration of the use stage was inherently part of the workshop development process which is described in the next section. With regard to the introduction of the workshop one should consider who the user is and how the support can be introduced to this user. The 'users' of the workshop are the facilitator of the workshop and the participants in a workshop. The participants will be introduced to the workshop in the session itself. The workshop will therefore start with a workshop introduction. Because of the iterative development, the facilitator role will initially be taken by the researchers, which makes an explicit facilitator-introduction unnecessary in the development phase. The final workshop was introduced by means of a manual, which allows dissemination of the technique to a large group of target users. The workshop introduction is further discussed in chapter 10.

5.2 Workshop development process

This section describes a further elaboration of the technique, based on the objectives in the previous section and describes the method for realisation and evaluation.

5.2.1 Elaboration of the technique

With regard to the development of the technique the following questions need to be answered:

- What is an efficient means to gather knowledge about use situations and use issues in a product development team?
- What is an appropriate means to represent and organise the gathered knowledge in a frame of reference?

Gathering knowledge of product use

To answer research question 1, it was decided to develop a workshop which combines informal techniques to gather knowledge of product use, such as the role-playing, storytelling and scenario techniques described in the previous section. An evaluation of the workshop can then lead to insight in which techniques give the best results with regard to gathering knowledge. This knowledge should consider possible use situations and use issues that occur when a certain product encounters those use situations. This knowledge can concern actual experiences of users and assumed experiences. To distinguish knowledge of experienced use and imagined use, we distinguish stories and scenarios. A story recalls an event that actually happened to a specified person and includes how that person experienced that event (Erickson 1996). A scenario, on the other hand, creates an event that might happen to a specified, possibly imaginary person, and speculates how that person might experience that event (see for instance, Nielsen 1990; Rosson and Carroll 2002). Stories and scenarios can be generated by means of for example storytelling, roleplaying and scenario building.

Format of the frame of reference

To support the recording of knowledge of product use in the workshop, a format is needed which allows the inclusion of knowledge of different use situations or use situation aspects and knowledge of what the consequences are when a certain product encounters those use situations.

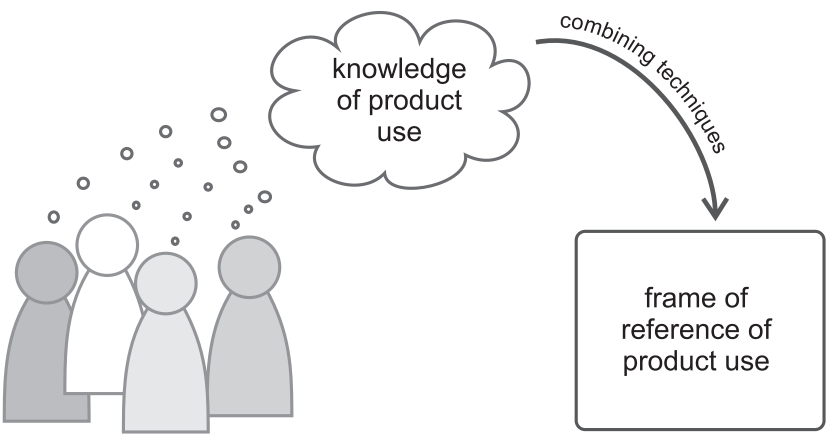


Figure 5.2: combining techniques in the workshop assumingly leads to bringing implicit knowledge of product use together in an explicit frame of reference of product use.

Both main functions of the workshop are shown in figure 5.2. The core functionality of the support is thus the gathering of experienced and imagined knowledge about product use and the recording of this knowledge in an explicit frame of reference of product use. It should be noted that the technique is not meant to replace existing means of formal usability evaluations. The technique can be used in addition to those formal evaluations to share the gathered knowledge with team members.

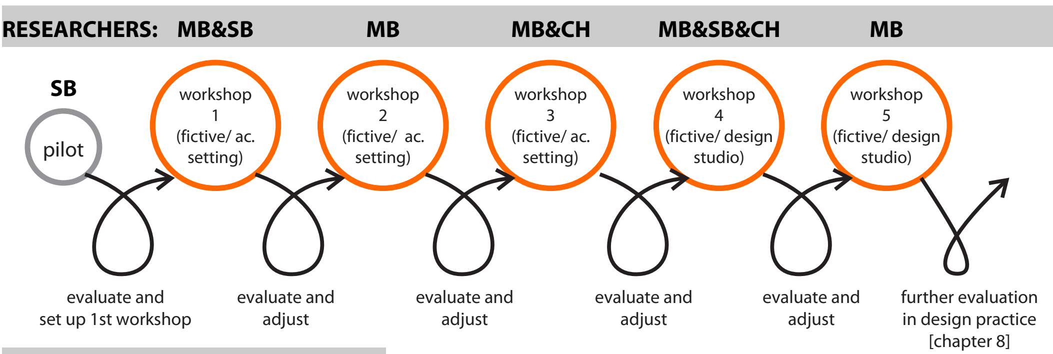
5.2.2 Method of development of the support

Since this research was aimed at developing a technique that is valuable for design practice, the workshop was developed in a way similar to user-centred product design. A further elaboration and realisation of the support was achieved by means of an iterative approach with multiple evaluations in which we involved the end-user of our technique: the design practitioners. This approach was advocated by for example Wixon (2003) who stated that the success of a design support depends on the extent to which it fulfils the needs of practitioners. The approach is summarised in figure 5.3. In each step, a workshop was designed, executed with experienced designers, evaluated, and adjusted accordingly. In total five formal workshops were executed. A short pilot session was executed by researcher Stella Boess as input to the first workshop session. Figure 5.3 shows which researcher participated in which workshop.

Research questions iterations

Each evaluation was aimed at giving input to a further development of the workshop. For this kind of formative evaluations, an 'application evaluation' is most appropriate. An application evaluation is aimed at assessing the applicability and usability of the support against the desired values of the key factors as presented in the intended impact model (Blessing and Chakrabarti 2009, page 184). Therefore, the following research questions were formulated for the evaluation of each of the workshops:

Figure 5.3: the development process of the workshop



CH = Christelle Harkema
MB = Mieke van der Bijl-Brouwer
SB = Stella Boess

1. What is the general usability of the workshop?
2. What is the application domain of the workshop as expected by design practitioners?
3. Did the different steps lead to an efficient increase of the completeness of explicit knowledge of product use? (see impact model in figure 5.1 and requirement 1 and 4)
4. What is the usability and success of the proposed format of the created frame of reference? (see requirement 2)
5. How could the gathered knowledge be used in the design process? (see requirement 3)

Cases

A fictive case was given to the participants to simulate a design brief. A case needed to be chosen which would be familiar to all the participants, so they would have reasonable implicit knowledge with regard to the subject. Furthermore a case was chosen with dynamic and diverse use situations. The fictive cases that were applied in the workshop were the design of a wireless, hands free presentation microphone and the design of a compact photo camera.

Participants and context

Experienced designers were involved in each of the workshops. Some of them were practicing designers, while others were academics who had been working in design practice in the past. The arrangement for each of the workshops is shown in table 1.

For the workshops with the larger groups, we split up the group in two for the parts of the workshop that were difficult to execute with more than 6 persons. The differences in time are due to the fact that steps were

Table 1: arrangement of the five workshop executions

Workshop	Participants	Context	Case
pilot	Ten designers and usability specialists of one company.	Company, 1 hour	Microphone
1	Thirteen experienced professionals from ergonomics, software design, product design and design education	Design for Usability symposium, TU Delft, 2,5 hours	Microphone
2	Three academics with one to ten years of experience in product design practice	University of Twente, 2 hours	Microphone
3	Three academics with one to ten years of experience in product design (others than in workshop 2)	University of Twente 4 hours	Compact camera
4	Nine practicing designers of one design studio	Design studio, 2 hours	Microphone
5	Six practicing designers of one design studio (other than workshop 4)	Design studio, 2 hours	Microphone

added to the workshop in the course of its development. Furthermore, in workshop 2, 4 and 5, the steps which were aimed at translating the gathered knowledge into targets and solutions were not evaluated for time reasons. This had no consequences for the development of the technique. In the course of the workshop development, we experienced that a complete workshop needs at least four hours.

Preparation workshops

For each workshop a plan was made with an explanation of each step. Furthermore the author prepared a detailed time schedule for each workshop with an indication of the duration of each step, based on experiences with this step in previous workshops and available time of participants. The facilitation of each step would be assigned to one of the researchers. Practical preparations included the preparation of workshop materials, organising a workshop location and inviting participants. Those tasks were divided among the researchers.

Introduction technique

Each workshop was started with a 10 minute introduction of one of the researchers to the goals of the technique and the goals of the evaluation of that particular workshop session. The organisation of the frame of reference of product use was explained by means of examples. During the workshop, each step was explained by the facilitator, often by means of examples.

Data gathering and analysis

Apart from the first workshop, each workshop was recorded on video. A group interview was conducted directly after the workshop to evaluate the workshop with the participants. For the first workshop a workshop assistant made minutes of this evaluation. The other group interviews were transcribed completely based on audio recordings. Afterwards, the execution of the steps was closely observed on the video recordings. Both data from the interview and observation were then used to answer the research questions 1,3 and 4. The group interviews were used to answer research question 2 and 5.

5.3 Development of the workshop in five iterations

This section will now describe the development of the workshop. Instead of describing each workshop set-up, evaluation and results completely, the development and motivation of the workshop characteristics over the course of the workshop development will be described for each characteristic. Those characteristics are the development of the steps of the workshop and the organisation of the frame of reference. Subsequent sections will present the final workshop set-up and answer the research questions defined in the previous section.

5.3.1 Results workshop steps

A combination of techniques was explored with regard to the amount and type of knowledge they would result in. We started with the techniques aimed at gathering experienced use and imagined use and envisioning future use and later we added steps aimed at prioritising information, indicating knowledge gaps and structuring information.

Experienced and imagined use

The basic idea was to employ techniques aimed at gathering experienced and imagined use. A simple set-up pilot session was therefore executed by Stella Boess (Van der Bijl-Brouwer and Boess 2010) to demonstrate the difference between the two. This was achieved by distinguishing stories and scenarios, as explained earlier. First the researcher told a story about a recent experience of using a presentation microphone. Participants then collected use issues that occurred in the story, while at the same time they started to tell related stories themselves. Subsequently a scenario was situated in the present by acting it out. Again, use issues were collected. Participants commented that working with stories worked well for them. The first story made participants associate their own memories and in this way elicited new stories. The participants also mentioned that the acting out provided insights one might not have when just imagining what a persona would do. In the subsequent workshops, the steps were defined as 'Remembering' (story-telling) and 'Experiencing' (role-play, see figure 5.4). Remembering would not only relate to personal memories of product use, but also to product use that was observed with others. For example, in the first structured workshop at the Design for Usability

Figure 5.4: participants are acting out a scenario in the 'experiencing' step in which two successive presenters at a pitching session hand over the microphone

symposium (Boess and Van der Bijl - Brouwer 2010), participants would relate to use issues they had been observing occurring to presenters in the morning session of the symposium. The idea is that in real design projects this can also refer to memories of product use observed in for example preceding usability evaluations. In the experiencing step, one or more participants would role-play, while the others were asked to observe and write down use issues.

Diversity in use situations

The imagined use in the pilot only considered the role-play for which one scenario was defined in advance. To further explore the diverse scenarios in which a microphone could be used, an additional step was added in the first formal workshop called 'imagining'. In this step, participants were asked to think up possible scenarios and related use issues. To stimulate the imagination of participants, they were given a large variety of random pictures of use contexts and users. Figure 5.5 shows a collection of these 'associative materials' which were used in the workshops with the microphone case. The imagining step not only resulted in assumed scenarios, but also served as an additional means for the participants to associate to stories in their memory. In other words, in this step, remembering and imagining occur simultaneously. One participant of design studio A indicated that the inspiration cards help you thinking of different situations without being too intrusive:

> *Participant (studio A): "I like that, [..] to inspire you with the things but also to narrow it down in a way that's not too intrusive. You are not telling people, now you are designing specifically for a conference. No, you are just putting these things out there and the first thing that comes to mind is actually a conference"*

The experiencing step was further broadened by adding a preparation step in which participants were asked to define two or three scenarios to

Figure 5.5: associative materials used for the 'Imagining' step. The yellow cards show possible use contexts for a presentation microphone, while the blue cards show possible users. This colour coding was later abandoned (see next section).

role-play and thus having them explicitly reflect on which scenarios they would like to know more about.

Reference products in experiencing

In the workshops we explored the application of different 'reference products' in the role-plays. In the case of the presentation microphone we once provided a real microphone and in the other workshops we provided simple mock ups of the microphone. In the compact camera case participants role-played the scenarios with real compact camera's. Working with mock-ups had the advantage that it was more easy for participants to associate to other solutions, while working with real products had the advantage of revealing more realistic use issues. However, when we told participants in the cases of the real products, that they could also add use issues related to other similar products, this did not lead to any problems. To prevent that use issues only relate to one specific type of solution, we advise to use either mock-ups or multiple types of real products.

Future use

In the pilot and first workshop, participants were asked to make a redesign in a short time using tinkering materials and then present the redesign by acting out a scenario. In both workshops, participants indicated that the step had little added value. In the second workshop this was due to a lack of knowledge of technological constraints. This 'Envisioning' step was therefore removed in the second workshop. However, to explore how the created frame of reference can be used in a real design process, it was reintroduced in the third workshop. After creating solutions individually or in pairs, participants were asked to explicitly describe both positive and

Figure 5.6: participants envisioning solutions for the use issues found in the preceding workshop steps.

negative issues of each other's solutions, related to the use situations in the frame of reference (figure 5.6). Subsequently those issues were added to the frame of reference as well. Thus, the frame of reference would reflect both current and future use.

Prioritising information

Since the remembering, imagining and experiencing step resulted in a very broad collection of use situation aspects and issues, participants in the second workshop were asked to indicate the most relevant issues and situations that would need to be taken into account in a subsequent solution generation process. This caused some problems, because they considered all the gathered information as relevant. An often-described aspect of individual designers' processes is that they tend to start from one or only a few guiding concepts. (see for example Visser (2009, page 194)). Therefore, a prioritising step was considered essential for connecting the frame of reference to the design process that designers are already using. In the third workshop the step was therefore more directly connected to the Envisioning step. Participants were asked to decide upon the situations and issues that they wanted to take into account in the solution generation step, in other words they were asked to define a target. This means that the target use situations and issues are used as the 'guiding concept', while the other issues are not considered irrelevant, but are just not used as a starting point for the first creativity session. This 'targeting' was achieved by firstly having participants indicating important or interesting issues and situations in the frame of reference by means of stickers (see figure 5.7) and subsequently have them decide in a group discussion on a common target.

Figure 5.7: participants are going through the information in the frame of reference of product use to indicate a target for the envisioning step.

Defining knowledge gaps

In the first workshops, one participant indicated that an overview of knowledge of use situations and use issues, might also make apparent what gaps in this knowledge are. This in turn allows for making a decision on which additional activities need to be employed to fill those gaps. This issue was further explored in the third and fourth workshop by researcher Christelle Harkema by adding a 'questioning' step (van der Bijl - Brouwer, Boess et al. 2011). This was based on the idea that while stories lead to facts about product use, scenarios lead to assumptions that need further verification. Knowledge gaps were indicated in the frame of reference by going through it and writing questions on sticky notes for each of these assumptions and for each additional question that was derived from the frame of reference. Apart from the confirmation of assumptions, questions concerned general questions about users or contexts, questions about technological opportunities and other questions about possible solutions. Participants indicated they found it pleasant to have an overview of the things you know and don't know, but indicated that a prioritisation of questions was needed to decide on which questions need to be answered first. In the fifth workshop, the questioning step was therefore further connected to possible following research activities, by having participants order the question notes with regard to their priority, and explicitly mentioning steps to get the questions answered, for example by means of an expert interview or user observation (see figure 5.8).

Clustering information

In the first three workshops, the knowledge of product use was gathered on notes in a predefined structure (see next section for the structure). Since participants indicated having problems with the structure, an additional step was added to the workshop, in which participants could create

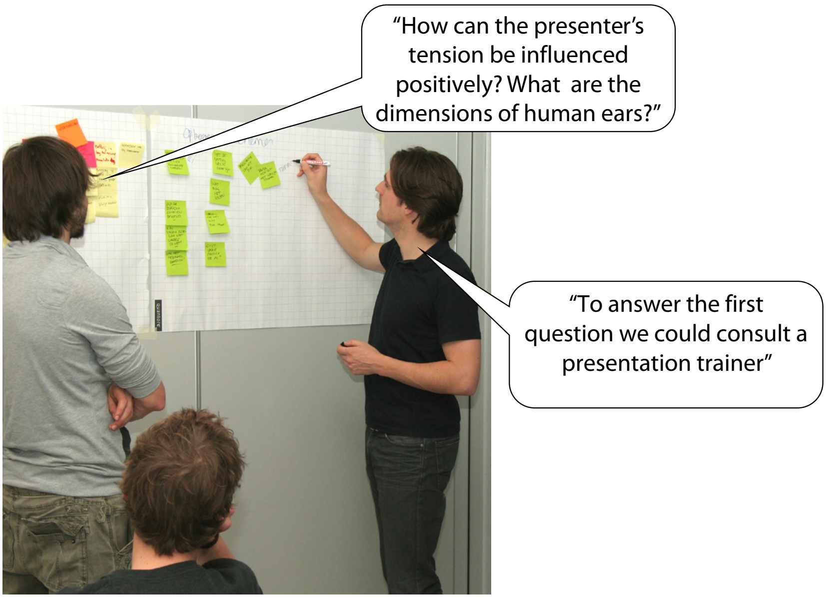


Figure 5.8: participants of the workshop are formulating steps to get answers to the questions written on the green notes.

their own preferred organisation of a frame of reference. Having team members organise and structure the data promotes designers to form a deeper understanding of the users' situations and create perspective for designing (Sleeswijk Visser, van der Lugt et al. 2007). This step will be further explained in the following section.

5.3.2 Organisation of the frame of reference of product use

All described workshop steps are executed around an explicit frame of reference of product use in which the experienced and assumed product use of current and future solutions can be collected. The knowledge was shared by means of telling or acting out stories and scenarios. Although a narrative or storyboard would be the most direct format to represent these stories and scenarios, it was not considered an appropriate format to be able to quickly record and represent them. A quick format was needed to prevent that remembering and imagining by participants was hampered by the recording process. Therefore, only the most relevant aspects of the stories and scenarios were written down.

Connecting use situations, solutions and issues

In the pilot session, use issues were written on a whiteboard. The downside of this approach was that it would not become clear how these use issues related to either the situation in which the issue occurred or to which solution or part of a solution the issue was connected. Therefore, we developed a 'matrix of product use' for the first three workshops. This matrix set out use situations against solutions on a flip chart wall and charted use issues on sticky notes on intersections of those situations and solutions (figure 5.10). As concluded in section 3.5.1, when identifying use situation aspects, it is important to consider the different use phases. Therefore, the use situation aspects were organised in use phases, which were assigned to different flip charts. Figure 5.9 shows an example of a categorisation for the use phases of the compact camera. Thus, the workshop would start with a preparation phase, in which participants would together enumerate use phases of the specific case. Then stories and scenarios would be described with regard to the most pronounced use issue and the aspect of the use situation to which it was related. The use situation aspect would be written on the flipchart (workshop 1, figure 5.10) or on a sticky note (workshop 2 and further) in the related use phase category.

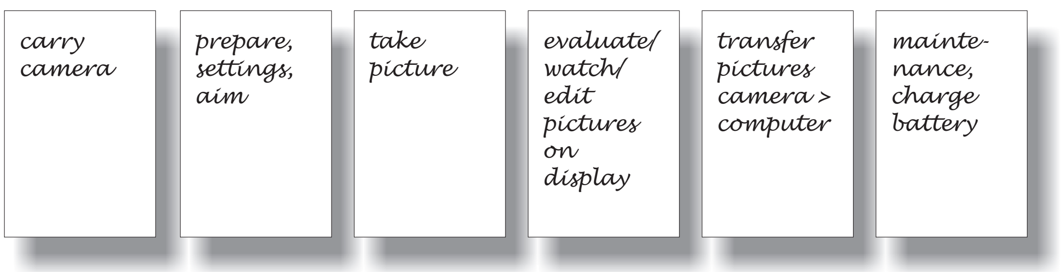


Figure 5.9: example of the categorisation of the use phases of a photo camera on the flip chart wall.

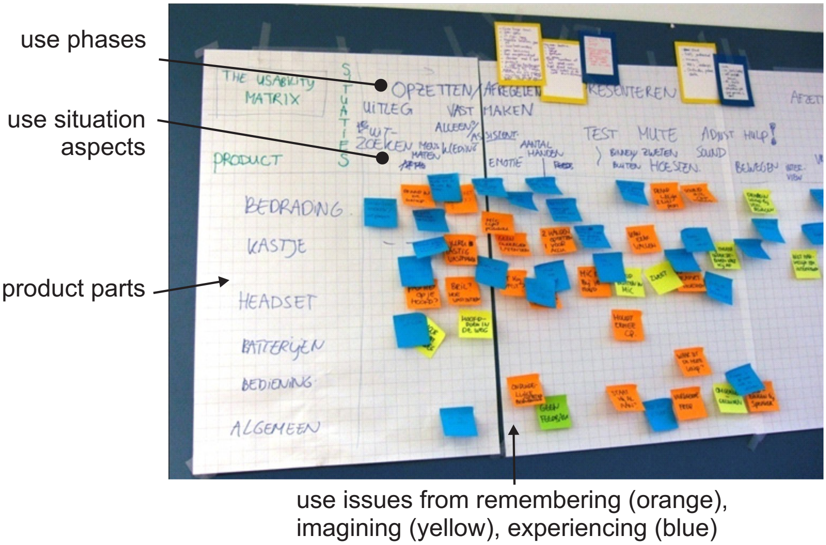


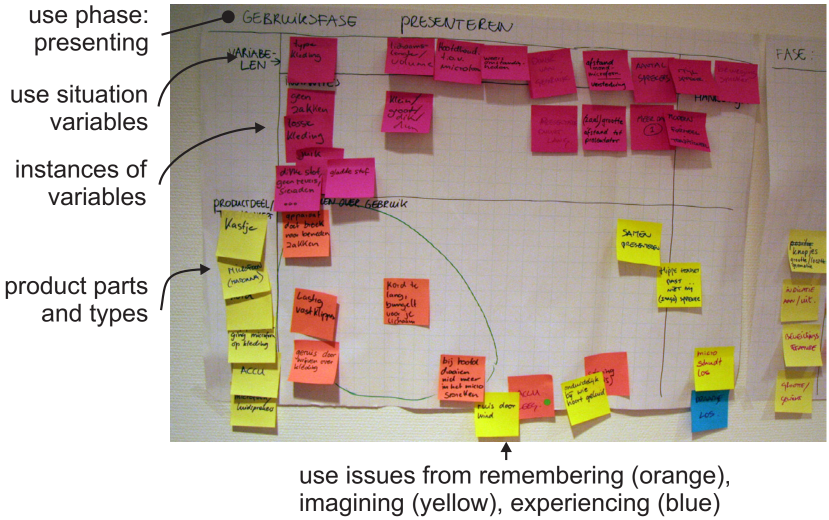
Figure 5.10: the first version of the matrix of product use, created in workshop 1, charts use issues on sticky notes in a matrix with a use situation/ use phase axis and a solution or 'product parts' axis.

Categorising

The categorisation in use phases made sure that all use phases would be covered in the session. However, one participant of workshop 5 indicated that those phases only considered the use phases of the primary user and that the secondary user (such as maintenance) could be forgotten. To solve this, participants should decide in advance which use phases of which user roles are taken into account. To further increase the completeness of the knowledge gathering, a similar approach was chosen to cover more relevant use situation aspects in workshop 2. For each use situation aspect, participants were asked to define a 'use situation category'. For example, many stories in the workshop were related to clothes, for example, when wearing a dress, there is no place to attach the battery of the presentation microphone (see figure 5.11). The use issue 'no place to attach the battery' is in this case connected to the use situation aspect 'wearing a dress'. One could easily imagine similar problems for other outfits. Therefore the category 'clothing' or 'outfit' would be defined for the use situation aspect. In workshop 2 (figure 5.12) and 3 (figure 5.13) those categories were called 'use situation variables', while the use situation aspects were called 'instances' of those variables. The use situation variables were assigned to one of the use phases. Thus, it was assumed that creating the category would provide an additional source for associations to other instances of the category, for example imagining how different clothing would influence the use of the presentation microphone.

Figure 5.11: the use issue 'battery cannot be attached' for the use situation aspect 'dress' is here solved by means of wearing a belt over the dress to which the battery can be attached.

Figure 5.12: a part of the matrix of product use created in workshop 2 which categorises use situation aspects as instances of 'use situation variables'



Orientation of the matrix

In workshops 1 and 2, the matrix set out use situations against solutions. In the second workshop, participants indicated that indicating product features on an axis of the matrix did not give much added value, because those features would already be clear from the descriptions of the issues (for example, the use issue 'battery capacity too low' obviously relates to the battery). Those participants also indicated they found the structure quite complicated and it took them quite some time to learn. Therefore it was chosen to abandon the solution-axis in the matrix in the third workshop. This also allowed for a better connection of use issues to use situation aspects, by being able to position them next to each other (figure 5.13). Multiple issues can be connected to one use situation aspect by making a column of connected issues next to the related use situation aspect.

Colour coding

In the first two workshops, different coloured sticky notes were used for use issues that resulted from either imagining, experiencing or remembering. This made it easy to see which of these steps led to which issue. However, for the application of the frame of reference in the design process, it is not necessary to know in which step the issue was generated. Instead it is of more value to know if an issue is based on an actual experience (a fact) or an imagined experience (an assumption). This division is independent of the steps, because for example the imagining step can lead to both facts and assumptions. It was chosen to indicate these differences by means of different coloured markers, red for assumptions and black for facts. The coloured sticky notes could then be used to indicate the differences between the different types of knowledge: pink for use situation aspects, yellow for use issues and orange for categories of use situation aspects. Blue sticky notes were used to indicate issues

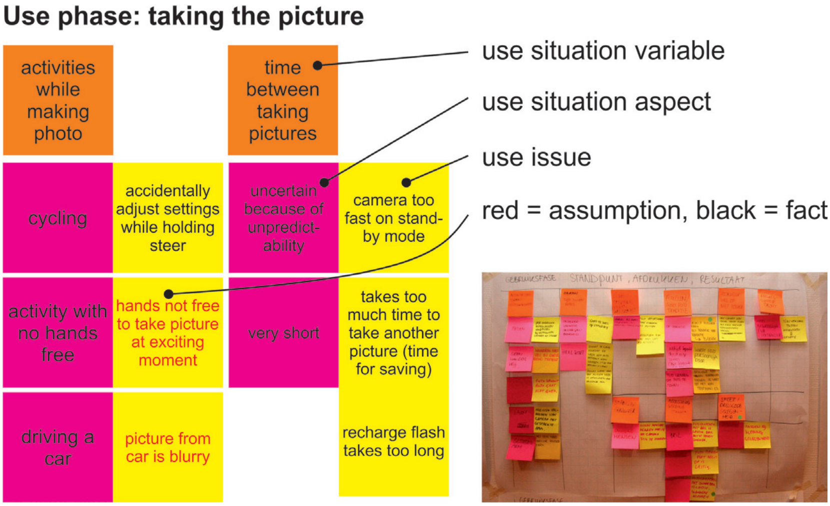


Figure 5.13: a part of the matrix of product use of workshop 3 with a new orientation without the 'solution/ product part axis'. Use issues can be placed next to related use situation aspects. Multiple issues can be connected to one use situation aspect by making a column of connected issues.

related to a specific developed solutions and green notes were used to formulate questions.

Independent issues

In each workshop, issues were mentioned that seemed not to relate to a specific use situation aspect. For example, the issue 'the on/ off button of the microphone is too small to control' could happen to any user in any use context. Those use issues are defined as 'independent use issues'. In the different matrices the independent issues were placed in a separate category, for example, in workshop 3 they were placed in a separate column. When a less strict organisation was adopted (see next paragraph), the issues could be placed without a corresponding use situation note to a category that was found relevant by the participants. For example, the aforementioned issue of a too small button could be added to the category 'controlling device' or 'battery', depending on the chosen categories.

From matrix to mind map

The categorisations of use situation aspects in workshop 2 and 3 were indicated as being complicated by the participants in those workshops. Abandoning the axis with product characteristics did not lead to the expected simplification. Participants managed to connect use issues to use situation aspects, but the translation in variables seemed difficult and was heavily supported by the facilitator. In the group interview participants expressed their doubts with regard to the necessity of this structure and asked if it could not be made simpler. Therefore a balance was needed between providing structure and giving the freedom to associate and evoke experiences. The idea that an explicit categorisation would lead to more associations to instances within the category was overruled by the complexity of this structure, which hampered the thinking process of associating to other stories and scenarios. Therefore it was chosen to abandon the definition of use situation variables in the fourth

Figure 5.14: a part of the product use mind map and the created categories of the participants of workshop 4 at design studio A.

workshop. Instead a 'structuring' step was added to the workshop, in which participants would go through all the gathered information, and define categories which they would find appropriate themselves (see figure 5.14). They were also allowed to let go of the categorisation in use phases. Each category was given a name by means of an orange note. This categorisation was needed for reasons of overview, so participants could more easily retrace information they had placed in the frame of reference. For that reason, it was not necessary to link the category to a specific information category. For example, categories defined included 'moving' and 'noise' (use situation), 'preparation' (use situation/ use phase), and 'feedback problems' (use issue). Since the thus created clusters were not mapped to a predefined matrix, the name of the frame of reference was changed to **'product use mind map'**: it is a format which maps knowledge of product use in the minds of participants. The structuring process was done together (figure 5.15) and did not lead to any problems. The advantage of going through the whole mind map was that it kept the associating process going and participants would keep on adding information.

Figure 5.15: participants of workshop 5 at design studio B structuring together the information in the mind map in clusters.

5.4 The Envisioning Use technique

Table 5.2: general set-up Envisioning Use workshop

Based on the development of the workshop in the five iterations described in the previous section, the workshop is given a general set-up which is summarised in table 5.2. Since the workshop is not just a 'knowledge gathering' technique, but also a technique to decide on which use situations and issues will be targeted and to generate solutions for future use, the workshop was given the name: 'The Envisioning Use technique'. The Envisioning Use technique is a workshop in which all implicit knowledge of product use and otherwise explicitly available knowledge of product use is brought together in an explicit frame of reference, the product use mind map. This is achieved by means of combining techniques aimed at remembering, imagining, experiencing and envisioning product use and structuring, targeting and questioning the thus created frame of reference (figure 5.16). A complete manual of the workshop can be found in (Van der Bijl - Brouwer, Boess et al. 2012). This manual was created after the evaluation of the workshop described in chapter 8. Small adjustments were made to the workshop format based on these evaluations. Those adjustments will be explained in the corresponding chapter.

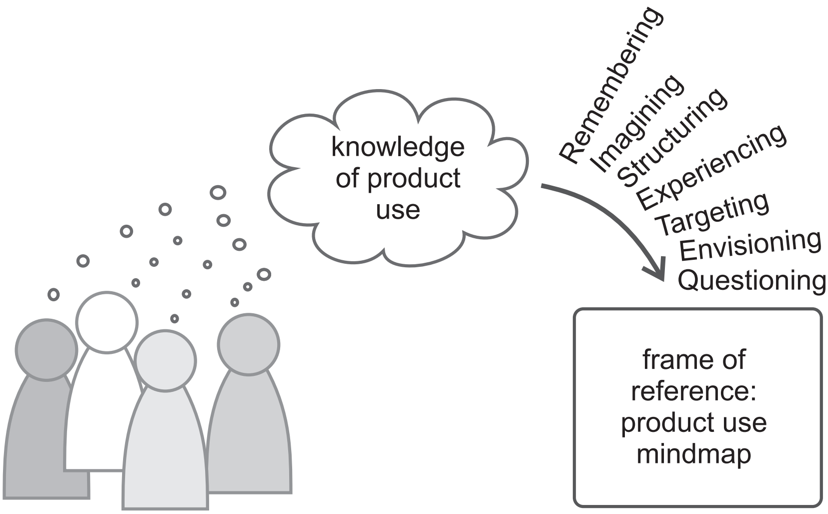


Figure 5.16: the Envisioning Use technique brings knowledge about product use together in a product use mind map by means of combining techniques.

5.5 Results of the workshop evaluation

The previous sections described the development of the Envisioning Use workshop. This section will now answer the research questions formulated in the first section, based on the results of the workshop evaluations with the participants.

5.5.1 General usability of the workshop

The first question considered the general usability of the workshop. Overall the workshops went well. Participants generally understood what they were asked and only in some cases they got stuck in their thinking process. In the course of the workshop development, the facilitating

Step	Explanation
Preparing	The team discusses which use phases and user roles will be discussed in this workshop. The use phases and roles are divided over four or five flip charts
Remembering	Participants are asked to tell personal stories about product use they have experienced themselves or seen happening to other people, for example in usability evaluations of precedent or competitor products. The issues surrounding that story are written on a yellow sticky note. If it is related to a specific use situation aspect, this aspect is written on a pink sticky note. Both notes are placed next to each other on the flip chart of the corresponding use phase.
Imagining	Participants are asked to imagine situations in which the product could possibly be used and what this means for use issues. As inspiration, random associative materials (images of users and contexts) can be provided. Assumptions about use should be distinguishable from actual knowledge and therefore be written with red marker.
Structuring	Participants are now asked to organise the information on the flip charts and form categories. The categories should be given names (on orange notes). There is no prescription of what the categories should consider. They can relate to a group of use situation aspects (e.g. weather conditions), use issues (e.g. related to efficiency) or product parts (e.g. the cover). After clustering it is possible to go back to remembering and imagining and further fill the clusters.
Experiencing	Participants can now choose a use situation that they would like to role-play. This can be based on the information on the flip charts or a new use situation they want to know more about. It should be clear what user and environment characteristics are. They are written on a pink 'use-situation-card'. The role-play can be executed with a simple mock-up of the product or a competing product. The use situation environment should be simply simulated. The team chooses one or more actors. The other members observe what is happening. The actors should try to empathise with actual end-users. During the role-play observers write issues on yellow notes. Actors can add more notes after the role-play. All notes are placed on the flip charts in the same way as in 'remembering'.
Targeting	Participants now choose which issues and situations they want to target in the design process. This can be done by placing stickers on relevant use situations and issues. The situations define test conditions for later (user)tests. The issues are input to the solution generation.
Envisioning	A short design assignment in which designers quickly generate solutions to the chosen target. Design proposals can be represented in sketches or by creating quick models by means of tinkering materials. Positive and negative issues of the designs are written on blue notes and added to the frame of reference. It is not always necessary to execute the envisioning phase. This depends on the status of the project and the goal of the team.
Questioning	In this step participants reflect on all the knowledge that is gathered in the frame of reference. With green notes they indicate on the flip chart which knowledge lacks. This can be related to use situation aspects, use issues or technical possibilities and includes the identification of assumed issues which need verification. After this exercise the green notes can be removed and ordered with regard to priority. The workshop is concluded with making a plan for further steps to answer the questions.
Wrap up	All results of the workshop should be translated in a form that can be taken into the design process. If it is not possible to keep the flip charts on the wall it might be a good idea to make pictures and digitise the frame of reference (see chapter 6).

researchers became more experienced in stimulating participants in solving those types of 'mental blocks' by either introducing more examples or proceeding to a next workshop step. However, several difficulties occurred with regard to the required use situation- use issue thinking.

In the shown iterations of the workshop it became already clear that the proposed structure of organising the information was found difficult by participants and hampered the thinking process to such an extent that it was chosen to abandon this strict categorisation. The only structure that remained was the division in use situation aspects and use issues. However, in the first workshop we did without the strict structure – at design studio A – participants still indicated they had difficulties with this division in use issues and use situations. They did manage to work with it, but they did not understand *why* they had to do this. The goal of this 'thinking in use situations' should therefore be explained more clearly in the introduction of each workshop. This added value of the division in use situations and issues is explained in section 5.5.4. In the final workshop in studio B, at which the reason for the division was explained more elaborately, participants did not indicate this problem. This suggests that the extended introduction had the desired effect.

5.5.2 Application domain of the workshop

All participants were asked about what they thought would be an appropriate design phase to apply the workshop and which type of products could be considered in the workshop. All participants indicated that it would be useful to do the workshop in an early design phase to set the non-technical requirements or to define the 'desired experience' of a product. At design studio A, participants indicated that it could also be useful to conduct the workshop at later design stages:

> *Participant (design studio A): "I would say it would be perfect to use, not only at an early stage, but every time that you start, that you have something. Now, this is our starting point,[...] let's do the full cycle again. With this early version of our design."*

Participants at both design studios indicated they would like to do the workshop with the client, because firstly clients usually have a lot of knowledge about product use and secondly because now sometimes they fail in creating a shared vision on product use with the client. The workshop could then be used to set the design brief with regard to product use. Participants of design studio B indicated that it would not be suitable for every type of client. He or she should at least have considerable knowledge of product development. Participants of design studio A indicated that clients do not always have the most realistic information about end-user experience. So development teams should consider thoughtfully if involving the client could lead to added value in the workshop.

Types of products

Participants discussed different types of products that could benefit from the insights gathered in the workshop. Participants at design studio B indicated that the workshop is particularly valuable for a new type of design project and that it would be less suitable for products that have been developed for quite a while and the use scenarios are already known to the developers.

On the contrary, a participant in workshop 2 indicated that since you work with actual memories and with existing products in the role-play, the workshop is very suitable for design projects in which a next version of an existing design will be developed. However, it is then very important that you can make the step from the existing situation to a completely new situation to prevent fixation to an existing solution. Participants of workshop 5 did not perceive this as a problem. They indicated that although the workshop often starts from detailed problems, it actually challenges them to come up with completely new solutions instead of incremental changes.

At workshops 2 and 4, participants questioned if the workshop would be applicable to products that designers are not familiar with. They suggested to provide participants with experiencing the product, either before or during the workshop.

It can be concluded that there is disagreement between participants with regard to the suitability of the Envisioning Use workshop for different types of products. Participants do agree that the workshop is particularly valuable in an early design phase, before or soon after the definition of the brief. Together these phases concern the phases which are defined in the Delft Innovation Model (Buijs and Valkenburg 2005) as the 'design brief formulation' and analysis and synthesis of 'strict development'. The latter stages are aimed at further refining the design brief, formulating requirements and developing concepts. They thus correspond to the phase which the participant of design studio A indicated as 'a new starting point for a new version of the design'.

5.5.3 Gathering knowledge of product use

The second question was if the different steps led to an increase of the completeness of explicit knowledge of product use. According to participants in all workshops, the workshop provides an efficient means to get insight into the broadness of use situations and use issues that play a role in the design of a certain product, as illustrated by the following quotes:

> *Participant (workshop 3): "The workshop is useful because it gives you an overview of multiple aspects, which aspects play a role […] and that more things play a role than you would initially think of with a product like this."*

Participant (design studio A): "Just within an hour, you get an amazing amount of output, which is really helpful."

It was particularly the combination of techniques and doing the workshop together which led to a broad collection of (imagined) experiences on product use in a short time:

Participant (workshop 2): "I would never have thought of doing this reasoning from memories, imagining and role-playing by myself, but you get a lot more information than just trying to create a list of requirements. To look at it from different perspectives together works really well."

Participant (design studio B): "The steps are quite complementing. Even the role-play led to a lot of new things, even though we had captured quite a lot in the preceding steps."

The role-play in the experiencing step was considered an important part of the workshop, but was particularly valuable because of its combination with the preceding remembering and imagining step. Participants of design studio B indicated that doing the steps before the role-play and doing the role-play on the spot makes participants more focused on use issues during the observation.

Holistic approach

One interesting recommendation was put forward by participants of both design studios. At studio A one participant indicated that for the 'imagining step' more specified, complete use situations might be described that are dedicated to the specific case, instead of giving random divided user and context cards. A similar suggestion was done by a participant of studio B who mentioned that apart from a bottom-up approach of reasoning to use scenarios, you could also follow a top-down approach to see if you get to other issues. This holistic approach to working with more focused scenarios in imagining, turned out to be valuable in the imagining step of the first workshop evaluation in a real case, which will be described in chapter 8.

Content of the product use mind map

Another unexpected effect with relation to knowledge gathering was the content of this knowledge. Although the aim of this research is to support development teams in designing products with a higher level of usability in intended use situations, the issues found in the workshop did not only relate to usability. They considered different kinds of product-user relations and included performance, usability and user experience. Examples are:

User experience issues:

- I do not like the idea that the microphone might be stained by the sweat/bodily fluids of other people

- I feel stupid when the microphone is not working without me knowing it

Usability issues:

- The headset is stuck in my hair
- I cannot find the mute button quickly in a dark presentation environment

Performance issues:

- The battery capacity is too low for a complete lecture
- The microphone causes crackling

User experiences are ‘a person’s perceptions and responses that result from the use or anticipated use of a product, system or service’ (Law, Roto et al. 2009). This is closely related to the term ‘satisfaction’ in the usability definition. Like usability, user experiences are strongly dependent on the use situation. Performance issues can also be related to a use situation, such as that the battery capacity of a microphone should be sufficient for a complete lecture. Therefore, an exploration of use situations such as proposed in the Envisioning Use workshop, could support the elicitation and definition of a target for performance issues and user experience issues.

Since the workshop proved suitable for exploring the three different kinds of product-user relations, it will not be presented as a pure ‘usability’ technique, but one that provides exploration of all mentioned user-product relations. Although the development of the guidelines (chapter 6,7 and 9) to design for DDUS was focused on usability, the term **use issue** will be used in the remainder of this thesis to refer to either performance, usability or user experience.

Although not explicitly asked, all gathered issues were initially issues that either concerned or would evoke negative emotions. Consequently envisioning new user experiences would probably be aimed at removing those negative emotions instead of searching for product-user relations that would evoke positive emotions. Therefore in later workshops, participants were explicitly asked to also consider those positive experiences.

Concluding, the combination of steps and doing the workshop together leads to a broad insight in use situations and issues, in other words an increase of the completeness of the frame of reference. These use issues are related to usability, as well as to user experience and performance. An additional recommendation is to apply a holistic scenario approach to gather more issues in imagining.

5.5.4 Organisation of the mind map

The third evaluation question was: what is the usability and success of the proposed format of the created frame of reference? As mentioned earlier, the organisation of the product use mind map gave some usability problems with regard to the time that was needed to learn the structure and the extent by which it limited the thinking process. The final organisation is based on a division in use issues and use situations. An initial organisation in use phases is employed to guide the first steps, but can later be abandoned by participants if they want to in the structuring step.

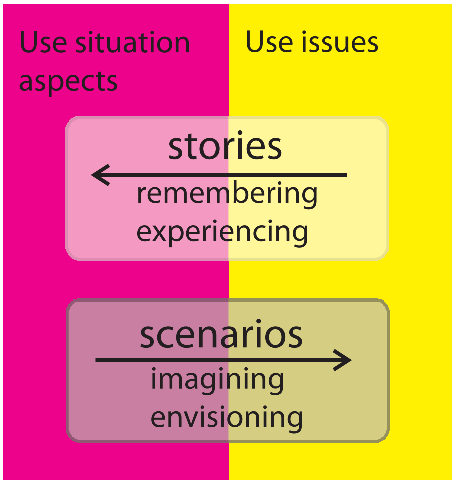


Figure 5.17: going back and forth between use situation aspects and use issues supports revealing use issues and use situation aspects.

Although the goal of the division in use situations and use issues was not clear to all participants, going back and forth between use situation aspects and use issues worked remarkably well. These relations between use issues and situation aspects and the different steps are shown in figure 5.17. In the remembering phase the stories of the participants usually start with a certain experience, a certain issue of use. From these use issues they reason back to the use situation aspects that played a role in this experience. Subsequently in the imagining phase, both the assembled use situation aspects and the inspiration cards support participants in associating to scenario's (possible use situations) that would result in corresponding use issues. Likewise, the experiencing step results in stories that lead to use situation aspects, and the envisioning step is based on use situation aspects (combined in scenario's) that lead to use issues. In this way associating between the different sources stimulates revealing knowledge of product use.

5.5.5 Using the frame of reference in the design process

Participants of the workshops were finally asked how they thought they could use the information that was gathered in the workshop in their actual design process. They mentioned that they expected an added value of the product use mind map for solution generation and evaluation purposes. For solution generation participants indicated that they would take the most important issues as input:

> *Participant (studio B): "I feel strongly inclined to just take the five to seven most important issues and start designing with that."*

> *Participant (workshop 3): "For use in design, aspects need to be prioritised, like we did now with the green dots."*

Participants of both design studios indicated that they would like to visualise those most important issues, for example by means of a sketch (participant studio B) or pictures of the role-play with quotes (studio A).

Participants furthermore indicated that the complete created frame of reference can be used for evaluation purposes:

> *Participant (studio B): "It offers a good reflection. When you have created a design you can compare it to the created frame of reference to look at what your design does to those users."*
>
> *Participant (studio A):"I can imagine that when you're further developing the design that you test it, or maybe even test three, most of the time we have several options and that with this kind of feedback and going back and looking at it in a different way you can improve it."*
>
> *Participant (workshop 3): "Trade-offs need often to be made in design. Therefore you need to prioritise. You create a design based on these priorities and in important meetings or mile-stones you come together and examine the original data to see if essential things are missing."*

Concluding, a translation of the product use mind map into a simple representation of priorities is expected to be useful input for creating solutions, for example in the form of requirements or visualisations. The last mentioned quote furthermore suggests that a more elaborate or complete representation is needed in evaluation and decision making. The application of the product use mind map in the following parts of the design process was included in the initial guidelines to design for DDUS, and further explored in the application of both the guidelines and the workshop to a complete design project. The guidelines and the concerning exploration are described in chapter 6.

5.6 Conclusions development of the Envisioning Use technique

This chapter showed the iterative development of the Envisioning Use workshop technique. The technique is aimed at increasing the completeness of an explicit frame of reference of product use by gathering experienced and imagined knowledge about product use. This knowledge should be recorded in an explicit frame of reference which is usable within the workshop as well as in the design process.

A technique was developed which combined story-telling and scenario techniques. The combination of techniques executed in a group proved an efficient way to gather a broad collection of relevant use situation aspects and issues. The use issues did not only concern usability, but performance and user experience as well. To optimise the usability of the thus created 'product use mind map' a simple frame organisation was proposed which allows going back and forth between use situations and issues, without imposing a strict structure that could hamper the thinking process. The added value of the division in use situations and issues should be made clear at the start of the workshop. The usability of the frame of reference was further improved by adding a structuring step to the workshop which provides overview to retrace use situations and issues.

To be able to connect the workshop to the rest of the design process firstly a ‘targeting’ step was added, aimed at prioritising the most important use situation aspects and issues to take into account in solution generation. Secondly, a ‘questioning’ step was added to indicate gaps in the knowledge and formulate steps to get the questions answered and fill the gaps. Participants proposed to create a simplified, visual representation of the frame of reference with the most important issues as input for solution generation and communication.

Participants expect the workshop to be of most value in early design phases before the definition of the design brief, but possibly also in later analysis and synthesis stages of strict development. Involving the client could assumingly increase the amount of knowledge of product use and could possibly support creating a shared vision on product use with the client. Since the workshops were executed with fictive cases and participants showed contradicting opinions with regard to the type of products the workshop would be applicable to, this issue was further explored in the application of the workshop to real design cases (chapter 8) and its application in the student projects (chapter 6, 7 and 9).

The expected link in the impact model in figure 5.1 which represents the influence of the Envisioning Use technique on an increase of the completeness of the explicit frame of reference can be confirmed based on the results of the study described in this chapter. The addition of the ‘questioning’ step to the workshop provides for a means to steer follow-up activities with regard to getting insight in possible use situations and relevant issues. Therefore another link can be added to the impact model, which shows the influence of the Envisioning Use technique on the quality of use situation analysis. It is expected that the Envisioning Use technique will improve this activity by supporting the definition of relevant questions. The addition of this link is shown in the impact model in figure 6.1.

The next chapter shows the development of the additional support to design for DDUS in the guidelines. Furthermore it shows the application of the Envisioning Use technique to a complete design project. In this study it became clear that the technique was not only useful to gather knowledge in an explicit frame of reference. It also had an unexpectedly large added value for the direct creation of a shared mindset of product use. Both influences of the technique were then evaluated in real design projects. These evaluations are described in chapter 8.

6

Development Of The Guidelines

6 Development of the guidelines

Chapter 4 described the problem that needs to be solved by means of the to be developed support. The decision was made to create two types of support, the workshop technique as described in chapter 5 and a workbook that contains guidelines to create and apply a frame of reference of use situations. Chapter 5 described the development of a format of the 'product use mind map', which can be used as a first version of the frame of reference. The guidelines support a further completion of the frame of reference by explaining how different existing design techniques can be used to update the frame of reference. The final goal of the guidelines is to support the application of the frame of reference to improve the external validity of usability evaluations and the quality of decision making with regard to choosing solutions and intended use situations.

This chapter firstly describes the development of the workbook. Like the development of the Envisioning Use technique, this part of the research has a prescriptive character. The workbook is realised to such an extent that its application can be explored and evaluated in a design project. In the Design Research Methodology of Blessing and Chakrabarti this concerns the realisation step of a 'comprehensive prescriptive study' (Blessing and Chakrabarti 2009, page 144). The realisation step includes identification of the core functionalities of the support and the development of the support to such an extent that the core functionalities can be evaluated.

The second part of the chapter describes the application of the workbook to a design project by students, to evaluate the initial workbook. This is an explorative evaluation, aimed at formulating recommendations for an improved workbook. It therefore concerns a formative evaluation (see for example Nielsen 1993; Hartson, Andre et al. 2001). In Blessing and Chakrabarti's design research methodology this type of evaluation is called an 'application evaluation' (Blessing and Chakrabarti 2009, page 184). The conclusions of this evaluation gave input to the development of a revised workbook which will be described in chapter 7.

6.1 Development of the initial guidelines

This section describes the argumentation and method for developing the initial workbook with guidelines. Firstly, the goals and core functionality of the support are described. Next, the choice is motivated with regard to which parts of the intended support were integrated in the actual support. Finally the method for further development is introduced.

6.1.1 Goal and core functionality of the support

Figure 6.1 shows the actual impact model that is based on the intended impact model as introduced in chapter 4 and the adjustments based on the conclusions of the development of the Envisioning Use technique in chapter 5. The goal of the support is to improve the external validity and focus of evaluations, thereby improving the quality of usability evaluations, which in turn will result in better quality of recommendations which ultimately will result in a better usability of the final product, on the precondition that other context factors are kept constant. The assumed way to improve the external validity and focus of evaluations is by creating an explicit frame of reference of product use that contains the relevant anticipated use situations and related issues, such as described in the preceding chapter. The frame of reference can be built or updated by on the one hand analysing use situations and on the other hand by anticipating use issues in use evaluations. Therefore the frame of reference should have an evolving character (see section 4.3.2). The guidelines should stimulate designers to make the frame of reference explicit (link number 1), to apply the frame of reference in evaluations (link number 2,3,4 and 5) and to let the frame of reference evolve by updating it in use situation analyses and use evaluations (link number 6 and 7).

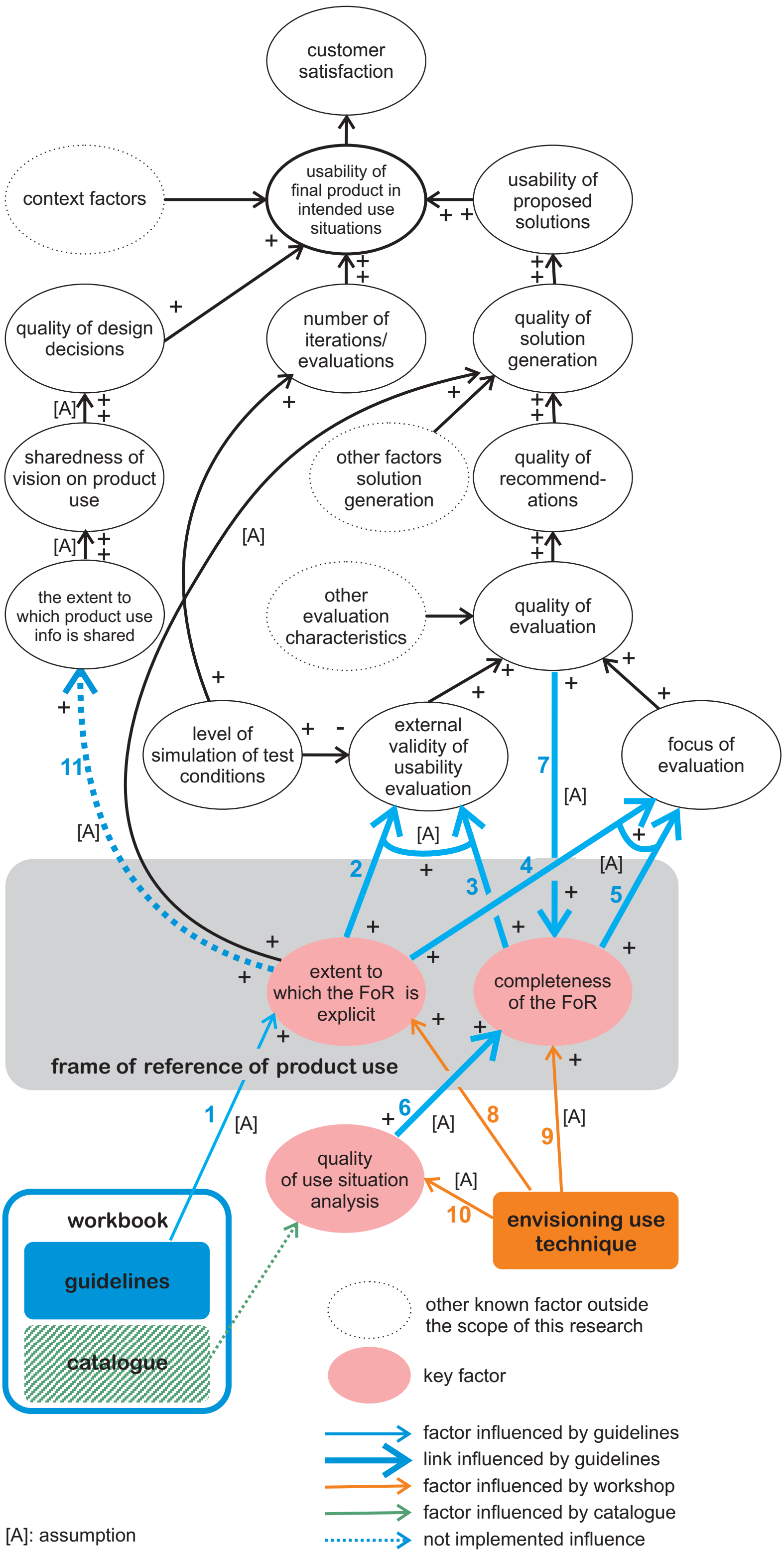
Chapter 5 already described the goal of the Envisioning Use technique. In this chapter the application of this technique will be evaluated in a complete design process. In the technique, an explicit frame of reference is created (the product use mind map) which is represented by link 8. The technique assumingly influences the completeness of the frame of reference positively by providing a means to create a first frame of reference (link 9). Secondly, the technique assumingly influences the quality of use situation analyses by providing a means to set questions for these analyses (link 10).

6.1.2 Differences between the intended and actual support and impact model

In the intended impact model (see chapter 4, figure 4.7) the idea was to create a workbook with guidelines to create and apply a frame of reference of DDUS and a catalogue of techniques to update the frame of reference. It was already motivated in chapter 4 that the catalogue was not developed in this stage of the design process. Therefore the catalogue and related link are indicated in the impact model in dotted lines.

As stated above the guidelines were focused on improving the external validity and focus of evaluations, thereby improving the quality of evaluations. Apart from improving the quality of use evaluations, the usability of final products can also be improved by a better quality of design decisions on the target use situations and choice of solutions (see chapter 4, section 4.1.3). The frame of reference can assumingly contribute to this factor by supporting the creation of a shared vision on product use through sharing the explicit frame of reference. Although

Figure 6.1: actual impact model with additional link between envisioning use technique and quality of use situation analysis (link 10)



the importance of this factor is acknowledged, this research focussed on the influence on usability in intended use situations through better quality evaluations. This influence is considered the core contribution of the support. It is assumingly larger than the influence of the quality of design decisions, since even perfect decisions on choosing the best solutions and target use situations cannot compensate for low usability of the solution proposals. In other words: when there is nothing good to choose from, a decision making process can never lead to a good result. Therefore the choice was made to focus on the application of the frame of reference in use evaluations. The initial workbook did therefore not support *how* the frame of reference could be employed to improve decision making. This link (11) is indicated in the impact model in dotted lines (figure 6.1).

6.1.3 Research questions for guideline development

The first question when developing a support tool for improving the integration of knowledge of DDUS in design is what the content and organisation of this knowledge should be. This question was answered in the preceding chapter by developing an organisation structure for the 'product use mind map' in the Envisioning Use workshop. With regard to the development of the guidelines the following questions need to be answered:

1. what is the best means of representation for the frame of reference for use in a complete design process?
2. which techniques can be used to update the frame of reference?
3. how can the frame of reference be applied in usability evaluations?
4. how can designers be stimulated to create, update and apply the frame of reference in above mentioned ways?

6.1.4 Method for developing the initial workbook

Since no guidance was found for a way to build and apply a flexible frame of reference of use situations for unfamiliar target use situations (see chapter 2), it was chosen to approach the generation of the support in an explorative and iterative way. This means that a rough 'prototype' of the workbook was developed and a formative evaluation was conducted by having students apply the workbook to a complete design project. The work of the students was used to develop a revised version of the workbook which will be described in chapter 7.

The initial workbook gives guidance on possible ways to answer research question 3. It was chosen not to develop a complete catalogue that gives answer to research question 2. Instead, the workbook contains some suggestions on techniques that can be used to update the frame of reference. A manual of the Envisioning Use technique was included to give guidance on the creation of a first frame of reference. To give answer to research question 1, students were asked to explore different kinds of representations for the frame of reference.

The answer to research question 4 describes the format and introduction of the support tool. As motivated in chapter 4, the choice was made to develop a workbook because this format allows for both a definition of the guidelines as well as an explanation of their application. However, the flexible character of the workbook makes it difficult to ensure that it will be effective and efficient. Therefore the added value of an additional introduction to the guidelines was explored in the evaluation of the support.

The consequences of this limitedly detailed workbook are that the workbook's usability might not be optimal and the incompleteness with regard to techniques for updating the frame of reference might not lead to the optimal completeness of the frame of reference. However, these aspects are at this stage of the support development less relevant than the exploration of the application of the frame of reference in use evaluations.

6.2 The initial workbook

The initial workbook is a ten page document which describes the general principles of the frame of reference, the content and organisation of the frame of reference, suggestions on different representations of the frame of reference, suggestions on use situation analysis techniques, instructions on the application of the frame of reference in use evaluations and a manual of the Envisioning Use technique. As motivated in section 6.1.2, the initial workbook does not include guidance on how to apply the frame of reference in sharing information on product use to support the decision making on a target use situation domain or choice for an appropriate solution (decision making). The following pages describe the content of the initial workbook. The full text from the workbook is shown in framed text boxes, while the motivation for relevant sections is written in between. The initial workbook starts with an explanation of the general principles of the workbook.

General principles initial workbook

Designing for dynamics and diversity in use situations requires the following design activities:

1. Use situation analysis: predicting which users and contexts the product will encounter and what different situations require from the product
2. Use evaluation: anticipating what will happen when a designed product will encounter those situations

1. Solution generation: creating solutions to fit the different use situations
2. Decision making: deciding which use situations will be targeted and which issues within these use situations will be addressed. Deciding which solutions to choose and which steps to take.

The next section describes how a frame of reference can be used to support those activities. Based on the insights gathered in the Envisioning Use technique, it was decided to advise to use different representations of the frame of reference as input to use evaluations and to solution generation. For solution generation a simplified representation might be more inspirational than a complete frame of reference such as the product use mind map created in the Envisioning Use workshop. The section furthermore describes how to categorise and link the information within the frame of reference, such as described in the iterations of the Envisioning Use workshop presented in chapter 5.

To be able to accommodate solutions to dynamic and diverse situations, a frame of reference is needed that captures knowledge about these use situations. Generated solutions can then be compared to this frame of reference in evaluations to be able to make decisions about those solutions. A simplified version of the frame of reference can serve as input to the solution generation process. The design materials in designing for DDUS therefore include this frame of reference of product use and the generated solutions.

The frame of reference contains an overview of possible users and contexts (use situations) that a product can encounter. Moreover it contains use issues surrounding those situations that describe what can, should or should not happen when a product encounters those situations. Finally it contains a target which defines which use situations and issues will be taken into account in this design process. The organisation of the frame of reference will be explained in more detail in the next section

The following section describes the different design activities and how they relate to the frame of reference. These design activities are based on the factors in the impact model. The evolving character of the frame of reference is based on the insights in the retrospective study described in chapter 3. Furthermore it describes how the frame of reference can be integrated in current design approaches, which was an important requirement for the support (see section 4.2.1).

The design activities and design materials are shown in figure 6.2. The first two activities are data analysis activities and are therefore placed next to each other because they often take place at the same time. The third activity is a creative step. The fourth activity is a decision making step which requires group meetings with stake-holders.

Because it is impossible to predict in advance which situations a product will encounter and which issues will arise during this encounter, the process of design for DDUS has a strong iterative character. Anticipating use situations and related issues will be achieved by gathering 'stories' of use of comparable products and by confronting early solutions with use situations in use evaluations. In those confrontations it will become more clear what important issues and use situations are. This will give new input to targeting and solution generation which in turn will give new solutions to confront with the frame of reference. The frame of reference itself therefore has a dynamic character: it evolves during the design process. The more iterations are executed, the more complete and reliable the frame of reference will be. Likewise, when comparable or preceding products are available, less iterations will be necessary because a lot of stories about those products will be available to construct a frame of reference, while many iterations will be necessary when a product is completely new to the market.

This approach is not meant to substitute existing design methods. Analysis, solution creation and decision making activities are already part of design processes. The guidelines mentioned in this workbook are meant to complement this existing design process. The frame of reference of product use can exist next to other tools that are used as a frame of reference such as (technical) requirements, function descriptions, collages etc.

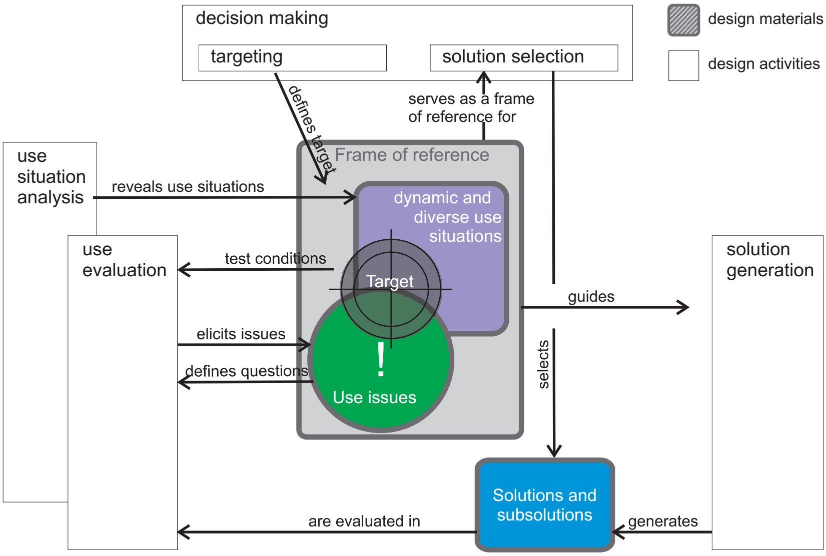


Figure 6. 2: activities in the design process and how they relate to the frame of reference of product use.

This workbook then describes the organisation and representation means of the frame of reference and different means to execute the different design activities. Finally a short manual is given for the Envisioning Use workshop which is recommended to be used to build a first frame of reference. The organisation of the frame of reference was explored in chapter 5. The categorisation of use situation aspects is taken from the literature review in chapter 2 and the retrospective studies of the design projects in chapter 3.

The frame of reference

In the frame of reference we basically distinguish two types of knowledge. Knowledge about the situations in which products are used and knowledge about the interactions between products and these use situations (see figure 6.3). The latter contains descriptions of the interaction itself and statements about the quality of the interaction. Besides these types of 'use knowledge' it contains a target which defines which use situations and issues will be taken into account in the design process.

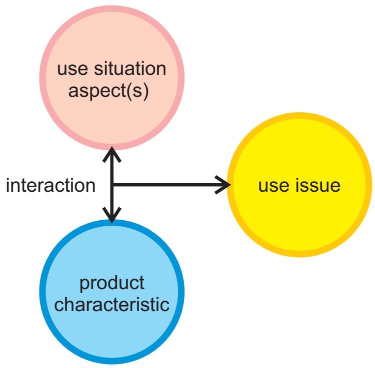


Figure 6.3: the different types of knowledge in the frame of reference

Use situation aspects

With a use situation we mean a certain user with a certain goal in a certain context. Several aspects of this use situation will have influence on the use of the product. Figure 3.5 shows different aspects of those three situation elements that were found in the design projects as described in (van der Bijl - Brouwer and van der Voort 2009).

Characteristics of the user can relate to mental characteristics such as knowledge, experience and cognitive characteristics. Furthermore they can relate to emotional characteristics or physical characteristics (dimensions, sensory aspects). All aspects can have a temporal (moods, fatigue) or a more firm character.

The goals of the user can be divided in motivations (why someone uses/ buys a product), practical goals (for which purpose the product is used) and preferences of use (how someone wants to use the product).

Aspects that concern the context include environmental characteristics (weather, busyness, lightness, and loudness), objects in the environment or tools that are part of the interaction and events that can occur during the interaction.

Target

The frame of reference can give a very broad view on use situations and issues related to current products and prototypes. However, it is often not desirable to develop a product that fits all use situations and issues. Therefore the use situations and use issues that should be taken into account should be clearly targeted. The target is divided in two types:

1. The use situations that the product is aimed at. These use situations will serve as test conditions in use evaluations (see section 'anticipating use').
2. The desired use issues such as the desired level of performance or the desired user experience.

Targeting is a decision making activity and should therefore be done in consultation with team members and the client. Motivations for a certain target can be market potential (no competitor product aimed at a certain domain of use situations), technical opportunities or other commercial or ideological goals.

The target can also include other (non use-related) requirements such as technical, legal, aesthetic or commercial requirements.

Organisation

To organise the frame of reference use issues should be somehow connected to the use situations or situation aspects that they relate to. Furthermore it can be useful to divide situation aspects over use phases such as described in the Envisioning Use workshop.

Clusters of use situation aspects can be created to further organise the frame of reference. They can relate to types of use situations, types of issues, or certain product parts.

At this stage in the development process of the guidelines, there is no insight in what an appropriate representation for the frame of reference is. Different means of representation are proposed to explore, based on literature and the insights gathered in the iterations of the development of the Envisioning Use technique in chapter 5.

Representations

Use situation aspects can be represented in text and/ or pictures depending on the aspect.

A specific way to represent user goals is by means of personas. Personas are hypothetical descriptions of a user that represents a certain part of the target group with a common goal. More information about creating personas can be found in (Pruitt and Grudin 2003).

The interaction between use situations and a product or prototype can be represented in a task analysis or current or desired scenario. Scenarios can be represented by different means of representation such as narratives, storyboards, video, animations, virtual reality and role-play.

The relations within the frame of reference can be represented on a flip-chart with sticky notes such as described under 'envisioning use technique'. However, these flip-charts are not very portable. Therefore the complete representation can be captured in photos or digitalised with mind mapping, spread sheet or database software.

Next to the complete frame of reference derivative representations can be created: a simplified representation of the frame of reference that can be used during solution generation or decision making. This can be done by creating a prioritised requirement list, scenarios, personas, collages etc.

Although it was decided not to develop a catalogue of techniques to analyse use situations, the literature analysis of chapter 2 and the analysis of techniques found in the retrospective analysis (chapter 3) was used to give advise on different techniques to gather insight in use situations. The following section explains these techniques and the importance of investigating the relevant or 'discriminating' use situation aspects.

Analysing use situations

In analysing use situations one tries to get insight in the types of users, goals and contexts that a product will encounter. It is important to make these situations explicit, because they will be used as a frame of reference in use evaluations. In the previous paragraph, different types of use situation aspects were described. It is possible to analyse individual use situation aspects separately. For example for a bicycle carrier it is interesting to analyse the dimensions of existing bicycles. However, often it is not clear which use situation aspects are discriminating: what are the aspects that influence the use of the product? For example, in the case of the bicycle carrier the colour of the bicycles is not such a relevant use situation aspect. Therefore it is also important to analyse use situations in their entirety. In these types of analyses stories of product use are gathered. Important use issues are then deduced from these stories. Therefore use situation analysis is often combined with analysing use issues.

Example: a story of a user revealed that the user had problems (use issues) controlling a photo camera during a skiing holiday while making pictures on the slope. The problems were due to the fact that the user was wearing gloves. From this story can be concluded that the use situation aspect 'outfit', in this case 'gloves' was important to take into account. More analysis in the type of gloves was therefore executed.

Because in early phases there are no stories available yet about the new product design (because the design does not exist), one can make use of the stories of comparable products like competitor products or previous versions of the product.

A table was included in the initial workbook with examples of techniques to analyse use situations (see appendix 3). The following section describes how the frame of reference can be applied in use evaluations to anticipate use issues. As described in chapter 4, the main idea is that actual dynamics and diversity of use situations are reflected in the test conditions of the evaluations. The previous section described the importance of discovering discriminating use situation aspects which are used to set the test conditions. These can often only be discovered when executing use evaluations. Therefore in early evaluations it will not be clear yet what these discriminating use situation aspects are (see section 4.1.1). Therefore this section of the workbook explains the difference between an explorative evaluation, in which it is not clear yet what discriminating use situation aspects are and more focussed evaluations which can be executed when these insights are available. The guidelines on setting objectives, reliability and simulations are based on literature (for example Rubin 1994). Particular attention is given to the role of informal usability evaluations or discount usability evaluations (for example, Nielsen 1994), such as testing by a designer him- or herself or testing with colleagues. In section 5.1.1 the importance of these kinds of evaluations was motivated.

Anticipating use/ analysing use issues

As mentioned in the previous chapter, 'predictions' about future use can be based on analysing comparable products. This counts for the use situations a product will encounter, but also for use issues that play a role. Use issues are aspects that say something about the interaction of a particular product with certain use situations, as explained in chapter 'frame of reference'. In 'anticipating use' we can therefore distinguish use evaluation of comparable products and use evaluations of design proposals represented by different means such as sketches, mock-ups or prototypes.

Objective and research questions

The objective of the use evaluations should be clearly related to use issues that are part of the frame of reference. However, evaluations can also have an explorative character, when it is not clear yet what important use issues are.

Defining test conditions/ sampling

In designing for DDUS it is important that test conditions in use evaluations represent as much as possible the targeted use situations of the frame of reference. When the frame of reference is rather complete and it is clear which use situation aspects will influence the use issue that will be tested, the selection of participants and other test conditions can be based on these aspects. For a certain aspect, for example body length, users with different lengths can be chosen, for example the extremes and some in between. However, when it is not clear what discriminating use situation aspects are, random test participants and environments should be chosen. During the evaluation it often becomes clear what discriminating situation aspects are and they can be added to the frame of reference for later evaluations. In the early design process use issues (problems) often have an independent character in the sense that they will occur in any use situation. Those issues do not need to be evaluated under specific test conditions. Testing with colleagues or other persons that are not directly part of the design process will often quickly give insight in those issues.

Reliability versus efficiency

Use evaluation can consider both elaborate, formal evaluations such as user testing with multiple end-users and more informal or 'discount' evaluations such as self-testing quick mock-ups or testing with colleagues or family or friends. Formal user tests have the advantage of being more reliable while designers executing informal user tests benefit from being much closer to the evaluation process. The latter type of evaluations can be easier integrated in an iterative design process. More information on executing use evaluations can be found in for example (Nielsen 1993) and (wikipedia 2012b).

Simulations versus actual use situations

The external validity of use evaluations is highest when both the product and the use situations (reflected in the test conditions) are realistic. Therefore the most valid results come from after sales feedback: 'test results' from completed products that are introduced to the market. However, during the design process this type of feedback cannot be generated. The product will be represented by a mock-up or prototype and several elements of the use situation need to be simulated. One needs to make a choice for which elements will be simulated and which will be actual elements. For example actual end-users can participate in an evaluation but a designer or researcher could also choose to 'simulate' the user in a role-play. The (practical) goal of the user is often simulated by giving the participant a task. Personal goals can be actual when actual end-users are selected based on motivation. The environment can be actual in an in-situ evaluation or it can be simulated by means of for example mock-ups, miniature environments, drawings, animations or virtual reality. Complete use situations can also be represented in different types of scenario representations. When it is not clear yet what discriminating use situation elements are (see 'defining test conditions) testing in actual use situations will give more insight in what these elements are.

As explained in the section about organisation of the frame of reference, it is necessary to define a target. The workbook gives a very short advise on how to deal with this targeting:

Targeting/ decision making

Target use situations that will be taken into account. These aspects should be taken into account in design evaluations. Target what should be achieved in those use situations, in other words, what the use issues are that are focus of the design project. For example improving efficiency or giving user an experience that equals or is better than the current experience for a specified range of use situations. What are the desired use issues in specified use situations?

The initial workbook is completed with a short manual of the Envisioning Use technique (see van der Bijl - Brouwer, Boess et al. 2012). A summary of this manual can be found in section 5.4. Readers of the workbook are advised to use the product use mind map created in the workshop as a basis for the frame of reference in the complete design process.

6.3 Set-up evaluation of the initial workbook

The workbook was evaluated in a comprehensive descriptive study II according to the framework of the Design Research Methodology of Blessing and Chakrabarti (2009, page 14). A descriptive study II investigates the impact of the developed support and its ability to realise the desired situation. The first evaluation of the initial workbook is a formative evaluation aimed at providing input for the further development of the workbook. Blessing and Chakrabarti define this as an 'application evaluation' which aims at "assessing the applicability and usability of the support against the desired values of the key factors."(Blessing and Chakrabarti 2009, p184).

6.3.1 Objectives and research questions

The research questions for the formative evaluation are aimed at evaluating if the support addresses the factors and links it is supposed to address (key factors and key links) and if those key factors and links are affected as expected. The key factors and links can be derived from the actual impact model (figure 6.1), and consider:

- The extent by which and how (the means of representation of) the frame of reference is made explicit (factor 'extent to which the FoR is explicit' and link 1)
- The extent by which and how use situation analysis and use evaluations influence the completeness of the frame of reference. (factor 'completeness of the FoR' and link 6 and 7)
- The extent by which and how the frame of reference is used to set up evaluations. (link 2, 3, 4 and 5)

Furthermore the application of the workbook in a complete design project allows for an evaluation of the Envisioning Use technique. The key factor and links considered here are:

- The extent by which and how the Envisioning Use technique influences the completeness of the frame of reference. (link 9)
- How the Envisioning Use technique influences the quality of use situation analysis (link 10)

Based on the above mentioned objectives the following research questions are addressed with regard to the application of the workbook in a complete design project:

1. Are the use situations and issues made explicit and how does the frame of reference evolve?
2. Which means of representation are used for the frame of reference?
3. How is the frame of reference created? What is the added value of use situation analysis and use evaluation with regard to the completeness of the frame of reference?
4. How is the frame of reference applied? What is the added value of the completeness of the frame of reference for setting up test conditions and questions for evaluations?
5. How is the envisioning use workshop applied? Does it influence the completeness of the frame of reference? Does it influence the quality of use situation analysis?
6. What are the benefits and limitations of the different means of representation of the frames of reference?
7. What are unexpected positive and negative side-effects of applying the guidelines?

6.3.2 Method

To evaluate the workbook and Envisioning Use technique, potential users of the support were involved to apply the support to a design case. A qualitative approach was chosen because the focus is not only on whether, but particularly on why and how the support is successful and applicable.

Test conditions

To be able to evaluate the guidelines they should be applied by experienced designers to preferably a real design project. However, 'evaluation in a natural setting involving a real task usually requires the support to be fairly robust and complete' (Blessing and Chakrabarti 2009, p207). Since this study is executed in an explorative stage of the development process, a simulation of the real use situations will also lead to valuable results with regard to the applicability of the support. Therefore the guidelines were applied by senior design students instead of experienced designers. To reflect a real context as much as possible, they were asked to apply the guidelines to a case provided by a real client. The project was executed within a design course. An advantage of working with students in a course is that they can be offered time to actually learn to work with the guidelines and they can be closely observed. A limitation is that firstly they have limited experience in working in design practice and secondly their goal is not only to satisfy the needs of the client, but also to get a good grade for the course. The criteria for a successful project will probably be different for the client than for the course instructor. Therefore the external validity of this evaluation will not be optimal. Since this evaluation is a formative evaluation, aimed at developing the workbook, instead of a summative evaluation, this limitation is accepted in this study.

Data gathering

The results of the design projects executed by the students were used to answer the research questions. The information that was needed to answer question 1 and 2 was insight in the frames of reference that were created during the design process. For this purpose students were asked to give access to all their digitalised design materials in an online file storage provider, such as Dropbox. Furthermore they were explicitly asked to create a 'portfolio' which shows both the evolution of the design solutions as well as of the frame(s) of reference. To answer question 3 on the applicability of the means of representation of the frame of reference, students were interviewed on this subject after the project. For question 4, 5 and 6 insight was needed in the design process itself, particularly how use situation analysis and evaluations were used to update the frame of reference and how the frame of reference was used to set up evaluations. This could partly be derived from studying the *results* of the design process in the portfolio. Furthermore students were asked to keep a log of their design activities, and write brief reports of each use situation analysis or evaluation activity. Finally students were asked to write a short process evaluation after the project in which they reflected on the project and the application of the guidelines. An additional group interview was conducted to confirm and complete the insights from these studies. Thus, multiple sources of evidence were used to answer the research questions related to the design process. This data collection process of 'data triangulation' is recommended for qualitative research by for example Patton (2002) and Yin (2009). Finally, to answer question 7, students were asked in the interview about unexpected positive and negative side-effects.

Criteria for accepting a factor or link as existing and successful

To assess the extent to which certain assumed influences in the impact model exist, it is necessary to give a definition of the terms used for the key factors (Blessing and Chakrabarti 2009, page 202). In this study this concerns the explicitness and completeness of the frame of reference

The explicitness is the extent to which relevant use situations and use issues are recorded in some explicit form (either digital or analogue). An estimation of the extent to which these situations and issues are made explicit will be based on a comparison of the frames of reference to the other gathered documents. As 'frame of reference of product use' are considered all those representations which *connect use situations or use situation aspects to issues*. So, the results of a study that describes emotional and psychological characteristics of different aged children (use situation aspects only) is not considered part of the frame of reference of product use, but the result of a brainstorm in which the results of this study are connected to what this means for the design of a specific product for these children is (see section 6.5.4).

The completeness of the frame of reference is the percentage of real use situation – use issue connections that are covered in the frame of reference. A 100% complete frame of reference contains all use situations that a product will actually encounter and all relevant issues in those situations. Since it is not possible to predict the future, this completeness can only be truly assessed when the product is introduced in the market. What can be measured during the design process is the increase of the completeness of the frame of reference caused by use situation analysis or use evaluations. The completeness of the frame of reference is therefore a relative instead of an absolute attribute.

6.3.3 Set-up of the evaluation

The guidelines were evaluated by students in an elective course 'design for dynamic use' for the master Industrial Design Engineering of the University of Twente. Offering the course as part of an elective program ensured that participating students were motivated to work with the guidelines. Students earned 5 European credit points (EC) when they successfully completed the design project. This means they were supposed to work 140 hours on the course (including instructions). The project itself was executed within a time span of 8 weeks. See appendix 4 for more detailed course information.

To reflect a realistic design context, students worked in teams and a real client was asked to offer a design assignment. The client was asked to brief the students in a short presentation. Furthermore students were asked to present their first design proposals in an intermediate presentation and their final design in a final presentation. The client was available for questions during the complete design project.

Introduction

As mentioned previously, the introduction of the workbook is important to further support the successful application of the guidelines. Instructions on the use of the guidelines were given in a lecture. The workshop was taught in a tutorial in which the students applied the complete workshop, facilitated by the researcher, to the fictive case of the design of a compact camera. Furthermore the students received weekly coaching by the instructors in which they were stimulated to apply the guidelines and also received feedback on their general design process. The instructors for the course were the researcher and a colleague who supervised the general design process.

Case

Four teams of five students participated in the project. The case was offered by the company 'Bongo Innovations BV' and considered the redesign of a carrier bike. This is a bike with a large box at the front which is currently mainly used in the Netherlands by parents to transport their children (see figure 6.4). This case was chosen because its use situations contain many dynamic and diverse aspects such as roads and weather conditions, age and size of children, other luggage to transport, parking space etc. At the time of the project (spring 2011) Bongo was about to introduce their first carrier bike to the market.

Figure 6.4: the carrier bike of Bongo

Set up assignment

The assignment students were given in the project was: analyse the dynamics and diversity of use, users and context of the carrier bike. Based on these analyses design a new version (of a component of) the Bongo carrier bike or an accessory that fits a broad, specified part of the analysed use situations. As described in section 6.4.2 (data gathering), students were asked to keep a log of their design process, write reports of their analysis and evaluation activities, write an evaluation of their process and make a portfolio of their solution development and of the development of the frame of reference of product use.

6.3.4 Data analysis

Data analysis design process

To answer research question 1 and 2 the portfolio gave in most cases sufficient insight in the frames of reference used. The online storage directories were investigated to search for other representations of use situations or situation aspects that might not have ended up in the portfolio itself.

To get insight in the design process (question 4, 5 and 6), insights from the log, portfolio, analysis reports, and written process evaluation were used to generate a summary of the approach of each team. The summary contains a description of each step, the use situations and use issues it concerns and the type of representation that is used for the concerning frame of reference. An example is shown in table 6.1.

Set-up of the interview

Based on the analysis of the design process and frames of reference as described above, an interview was set up to firstly confirm this analysis and where necessary fill in gaps in the information. Secondly the interview was used to discuss the benefits and limitations of the means of representation of the frame of reference (question6) and the unexpected side-effects (question 7). A standardised open ended interview was used to set up the interview, because it ensures that all topics are covered within the limited time of the interview (30 minutes), while still allowing some flexibility to pursue topics that emerge unexpectedly (Blessing and Chakrabarti 2009, page 271). The general set of interview questions was aimed at getting insight in how students perceived the added value of their approach with regard to creating a frame of reference of use situations and applying

Table 6.1: an example of a part of an approach summary of one of the teams

Activity	Use situation target	Use issues	Representation
Analysis of online user feedback	General bike use		Quotes
Workshop 1	General bike use	Space to store, movement when getting off Getting on the bike, steer moves away when taking a bend	Highlights in mindmap 1
Competitor analysis	Based on differences private and business market, choice for business market		Competitor matrix price-transport luggage
Bongo analysis and 'analysing user information'	Holiday parks business: different users for one bike, weather conditions; cleaner, catering, technical service, security, activity team	Above mentioned issues not relevant; Gear gets wet, protecting gear, adjusting steer and seat, getting heavy stuff in the bike	Mind map and collage 2

it in the design process. They were also asked about the benefits and limitations of their means of representation of the frame of reference. Finally, for each team questions were formulated, aimed specifically at indistinct matters observed in the submitted reports and portfolio.

Data analysis interview

The group interview was transcribed completely. Subsequently relevant sections of the transcripts and written process evaluation were identified and assigned to the research questions.

6.4 Results

This section firstly introduces the general project results. Subsequently each of the research questions is answered and concluded. Finally, the research method is shortly evaluated.

6.4.1 Summary of the project results

Team 1,3 and 4 chose initially to focus their design project on a use situation domain that was suggested by the client: using a carrier bike at holiday parks by the employees (cleaners, catering, technical service) to transport their tools or goods to and from cottages and other park buildings. Those teams found out at different stages during the project that this target market was not interested in using a carrier bike for this purpose. They then all chose a different target use situation domain. The next pages show the final target use situations and results of each team.

Figure 6.5: team 1 designed a carrier bike to rent to parents on holiday parks to transport their children in and around the park. The most important issues they worked on was to make the bike appealing for children so they could persuade their parents to rent the bike. Furthermore it should be comfortable to sit in and allow different positions for multiple children. Their final design had the appearance of a car and little play-steers for the children. Furthermore it had adjustable benches to allow the different positions

Figure 6.6: team 2 chose the current use situation in which carrier bikes are mainly applied: using a carrier bike in the city by parents to transport their children and luggage. They initially focused at the design of a carrier bike that can be adjusted to the changing needs of growing children. Although parents were interested in this concept, they had to focus on a more specific issue to be able to finish their project within time. This issue concerned the different weather conditions in which the bike is used. Their final design is a hood which protects against wind, sun or rain while still allowing contact between parents and children.

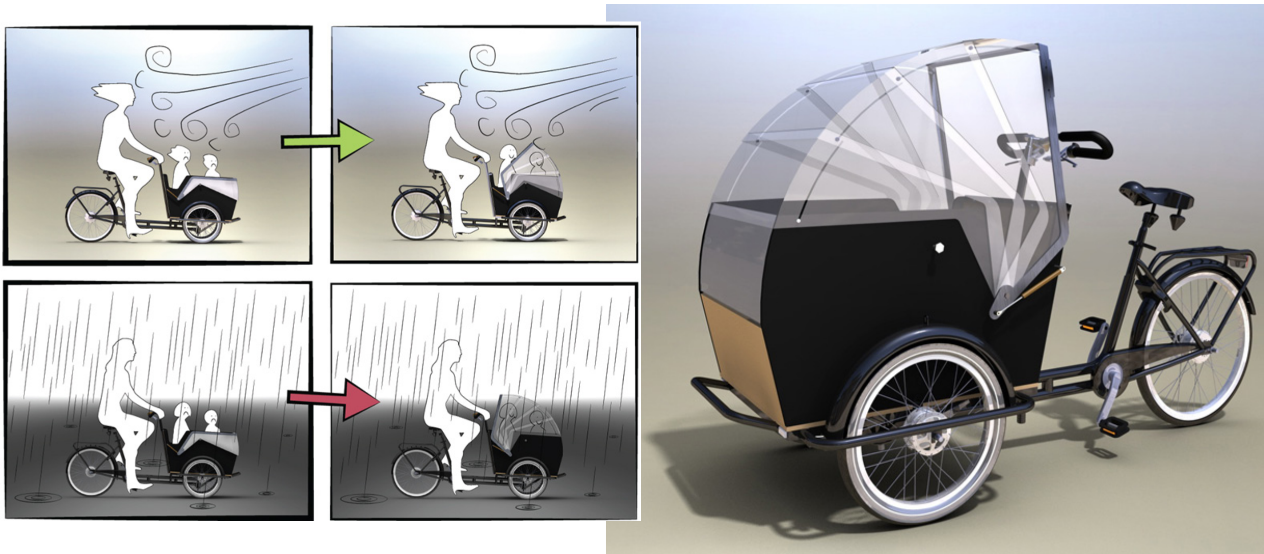


Figure 6.7: team 3 designed a carrier bike to rent to general visitors of holiday parks for specific purposes (themes) such as a party, a picnic or going to the beach. The main issues they worked on was to allow easy adjustment of the bike to another theme, make it easy to store and reach all necessary tools for the theme and easy loading and unloading. They designed a bike with detachable theme-boxes one could drive out of the main box.

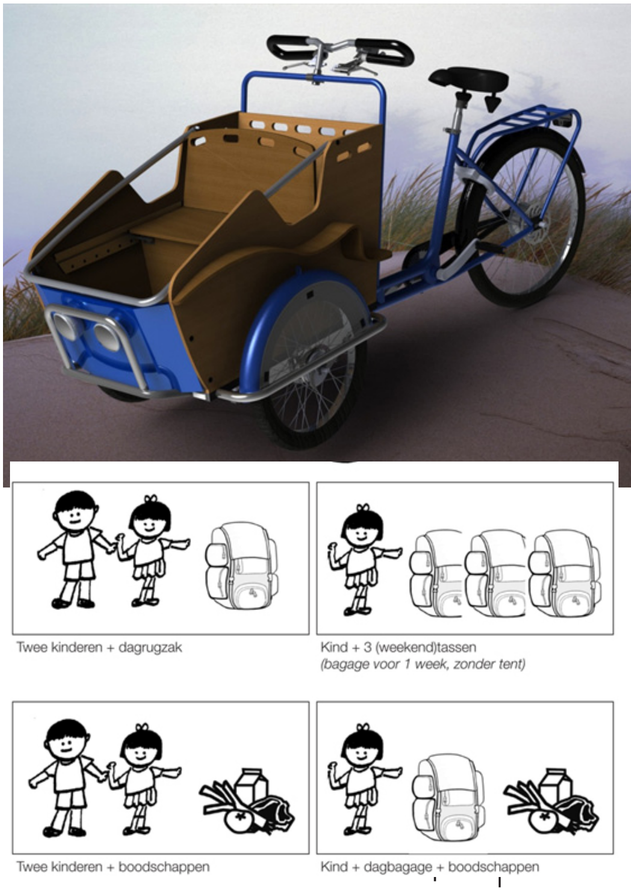


Figure 6.8: team 4 designed a bike to rent to campers on Vlieland (Dutch island which does not allow tourists to bring their own car) to transport children, luggage and camping gear. The main issues they dealt with in their design were allowing transport of different kinds of combinations of (camping) luggage and children, and easy loading and unloading. They designed a bike with adjustable luggage- and passenger space.

6.4.2 Question 1: the evolution of the explicit frame of reference of product use

The first research question was: were the use situations and issues made explicit and how did the frame of reference evolve? To answer this question, this section gives a summary of the evolution of the frames of reference of each team and furthermore discusses the explicitness, consistency and completeness of those frames of reference

Evolution of the frames of reference of product use

Since all teams were specifically asked to build a frame of reference of use situations, they all did so. The extent to which it evolved explicitly, strongly differed per team. Below a short summary is given of how the explicit frames of reference of each of the teams evolved. A visualisation of the evolution of the frame of reference can be found in appendix 5. An exact number of 'versions' is difficult to give, because some groups presented each minor adjustment as a new version while other groups only presented a completed version when a new target was chosen. Those differences will be made clear in the summaries. Furthermore, different views on or representations of the same use situations and issues were considered as one frame of reference. As mentioned in the setup of the research, a representation is considered a 'frame of reference of product use' when it connects use situations to use issues.

Team 1 created five versions of the frame of reference in different representations and views (see next section). The frame of reference was updated after each analysis or evaluation study and after each workshop and/ or change of target. For example, when they decided to change their target to rental of carrier bikes to visitors of a holiday park, they explored which issues would be important for this use situation by means of a scenario analysis. These issues were adjusted in the frame of reference. The frames of reference are clearly connected to each other, for example by also showing the issues that are not relevant anymore. At two moments in the project scenarios were created that were directly connected to one of the frames of reference.

Team 2 created five versions of the frame of reference. They updated the frame of reference after each workshop or brainstorm and before the first presentation session. The first three versions were aimed at family issues in general, a fourth one aimed at the ages of children and a fifth one aimed at different weather conditions (see figure 6.9). For example, after they analysed the characteristics of different aged children in literature they did an Envisioning Use workshop to explore what this meant for the use issues concerning the carrier bike, and then made a new frame of reference. The consecutive frames of reference were added to one poster representation to show the connection between the different frames (see appendix 5c).

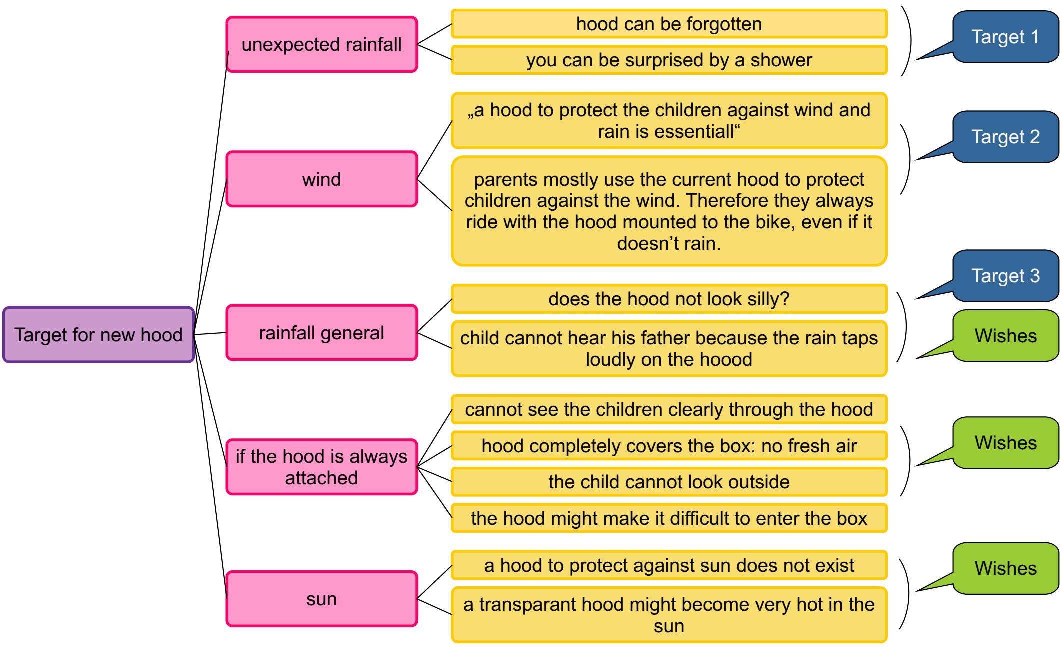
Team 3 created four versions of a frame of reference. The first three were created after an exploration of the initial targets in a brainstorm or workshop that was increasingly detailed. The third frame of reference was based on different scenarios for holiday park employees. When a new target was chosen, no new frame of reference was created until after the final user test. For example, the last target considered rental of bikes to visitors on holiday parks. For this target only an overview was made of environments, rental purposes and luggage. No specific issues were connected explicitly to these use situation aspects. The different frames of reference were not explicitly connected to each other.

Team 4 created three versions of a frame of reference of which only the last one was reported in the portfolio. The first one is the product use mind map created in the first workshop, concerning use at a holiday park. The second one was presented in the intermediate client presentation and considered the four target issues for the rental of the bike at Vlieland. The third one was a complete frame of reference for this use situation that was used to set test conditions for the user test.

Explicitness

The explicitness of the frames of reference differed strongly between the teams. While the frames of reference of team 1 and 2 reflected at each moment in the design process what the relevant use situations and use issues were, this was not true for team 3 and 4. Team 3 stopped making explicit representations after choosing a new target until after their final user test. Team 4 only presented their final frame of reference to set their test conditions. They mentioned they hardly used the work book during the project, as reflected in the following quote from their process evaluation:

Figure 6.9: a part of the frame of reference of team 2 which shows issues related to varying weather conditions



Written process evaluation (team 4): "a benefit of the workbook is that it gives a lot of structure in the beginning of the design project by means of the Envisioning Use technique. Later we fell back in our usual design approach, because the guidelines were less clear here."

Consistency

Another striking aspect of the frames of reference was the consistency between the different frames of reference of one team. The first team showed a frame of reference that was updated at several moments in the design process. Issues that were not relevant anymore were made 'transparent', while new issues were added. Team two applied a similar approach. The other teams showed completely new frames of reference that replaced the previous ones. The downside of the latter approach is that it is difficult to see what is the overlap between the frames of reference and consequently which issues are replaced by others for which reason. Although this limitation of the analysis of evolvement of the frame of reference is partly a research issue, it might also be important in design activities, because issues are more easily overlooked or forgotten.

Completeness

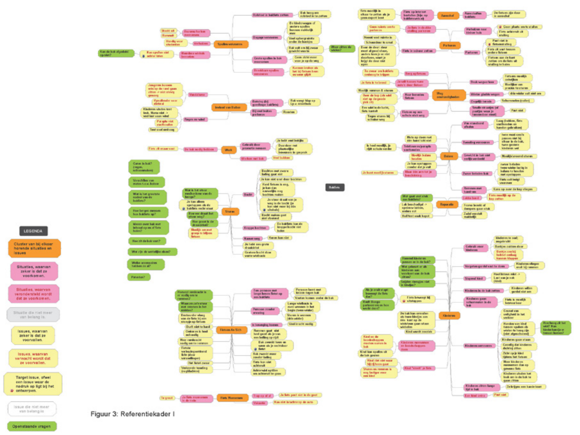
The completeness of the frames of reference differed as well. The workbook advises to use a simplified version for inspiring solution generation and communication. Three of the four teams used this kind of simplified representation in which they listed the most important issues. In one case (team 4) this simplified version was presented without a complete frame of reference. This risks a lack of consistency as described above.

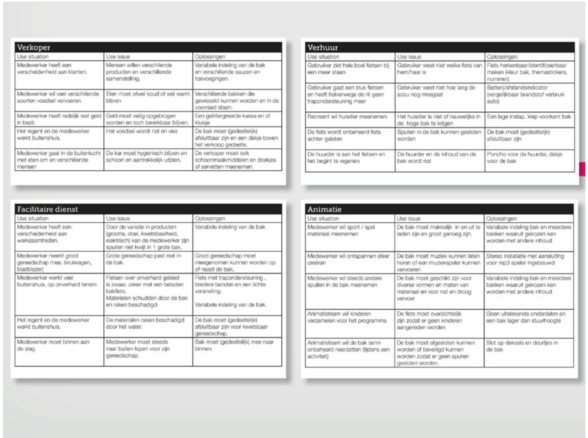
Conclusion question 1

The relation between the guidelines and building a frame of reference is positive, but not constant. The guidelines mainly stimulate building an explicit frame of reference in initial design phases. The results also showed that the consistency between different frames of reference within one design project differed strongly. When there is no consistency between frames of reference, it might be possible to overlook use issues or use situation aspects, since it is difficult to analyse the differences between the frames of reference. It was therefore concluded that the consistency of the frame of reference needs more attention in the guidelines.

6.4.3 Question 2: the representation of the frames of reference of product use

The second research question was: which means of representation were used for the frame of reference? The representations that were used to present a frame of reference of product use can be categorised in structured textual presentations, collages and scenarios.





Verkoper

Use situation	Use issue	Oplossingen
Medewerker heeft een verscheidenheid aan klanten.	Mensen willen verschilende producten en verschillende samenstelling.	Variabele indeling van de bak en verschillende sauzen en toevoegingen.
Medewerker wil veel verschillende soorten voedsel vervoeren.	Eten moet ofwel koud of wel warm blijven	Verschillende bakken die gewisseld kunnen worden en in de voorraad staan.
Medewerker heeft redelijk wat geld in bezit.	Geld moet veilig opgebrogen worden en toch bereikbaar blijven.	Een geintergreerde kassa en of kluisje
Het regent en de medewerker werkt buitenshuis.	Het voedsel wordt nat en vies	De bak moet (gedeeltelijk) afsluitbaar zijn en een dakje boven het verkoop gedeelte.
Medewerker gaat in de buitenlucht met eten om en verschillende mensen	De kar moet hygienisch blijven en schoon en aantrekkelijk uitzien.	De verkoper moet ook schoonmaakmiddelen en doekjes of servetten meenemen.

Verhuur

Use situation	Use issue	Oplossingen
Gebruiker ziet hele boel fietsen bij een meer staan	Gebruiker weet niet welke fiets van hem/haar is	Fiets herkenbaar/identificeerbaar maken (kleur bak, themastickers, nummer).
Gebruiker gaat een stuk fietsen en heeft halverwege de rit geen trapondersteuning meer	Gebruiker weet niet hoe lang de accu nog meegaat	Batterij/afstandsindicator (vergelijkbaar brandstof verbruik auto)
Recreant wil huisdier meenemen	Het huisdier is niet of nauwelijks in de hoge bak te krijgen	Een lage instap, klep voorkant bak
De fiets wordt onbeheerd fiets achter gelaten	Spullen in de bak kunnen gestolen worden	De bak moet (gedeeltelijk) afsluitbaar zijn
De huurder is aan het fietsen en het begint te regenen	De huurder en de inhoud van de bak wordt nat	Poncho voor de huurder, dakje voor de bak

Facilitaire dienst

Use situation	Use issue	Oplossingen
Medewerker heeft een verscheidenheid aan werkzaamheden.	Door de variatie in producten (grootte, doel, kwetsbaarheid, elektrisch) kan de medewerker zijn spullen niet kwijt in 1 grote bak.	Variabele indeling van de bak.
Medewerker neemt groot gereedschap mee. (kruiwagen, bladblazer)	Grote gereedschap past niet in de bak.	Groot gereedschap moet meegenomen kunnen worden op of naast de bak.
Medewerker werkt veel buitenshuis, op onverhard terrein	Fietsen over onverhard gebied is zwaar, zeker met een beladen bakfiets. Materialen schudden door de bak en raken beschadigd.	Fiets met trapondersteuning , bredere banden en een lichte versnelling. Variabele indeling van de bak.
Het regent en de medewerker werkt buitenshuis.	De materialen raken beschadigd door het water.	De bak moet (gedeeltelijk) afsluitbaar zijn voor kwetsbaar gereedschap.
Medewerker moet binnen aan de slag.	Medewerker moet steeds naar buiten lopen voor zijn gereedschap.	Bak moet (gedeeltelijk) mee naar binnen.

Animatie

Use situation	Use issue	Oplossingen
Medewerker wil sport / spel materiaal meenemen	De bak moet makkelijk in en uit te laden zijn en groot genoeg zijn.	Variabele indeling bak en meerdere bakken waaruit gekozen kan worden met andere inhoud
Medewerker wil ontspannen sfeer creëren	De bak moet muziek kunnen laten horen of een muziekspeler kunnen vervoeren	Stereo installatie met aansluiting voor mp3 speler ingebouwd
Medewerker wil steeds andere spullen in de bak meenemen	De bak moet geschikt zijn voor diverse vormen en maten van materiaal en voor nat en droog vervoer	Variabele indeling bak en meerdere bakken waaruit gekozen kan worden met andere inhoud
Animatieteam wil kinderen verzamelen voor het programma	De fiets moet overzichtelijk zijn zodat er geen kinderen aangereden worden	Geen uitstekende onderdelen en een bak lager dan stuurhoogte
Animatieteam wil de bak semi-onbeheerd neerzetten (tijdens een activiteit)	De bak moet afgesloten kunnen worden of beveiligd kunnen worden zodat er geen spullen gestolen worden.	Slot op deksels en deurtjes in de bak

Figure 6.10: structured textual presentations: a mind map (team 1) and a table (team 3)

Structured textual presentations

All teams started with a product use mind map that resulted from the Envisioning Use workshop. Subsequently they transferred this mind map in either a digital mind map or a table (figure 6.10). The mind map presents the information in the same way as the product use mind map, with different colours for use issues, use situations, categories and questions. The tables connected use situation aspects, use issues and possible solutions in rows. Team one, two and four used simplified 'views' of the mind map or table next to a complete view.

Collages

Most teams presented collages of users and environments. However, these collages did not clearly connect use situations to use issues. For example a collage was made with pictures of the use environment of the carrier bike for Vlieland by team 2, without mentioning what this means for the carrier bike (figure 6.11). Often these types of collages were presented together with a mind map representation that did connect use issues to use situation aspects, but these sometimes considered other aspects.

Figure 6.11: use situation description of the environment in a collage, without connected use issues

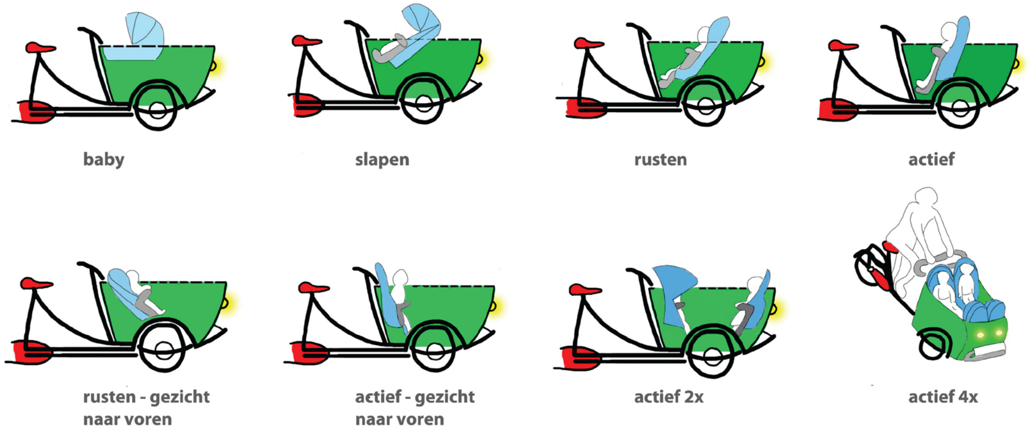


Figure 6.12: storyboard of box concept for different activities and children, without explicitly describing use issues.

Scenarios

All the teams used some form of scenario (storyboard or narrative), but none of them considered them as part of the 'frame of reference'. These scenarios showed how a future solution, on different levels of detail, could work in the chosen situations. In some cases the scenarios only described the interaction without explicitly mentioning the issues concerning the quality of interaction. For example, team 2 showed a concept of a box that fits different activities and ages of children in a storyboard, without explaining the resulting issues in the storyboard (see figure 6.12). In other cases the issues were integrated in the scenario. For example team 4 described for different scenarios which type of luggage should fit in the box.

Conclusions question 2

The representations used, considered structured textual representations in complete and simplified views, collages and scenarios. The latter representations were not considered a 'frame of reference of product use' by the students and according to the definition they indeed are not when they do not connect use situations to use issues. When they do connect use issues to use situations, they are a useful format (see section 6.4.7). The benefits and limitations of the different representations are discussed in the answer to question 6.

6.4.4 Question 3: the creation and update of the frame of reference.

The third research question was: how was the frame of reference created? What was the additional value of use situation analysis and use evaluation with regard to the completeness of the frame of reference? The results concern firstly exploring use issue – use situation connections and secondly verification of assumptions in the frame of reference.

Exploring use issue – use situation connections

All teams created a first frame of reference in the Envisioning Use workshop (see answer to question 5). Subsequently, techniques such as consulting literature, consulting online forums, user interviews and online surveys were used to gather new insights or confirm assumptions. What is important to notice here is that information could only be added to the frame of reference when it was connected to particular use issues concerning the product. For example team 2 conducted a literature analysis of children's changing thinking level, physical and social abilities and interests. To be able to use this information in the design process, it first needed to be explored if these characteristics would have any relevant influence on the use of the carrier bike. Therefore they executed an extra envisioning use workshop to connect those characteristics to bicycle issues. One of the resulting issues they added to their frame of reference was that younger children want to keep visual contact with their parents and therefore sit face backward, while older children want to sit face forward to be able to look around.

On the other hand some types of analysis gave directly insight in how certain usability issues related to a use situation. For instance, quotes from online review forums were used for this purpose, such as: "riding the bike with four children and a lot of groceries [use situation] is not heavy when you use an electric powered bike [use issue]".

This connection between use issues and use situations is necessary to be able to select relevant test conditions for use evaluations. A simple example is that when you want to evaluate the preferred position of children in the box, it is important to include children of different ages (see answer to research question 4).

Apart from the initial workshop, other 'internal' activities were employed to explore use situations and how they connect to use issues. Internal activities concern techniques which rely on assumptions because no end-users or other evidence is used to confirm the use issues. These techniques included different versions of the Envisioning Use technique. Team one, two and three applied the workshop not only to create a first frame of reference, but also in later stages to share newly acquired information and link it to case specific issues or to imagine issues for a newly defined target. The former purpose is illustrated in the example of team 2 described above. An example of the latter purpose is the workshop executed by team 1 to explore the issues related to the newly defined target group of renting a carrier bike to parents on holiday parks. Apart from the workshop, scenario analyses were used to explore use situation – use issue relationships, in which scenarios were written and explored individually or in a group, as explained by the following students:

Student A (team 1): "we used the scenarios to create the mind map and then we worked with the mind map"

[…]

Student B (team 1)"yes, we all wrote scenarios and from that we derived a couple of use issues"

The quote below suggest that in later design stages, scenario representations can be more useful than a 'bottom-up' structured representation to explore use issues.

Student (team 4): the scenarios supported imagining how the product would be used.[…] The other thing [mind map] helped as well, but it is a little bit messy collection […] The scenario helped a lot in the situation we targeted […] The scenarios were particularly convenient later in the design process, when you have something concrete.

The scenarios therefore seem particularly useful to explore use situations and connected use issues for created solutions, in other words, to explore future use.

Verifying the frame of reference

While the explorative activities were used to add new issues to the frame of reference, use evaluations turned out to be very important to verify those issues. This can be illustrated by a problem that occurred with team one and three who waited longer to verify their frame of reference in use evaluations than the other two teams did. Both teams lost some time because they initially targeted the holiday park employees who turned out not to be interested in the carrier bike. The idea was to have the bike used by cleaners or technicians to transport their tools from one cottage to another. They then built a frame of reference of product use, based on assumptions from a workshop or a scenario analysis. However, in an interview it turned out a carrier bike was not considered desirable by the visited holiday park managers, because it was too large and inflexible for the cleaners and too small for the technicians' tools. Therefore they had to change their target use situations. This shows that verification of assumed issues should be done as soon as possible to prevent loss of time.

Evaluations did not only lead to verification of assumptions, but also resulted in new issues and related use situation aspects. For example, when team 1 showed their sketches of carrier bikes for a holiday park to parents, parents indicated that children with different interests might be more or less attracted to the selected theme for the appearance of the bike.

With regard to usability issues, internal evaluations such as testing yourself were also used to update the frame of reference. However, the evaluations that were mentioned in the portfolio only considered evaluations of current solutions. Therefore they could not be used to verify issues of newly generated solutions. An example is an analysis of team 1 of the manoeuvrability of the bike on different road conditions by trying out an existing bike on different types of roads and tracks on the university campus.

Conclusions question 3

When we consider the extent to which the above mentioned activities influenced the completeness of the frame of reference, it can be concluded that 'use situation analysis' is only useful for an update of the frame of reference when it explores use issue – use situation relationships. Both the internal as well as the external explorative activities resulted in a large addition of new issues. The evaluative activities also added new issues to the frame of reference, but were most of all useful to verify issues or use situation aspects. This verification of the frame of reference is important to prevent spending too much time on working with a frame of reference that later turns out to be irrelevant.

6.4.5 Question 4: application of the frame of reference

The fourth research question was: how was the frame of reference applied? What was the additional value of the completeness of the frame of reference for setting up test conditions and questions for evaluations? To answer these questions, the application of the frame of reference in use evaluations is summarised for each of the teams.

Summary of the application of the frame of reference in evaluations of solutions

Team one used the frame of reference in their final use evaluation test to decide upon the test conditions, for example different aged children and children with different interest were selected to participate. It was not possible to do the test at a holiday park, but the most important use situation aspect, that children and parents walk around together, was simulated by going to a school when it was out. The frame of reference was also used to set research questions by selecting the most important issues that they wanted to have confirmed, for instance 'children are not interested in the theme of the box'.

Team two selected less focused test conditions for their evaluation of their design for a hood (in a prototype without an actual riding bike). Based on their frame of reference it would have been useful to involve parents who have experience with riding a carrier bike in different weather conditions. However, they executed the evaluation rather opportunistically by choosing a place to test the prototype at which they were not sure they would find parents with this experience. They eventually only interviewed four passers-by who had no experience with carrier bikes at all. Their research questions concerned only two higher level issues: perceived appearance and functionality. They did not ask questions about for example the preferences with regard to communication between parents and children, which was considered an important issue in the frame of reference.

Team three chose two different target groups to test their prototype: a young family and students. Both groups could be visitors of a holiday park. Like team two their research questions were high level: how do people use and experience the prototype? It is not clear if they used a frame of reference to set more detailed research questions. The test conditions do correspond with the description of the target user and environment. One student said:

Student (team 3): "I liked the combination of mapping all the issues beforehand and then doing the test. It makes you more focussed on these issues"

This suggests they either created an observation check list based on a frame of reference which was not presented in the portfolio or the issues were taken into account more implicitly. No data is available that confirms this.

Team four connected their research questions more clearly to specific issues that were part of their frame of reference, for instance: can different kinds of combinations of children and luggage be easily fit in the box?. The connected use issues were also reflected in test conditions, for example by having adults test different scenarios for the content of the box (see figure 6.8b, project results).

The extent to which the frame of reference was applied in use evaluations.

The results of the teams show that for external evaluations the frame of reference was in some cases explicitly used to set up the test. No direct evidence was found in the documents or interviews on if the frame of reference was used for internal or implicit evaluations of solutions. Team 1 mentions a test in which they tested the bike on different road conditions on the university campus. However, this concerns the current product and not a particular future solution. It is therefore not clear what the influence of the frame of reference is in internal evaluations. However, the results of all the teams showed that solutions were clearly connected to the frame of reference, even when this frame of reference turned out to be untrue after verification, such as was the case with the intermediate solutions of team 3 (figure 6.13). The lack of external analysis and evaluations at that intermediate stage suggests that some internal process led to the connection of the solution to the frame of reference. It cannot be concluded to what extent this internal process is based on internal evaluations.

One team indicated they did not apply the frame of reference enough:

Student (team4): "Later in the project we did not use the frame of reference enough. Eventually we did it [for the use evaluation], but next time we should monitor this better."

Team 2, who did not use the frame of reference in their final evaluation, indicated they did not apply the frame of reference, particularly due to the mind map format they used:

Student (team 2): "Eventually the frame of reference is something we only made 'for the course', and not something we experienced as a convenient tool to structure the process.... Without an explicit frame of reference it would probably be even more difficult to keep an overview of all relevant issues and situations, but if a more usable way could be found to visualise the frame of reference, the method would definitely benefit."

So although they used the same kind of format as team 1 for their frame of reference, they did not experience it as valuable for their design process.

Conclusions on question 4

The above mentioned results do indicate that the frame of reference supports setting up test conditions (team 1 and 4), although it cannot be concluded that the level of completeness of the frame of reference contributed to this issue. Conversely it cannot be concluded that the test conditions cannot be set without the frame of reference, because team 3 set up a realistic test environment without explicitly using the frame of reference. The results furthermore show that research questions are more focused when the frame of reference is used. The teams that did not use the frame of reference, defined research questions that had a more general character than the research questions of the teams that did use the frame of reference in doing so. The study does not give direct evidence that the frame of reference was used to set test conditions or questions for internal evaluations.

Finally some of the teams indicated that they felt they did not apply the frame of reference enough in their design process. This could be caused by the lack of overview in some of the complete representations of the frame of reference (see for example appendix 5c). Since the success of the explicit frame of reference depends on the extent to which it is applied, this issue needs to be investigated more in the following study.

6.4.6 Question 5: the envisioning use workshop

Question 5 was: how was the envisioning use workshop applied? Did it influence the completeness of the frame of reference? Did it influence use situation analysis?

Application and added value for the completeness of the frame of reference

All teams applied the workshop at the start of the project. The resulting product use mind map was in three of the four cases translated in a digitised structured textual representation. Team 4 did not show how they used their product use mind map.

Team one, two and three applied the workshop also in later stages to share newly acquired information and link it to case specific issues or to imagine issues for a newly defined target, as described in section 6.5.4. For example, team two executed the workshop when participants had gathered information about the thinking level, physical and social abilities and interests of different aged children. They then shared and explored related issues in a workshop. Team one and three executed a new workshop to explore the issues related to the newly defined target group. Team 4 indicated after the project that they regretted not having done a second workshop after redefining the target use situations.

Quality of use situation analysis

The questioning step in the Envisioning Use workshop was used to guide external analyses. Team one kept the questions explicit in the frame of reference and executed different types of analyses to get them answered. Team 2 formulated some questions in their explicit frame of reference as well, but they are not clearly linked to specific analyses. Team 3 formulated questions in the workshop and had them answered by interviewing the client. In later frames of reference and the second workshop they did not explicitly mention questions and related analyses. Although team 4 did not make questions explicit in their presented frames of reference, they indicated that the workshop stimulated thinking about questions and then that stimulated them to get them answered. This is illustrated by the following quote of one of the team members about how they were stimulated to interview holiday park employees:

> *Student (team 4): by doing the workshop we really started thinking about questioning and that stimulated us to go there [the holiday park] and if we hadn't done this, we might not have realised it was not a good market.*

Questions did not only result from the envisioning use workshop, but also from scenario analyses. For example, team 1 made assumptions and connected questions with regard to renting bicycles explicit in their frame of reference after doing a scenario analysis for this target, for example concerning if parents would rent a bike at a holiday park. This question was later answered by interviewing parents.

Conclusions question 5

From this can be concluded that particularly the explorative character of the workshop contributed to the completeness of the frame of reference, by explicitly connecting use issues to use situations and vice versa. The workshop can be executed at different stages in the design process for setting the initial frame of reference of product use or in later stages to explore use issue – use situation relationships when a new target is chosen or new information about the use situation is gathered. Questions formulated in the workshop guided explorative and evaluative activities directly or through documenting them in the explicit frame of reference. These questions could also result from other explorative activities like scenario analyses. From this can be concluded that both the Envisioning Use technique as well as scenario analyses had a positive influence on the completeness of the frame of reference and on guiding use situation analysis.

6.4.7 Question 6: benefits and limitations of the means of representation

Question 6 was: what were the benefits and limitations of the different means of representation of the frame of reference? The related issues considered in this section are level of overview, efficiency, exploring use issues and evaluation of solutions.

Overview for communication and simplifying design

The complete structured textual representations did not prove very useful for communication purposes. Contrary to this, the simplified mind maps and tables worked well in communication with the instructors. This might be due to the lack of overview in the complete mind map. As mentioned at the results for question 4, team two did not apply their mind map at all because of the lack of overview.

Another limitation of the complete frame of reference is that some students indicated that it gave them the feeling they had to do something with all the information. Because that is not possible it can give a very unsatisfactory feeling. Team 3 actually tried to deal with all the data and therefor lost a lot of time in dealing with irrelevant information, as illustrated by the following quote:

> *Student (team 3): "There is no convenient way to remove information. We thought, maybe we have to keep everything, because maybe we will have to look back later. But you don't do that and now we do and everything gets very complex."*

Updating the frame of reference

When asking about the limitations of the frame of reference, students often complained about the usability of the digitised mind maps. A digitised mind map took a lot of time to create and update. Working with multiple persons on one digitised frame of reference did not work because that resulted in loosing overview. One solution, proposed by the students, could be to make one person responsible for the frame of reference. This person should also communicate important changes to the team.

Connecting use issues to use situations: evaluation and communication

Both the complete mind maps and simplified mind maps were used to set use evaluations. The representations that did not connect use issues to use situations, such as collages, were not appropriate to set up use evaluations. Since they do not clearly link use situations to use issues, they do not make clear which use situations are relevant to get answers to evaluation questions regarding specific issues.

Storyboarding and showing concepts in the use situation (see figure 6.13) worked well for communicating and discussing solutions in an oral presentation. The lack of explicit related use issues could then be compensated by an oral explanation of the issues.

Figure 6.13: A sketch of a solution for the carrier bike is shown in its use context (with cleaner and cleaning tools), but without an explicit indication of use issues (e.g. frequently used tools should be easy to reach). These issues were mentioned in the accompanying oral presentation.

Conclusions question 6

A complete structured textual representation like a mind map is useful to set evaluations but lacks overview for communication purposes. Moreover, it can be overwhelming when designers have the idea they have to deal with everything in this complete frame of reference. For communication purposes, the simplified versions of the frame of reference worked better. Storyboards and representations of solutions in a specific use situation were only useful for communication when they were accompanied by an oral explanation of related use issues. This type of representations could be better employed by guiding designers in making these use issue explicit *within* the representation.

6.4.8 Question 7: side effects

Question 7 was: what are unexpected positive and negative side-effects? The most important unintended effects were the creation of a mindset aimed at diverse use situations and the difficulty and importance of targeting.

Importance of the mindset

The most important and unexpected result of the projects was that students indicated that the approach was particularly strong in getting the knowledge in the head and thereby taking it into the design process. The following quote illustrates the importance of this mindset:

Researcher: "How did this project differ from other projects? User centred design is not new for you"

> *Student A (team 2): "That's right, but usually a lot later, only when you have a solution and you do a user test […], but not from the beginning".*

Student B (team 2): "Yeah, now you design more for them, you are really from the beginning, with the workshop and all that, <u>in your mind</u> dealing with use situations and issues"

The importance of this mindset or implicit frame of reference can be seen in the work of team 2. They executed multiple workshops to explore use situations and issues, but they acknowledged they did not really use the explicit frame of reference. However, their solutions are clearly based on the issues that resulted from these workshop sessions. For example the issue 'keeping contact with children while protecting them from different weather conditions' is clearly integrated in their solution of a hood.

This mindset was created by exploring issues in 'internal activities' such as 'imagining' in the Envisioning Use workshop. Apparently this leads to both an addition of use issues to the explicit frame of reference, as well as to a mindset that supports solution generation. The following quote illustrates that a 'brainstorm' aimed at diverse use situations supports 'thinking from the perspective of the user':

Student (team 2): "I think that the difference [compared to previous projects] is that indeed in your mind you are already [dealing with use situations and issues], because we just brainstormed things like, what are possible situations, where can people use a carrier bike, for what purposes can people use a carrier bike? Really, thinking from the perspective of a user. That you think, what would he want, what would he like to do with it, what does he take with him?"

The following quote suggest that 'getting the knowledge in the head' is supported by exploring use situations in a 'structured way':

Student (team 3): "Then we looked further in the rental market, but we did not do that with another Envisioning Use workshop"

> *Student (team 3): "No, but I think, with the method, we found problems in a structured way and therefore we had more structure in our approach […] Then later when creating solutions it's in your head, and you don't go back look in those things [explicit frame of reference], so."*
>
> *Researcher: "It helped getting it in your head?"*
>
> *Student (team 3): "Yes, I think so, because than you communicate it in a structured way and everybody knows."*

This suggests that creating and exploring the explicit frame of reference supports creating an implicit frame of reference. So in addition to the direct assumed influence of the explicit frame of reference on solution generation and communication, it indirectly affects these activities through the updated mindset.

Difficulty of targeting

Defining a target was important to give the project a clear direction. The results from teams 1, 3 and 4 show that it is difficult to choose a successful target use situation – use issue combination. They followed the suggestions of the client to aim at the use situations at a holiday park, but it turned out their ideas were not found desirable by holiday park managers (the client had not explored that new market himself yet). This resulted in a loss of time. When choosing a new market, obviously it becomes important to check the desirability of the product for this market. Since this does not only concern usability, this aspect was not included in the guidelines. The guidelines only mention: "*motivations for a certain target can be market potential (no competitor product aimed at a certain domain of use situations), technical opportunities or other commercial or ideological goals.*" Some teams explicitly executed a competitor analysis for this purpose. However, the results of the teams show that verification of the issues is essential to find an appropriate problem domain, which in turn is a precondition for a successful product.

Conclusions question 7

The conclusions with regard to question 7 are firstly that a side-effect of explorative activities is that they result in a mindset aimed at DDUS. Some teams indicated that this mindset was a very useful result of applying the guidelines. Particularly in solution generation it can have a large impact, because the designer can always have it at his or her disposal. Secondly in targeting successful use situation – use issue combinations it is important to verify the desirability of the product for the chosen target use situations as soon as possible.

6.4.9 Evaluation of the research method

Apart from the research results, the study can be evaluated on its research process as well. To get insight in the design process it was decided to ask students to create and communicate a number of complementary documents: a log, reports for each analysis or evaluation, a process evaluation and a portfolio of the development of their design and frame of reference. Furthermore they were asked access to their online file storage and they were asked to participate in a group interview. Some teams indicated that they found it difficult to work with all these different kinds of documents. It might have distracted them from actually doing the project. Particularly keeping the log and giving insight into their file storage was indicated as being a hassle. One team clearly presented a designated file storage for the instructor which gave limited insight in their actual design materials. Since the file storage in general provided limited data for the research results, it was chosen to abandon this approach for the following study (see chapter 9). Furthermore it was decided to assign the task of keeping the log to the instructor/ researcher based on the weekly meetings.

6.5 Conclusions

This chapter described the development of an initial workbook with guidelines to create a design approach aimed at dealing with dynamic and diverse use situations in the design process. The basic principles of the workbook were aimed at building an explicit frame of reference of use situations and connected use issues. This frame of reference could then be used to set up test conditions for evaluations. Other expected effects of the frame of reference, that were only limitedly considered in the workbook, were improved communication about product use and better guided solution generation. The workbook furthermore described how to create and update the frame of reference by means of use situation analysis, use evaluations and the Envisioning Use technique.

A formative evaluation of the workbook was conducted by means of applying it to a design case. This case concerned the development of a carrier bike by student teams. These students were asked to explore the format of the frame of reference. The conclusions with regard to this evaluation are:

- The guidelines supported building an initial explicit frame of reference, but more guidance is needed in keeping a consistent frame of reference throughout the design process.
- 'Use situation analysis' was useful for an update of the frame of reference when it explored use issue – use situation relationships.
- Both the internal as well as the external explorative activities resulted in a large addition of new issues.
- The evaluative activities also added new issues to the frame of reference, but were most of all useful to verify issues or use situation aspects.
- The frame of reference supported setting up test conditions (team 1 and 4), although it cannot be concluded that the level of completeness of the frame of reference contributed to this issue.
- The research questions for evaluations were more focused when the frame of reference was used to set up the evaluation.
- A complete structured textual representation such as a mind map was useful to set up evaluations but lacked overview for communication purposes.

- For communication purposes, the simplified versions of the frame of reference worked better.
- Scenarios were useful to explore use issue – use situation relationships.
- Scenario representations (narrative and storyboard) and visual use situation representations (collages) often lacked an explicit connection to use issues.
- This study does not give direct evidence that the frame of reference was used for internal evaluations. In general the explicit frame of reference was not used enough according to the students.
- Particularly the explorative character of the workshop contributed to the completeness of the frame of reference, by explicitly connecting use issues to use situations and vice versa.
- Questions formulated in the workshop guided explorative and evaluative activities directly or through documenting them in the explicit frame of reference.
- The workshop is useful to set the first frame of reference of product use, to explore a new target and to connect newly gathered information about use situations to use issues.
- A positive unintended effect of explorative activities was that they resulted in a mindset aimed at diverse use situations. This mindset was experienced as beneficial in solution generation.
- In targeting successful use situation – use issue combinations it is important to verify the desirability of the product for the chosen target use situations as soon as possible.

The next chapter will further discuss these conclusions and translate them in an adjusted revised version of the workbook.

7 Guidelines To Design For Dynamic And Diverse Use Situations

7 Guidelines to design for dynamic and diverse use situations

Chapter 6 described the development of an initial workbook with guidelines to set up a design approach for dealing with dynamic and diverse use situations. The initial workbook was applied and evaluated in a design case. In this case students designed a (part of) a carrier bike for a self-chosen spectrum of use situations. The results of this evaluation gave input to the development of a revised workbook with new guidelines. This workbook, as well as its development and motivation, is described in the first section of this chapter. In the second section, a new impact model is presented which was created based on the conclusions.

7.1 Development of the revised guideline set

Based on the answers to the research questions of the support evaluation (section 6.4), conclusions about the appropriateness of the workbook and related adjustments are formulated in this section. Since the workbook needed elaboration on several issues, a list of explicit guidelines was added to the workbook. Each guideline refers to a distinct part of the workbook in which the application of the guideline is explained and illustrated by means of examples. The explicit guidelines are motivated here. This revised workbook was evaluated in another student project (described in chapter 9), resulting in a final workbook. The complete revised workbook discussed in this chapter, with a further explanation of the application of the guidelines can be found in appendix 10. This appendix also shows the differences between the revised workbook presented here and the final workbook presented in chapter 9. The topics that are discussed in the first part of this section concern the explicitness and consistency of the frame of reference, the means of representation of the frame of reference, the application of the frame of reference in evaluations, the application of the Envisioning Use technique, and targeting. The discussion of these topics led to a new process model of design activities connected to the frame of reference of product use, which is presented at the end of this section.

7.1.1 Building an explicit and consistent frame of reference

The first goal of the evaluation was to evaluate the relation between the guidelines and the extent to which the frames of reference were made explicit throughout the design process (link 1 in the impact model). This differed strongly per team. Some made every step explicit (team 1) while others only showed the final version (team 4). Therefore, the relation between the guidelines and building a frame of reference is positive, but not constant. The explanation of team 4 that the workbook provided better guidance in the beginning of the design project than in later stages, suggests that updating and applying the frame of reference in later design stages needs more explanation. The results also showed that the consistency between different frames of reference within one design project differed strongly. A lack of consistency incurs the risk that it becomes unclear which issues are removed and consequently they might be forgotten. Therefore the revised workbook contains the following explicit guideline:

> 'Keep track of a consistent frame of reference with use situations and related use issues throughout the design process'

The application of the guideline is explained in the workbook (appendix 10).

7.1.2 The means of representation of the frame of reference

The second goal of the evaluation was to explore the means of representation of the explicit frame of reference (link 1, *how* the frame of reference is made explicit). Working with the explicit frame of reference functioned well only for team 1. The other teams used it only partly. It seems that this is caused to a large extent by the lack of overview in the complete mind maps or other structured textual representations. Relevant information that is not priority should be available for application in use evaluations, but should not attract attention in other activities such as solution generation and communication. To prevent this, the revised guidelines stimulate to use a frame of reference with different views. The views on the frame of reference are the complete view of all relevant information (which can be used for evaluations), the simplified view which shows just the target of the complete view (for solution generation and communication) and a 'recycle bin' which preserves irrelevant data for reuse. (see figure 7.1). An explanation of those views can be found in the workbook in appendix 10. The connected guideline that was added to the workbook is:

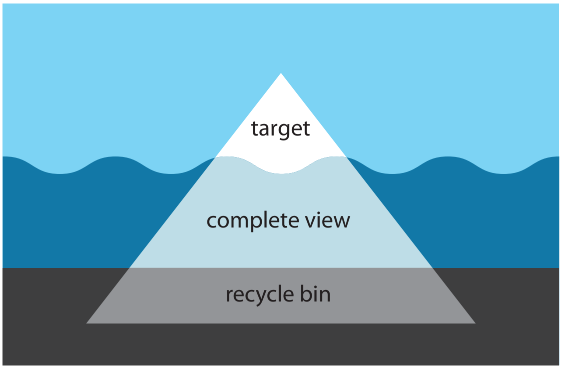
> 'Present: use a simplified, visualised representation of the frame of reference to inspire solution generation'[1]

7.1.3 The implicit frame of reference

Apart from the explicit frame of reference, the results clearly show the importance of the implicit frame of reference, or mindset that is created during the design project. The mindset seems to have a positive influence on solution generation. The results furthermore show that this mindset is supported by 'brainstorms' such as the Envisioning Use technique. Since one intended goal of the explicit frame of reference was to improve the 'sharedness of a vision on product use' (see impact model figure 6.1, link 11), the implicit frames of reference should be aligned as much as

[1] This guideline was changed in the final workbook to: *'Use a simplified, target representation of the frame of reference to inspire solution generation <u>and support team communication</u>'.*

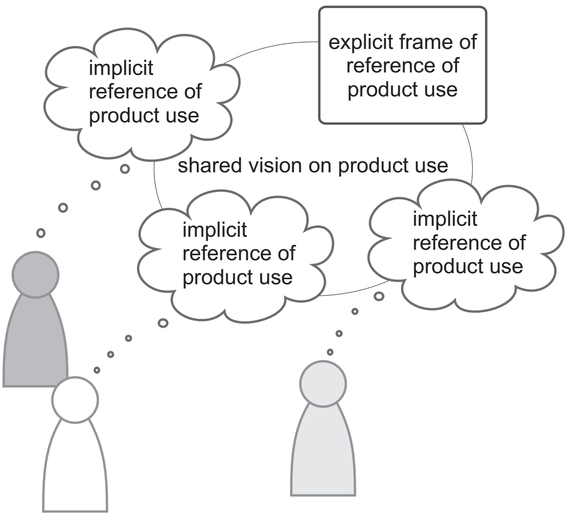
Figure 7.1: different views on the frame of reference



possible (see figure 7.2). A shared vision on product use is necessary to make well-founded design decisions, as was discussed in chapter 4. The assumed influence on the extent to which product use information is shared was expected to result from the extent to which the frame of reference was made explicit. However, the study did clearly show that the mindset and consequently a shared vision were positively influenced directly by doing the workshop, without the necessity of creating an explicit frame of reference. The connected explicit guideline that was added to the workbook is:

> 'Make all members of a design team aware of dynamic use and create a shared mindset by having members actively work with information about use'

Figure 7.2: the implicit frames of reference of product use in the minds of team members should be aligned to form a shared vision on product use. This shared vision should be reflected in the explicit frame of reference of product use.



7.1.4 Creating the frame of reference

The third goal of the evaluation was to analyse if and how 'use situation analysis' and 'use evaluation' contributed to the completeness of the frame of reference (link 6 and 7 in the impact model). Important aspects that were found are the importance of exploring use issue – use situation relationships, verifying issues and the application of scenarios.

Exploring use situations – use issues

The analysis of the different representations for the frame of reference showed that it is important to connect use issues to use situations in the frame of reference if you want to use it to set up evaluations. This became apparent as well in the analysis of how the frame of reference was created. It is important to explore how use situations and use issues are connected. The term 'use situation analysis' in the workbook suggests that use situations can be analysed independently of use issues. Although the explanation of the activity in the workbook mentions that *'to get insight in discriminating situation aspects it is necessary to connect them to use issues'*, the term and explanation may have caused confusion. Therefore it seems appropriate to replace that term in the guidelines by 'exploration' of DDUS. This insight was translated in a new process model of design activities connected to the frame of reference which is explained in section 7.1.8. Furthermore, the need for the connection between use situations and related use issues in the organisation of the frame of reference was underlined more in the workbook. The related explicit guidelines are:

> 'Structure the frame of reference: connect use issues to the use situations in which they occur'

> 'Explore: explore use issues related to chosen use situations (scenario analysis, EU workshop)'

Verification

Exploration of product use can take place with regard to imagined situations and issues in 'internal explorations' such as the imagining step in the Envisioning Use technique and scenario analysis, and with regard to actual situations and issues in 'external explorations' such as reviews of competitor or previous products. In the initial workbook, such evaluations of current solutions were categorised as 'evaluations'. However, evaluations of current solutions have a different purpose than evaluating future solutions or design proposals. Evaluations of current solutions – in other words analyses of current use - can be used to anticipate which use situations and use issues might be relevant for a future solution. In that sense they can lead to assumptions about future use. Evaluations of design proposals can then be used to verify those assumptions and create recommendations for adjustments of the design (see the initial impact model in chapter 4, figure 4.6). Therefore the term 'external exploration and verification of DDUS' [2] is used to refer to evaluations of current use.

[2] In the final workbook these types of activities were further specified as 'external exploration and verification of current use', to distinguish them from explorative activities aimed at future use (see chapter 9).

The difference between internal exploration and external exploration and evaluations is that the internal exploration and evaluations will mostly lead to assumptions, while external exploration and evaluations will lead to facts. To get to those facts however, it is useful to firstly conduct internal explorations to formulate the questions, for example by means of the Envisioning Use technique These questions will then give more focus to the external explorations and evaluations. Those conclusions led to the following explicit guidelines:

> 'Anticipate: learn about future use situations from analysing the present (external exploration of DDUS)'

> 'Verify: verify assumed issues for future use situations (external evaluations)'

Scenarios

Scenarios proved a valuable tool to explore use issues and use situations, particularly later in the design process. Students did not consider scenarios as part of the frame of reference. It should be made more clear in the workbook that these kind of 'real world representations' are also important as a frame of reference. Not only do they support exploration, they are also a very useful tool for communication as stated by Rosson and Carroll (2002, page 23): "Scenarios use a universally accessible language. All project members can "speak" the language of scenarios.".

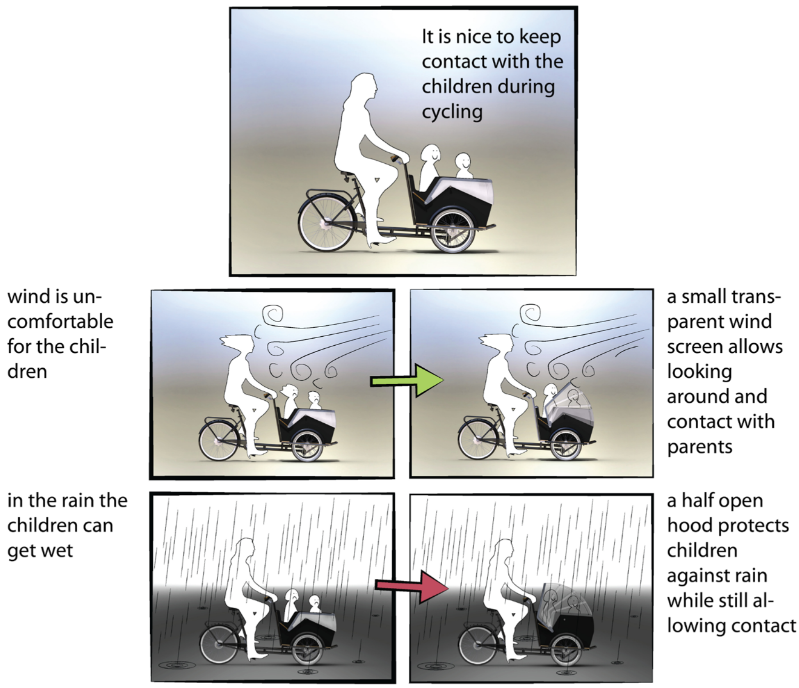


Figure 7.3: storyboard representation of team two's design for an 'all weather-hood' completed with explicit issues by the author of this thesis

The storyboards and scenarios are very useful for presenting and communicating use situations and future solutions with related use issues. However, since use issues were not always mentioned explicitly by the teams in those representations, this should be made more clear in the guidelines. This issue is covered in the guideline about structuring the frame of reference in use situations and issues. An example of how issues can be made explicit in a storyboard is shown in figure 7.3 which shows the original storyboard of team 2, completed with use issues by the author. Therefore the revised workbook contained more information on the use of scenarios, as well as the following explicit guideline:

> 'Keep the frame of reference close to the actual world to stimulate use issue exploration and adoption of the frame of reference by all team members'. [3]

7.1.5 Applying the frame of reference in evaluations

Selecting test conditions

The fourth goal of the evaluation was to evaluate the extent by which and how the frame of reference is used to set up test conditions that define the external validity of the evaluation (link 2 and 3 in the impact model) and to set up the questions that define the focus of the evaluation (link 4 and 5 in the impact model). The results do indicate that the frame of reference supports setting up test conditions (team 1 and 4), although it cannot be concluded that the level of completeness of the frame of reference contributed to this issue. Conversely it cannot be concluded that the test conditions cannot be set without the frame of reference, because team 3 set up a realistic test environment without explicitly using the frame of reference.

Selecting research questions for use evaluations

The results furthermore suggest that research questions are indeed more focused when the frame of reference is used to formulate them. The teams that did not use the frame of reference, defined research questions that were less focussed than the research questions of the teams that did use the frame of reference in doing so. When questions are focussed on specific assumed issues, the test can be used to verify those issues. When questions are more higher level, such as 'what is the ease of use of this solution?', the test will probably lead to a more random collection of issues.

Internal and external evaluations

As mentioned above, verifying assumed issues for future solutions in external evaluations is important. The workbook mentioned that in early design phases it is also useful to base use issues on internal kinds of evaluations, such as testing yourself or testing with colleagues or family, even if these evaluations only lead to assumptions. This study does not give direct evidence that the frame of reference was updated based on these kinds of evaluations.

[3] In the final workbook this guideline was reformulated in a manner which reflects the added value of scenarios more clearly: *'Use scenarios to explore connections between use situations and use issues and to communicate those connections'*

Moreover, it did not show that the frame of reference was used reciprocally to contextualise those internal evaluations. Since some students indicated that they did not use the frame of reference for evaluation purposes, or did not use it enough, it was concluded that this main goal of the frame of reference needs more explanation in the workbook. These conclusions led to the formulation of the following guidelines:

> 'Evaluate: use targeted use situations to set test conditions for use evaluations (external/ internal use evaluations)'

> 'Evaluate: use targeted use issues to set research questions for use evaluations'(external/ internal use evaluations)'

7.1.6 The application of the Envisioning Use technique

The fifth goal of the evaluation was to validate the assumed contribution of the Envisioning Use workshop to the completeness of the frame of reference (link 9 in the impact model).

Value for the explicit frame of reference

The added value of this technique for the exploration of use issues and use situations and thereby its contribution to the frame of reference became apparent in all the student projects. It is not only useful to set an initial frame of reference by means of the product use mind map, but also to update the frame of reference in later stages. This can firstly be done to share newly acquired information and link it to case specific issues. Secondly it can be used to imagine issues for a newly defined target. This added value can be made more clear in the workbook by specifically connecting the technique to internal exploration of DDUS (see also next section).

Value of the workshop for a shared implicit frame of reference

Furthermore the Envisioning Use technique proved valuable in creating a mindset or implicit frame of reference, as explained in the conclusions about the means of representations of the frame of reference. Doing the workshop together could consequently lead to a 'shared mindset' or 'shared vision' on product use. As argued in section 4.1.2, a shared vision can support making design decisions. This was assumed to result from the extent to which product use information would be shared, which in turn was expected to result from the extent to which the frame of reference was made explicit (link 11 in the impact model). The application of the explicit frame of reference for creating a shared vision was not included in the current version of the workbook. However, the study showed that the mindset and consequently a shared vision were positively influenced by doing the workshop. This means that when new information about product use becomes available during the design project, this information

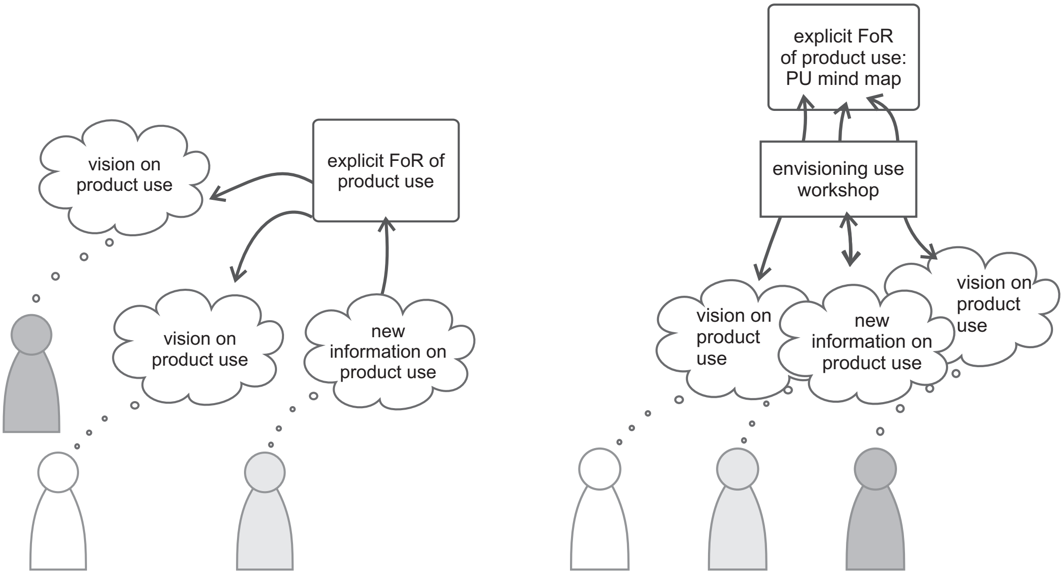


Figure 7.4a: creating a shared vision by adding new information on product use to the explicit frame of reference (FoR) and figure 7.4b: creating a shared vision by adding new information on product use in an envisioning use workshop.

could be added to the 'shared vision' by means of either an update of the explicit frame of reference (figure 7.4a), or doing an Envisioning Use workshop (figure 7.4b). The main assumed advantage of sharing information in an interactive meeting is that team members actively work with the data and therefore will more easily remember the data . This issue is made explicit in the earlier mentioned guideline: 'make all members of a design team aware of dynamic use and create a shared mindset by having members actively work with information about use'.

7.1.7 Targeting

The final issue that was discussed in the results of the evaluation concerned the difficulty of targeting. This mainly concerned the uncertainty with regard to the desirability of the product when the target use situations were unfamiliar. When a familiar target was chosen, users would already know the product and a competitor analysis would show that the product was desirable for this target group. When a new market was chosen as a target, there was more uncertainty about the desirability of the product. Quick verification was necessary to prevent losing a lot of time working on an inappropriate combination of target use situation and solution, as happened to team 3. Since this issue mainly concerns requirements that stem from beyond usability, it was not supported in the workbook with an explicit guideline. Instead a short explanation is given on the importance of verification of the appropriateness of the target use situations. Furthermore the workbook explains that targeting is a decision making activity and thus can benefit from the application of a (simplified) frame of reference. The importance of verification of use issues in general was already underlined in the concerning guideline for evaluation.

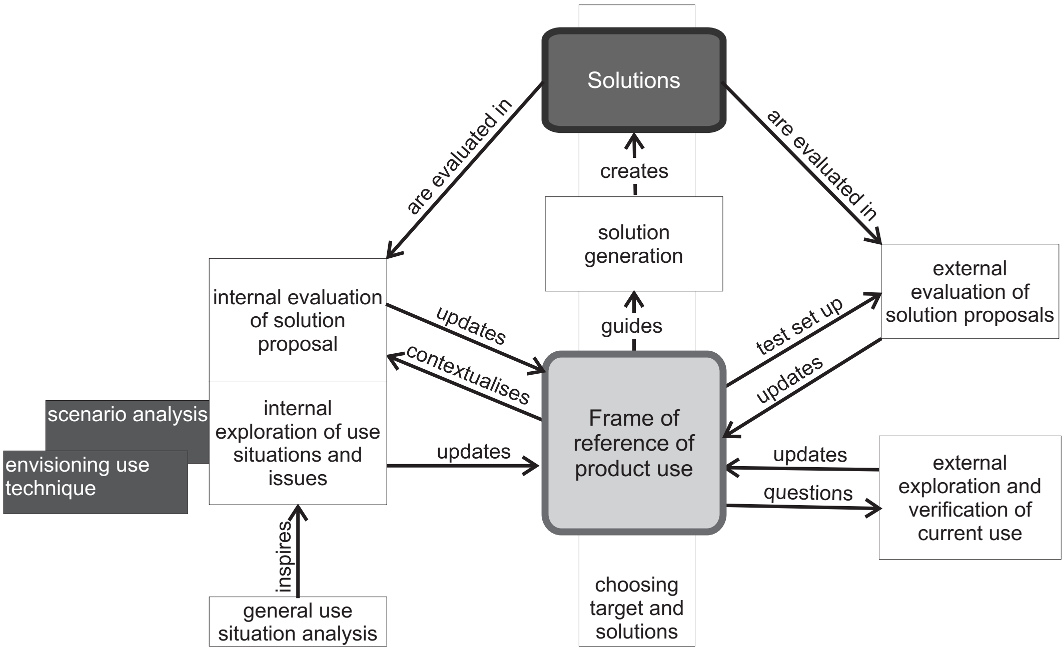
7.1.8 New process model of design activities connected to the frame of reference of product use

Based on the conclusions it was decided to create a new process model of design activities connected to the frame of reference of product use, which distinguishes 'exploration of DDUS' as opposed to 'use situation analysis', and evaluations of solutions. This model replaces the first process model of designing for DDUS (figure 6.2) and was used in the revised workbook to explain the guidelines.

In this model the following groups of activities to deal with the frame of reference of product use are distinguished (see figure 7.5):

- External analysis/ exploration: exploration or verification of the relations between use situations and issues in the frame of reference, for example by means of user analysis or expert interviews
- External evaluations: confronting a solution to a use situation based on the frame of reference, for example by means of user tests
- Internal analysis/ exploration: exploring the relations between use situations and issues, for example by means of scenario analysis or the EU workshop
- Internal evaluations: confronting a solution with the frame of reference, either implicitly or explicitly, for example by means of self-evaluations or placing ideas in context

Figure 7.5: new process model of how design activities relate to the frame of reference of product use



- Solution generation: creating solutions inspired by the frame of reference
- Decisions on target and solution > choose an appropriate target and solution with a team or with the client

Internal activities concern those activities in which no verification of information about actual use situation aspects takes place, for example evaluations that do not involve potential end-users or exploration of use issues based on assumptions. Evaluations that are executed opportunistically with people that are close to the development team (e.g. colleagues or family) are also considered internal activities when the selection of these test persons is not based on the defined target group. However, the area between internal and external evaluations is grey, because in some cases an opportunistically chosen test person might also be an actual end-user of the intended target group.

Internal exploration

Internal exploration considers all those activities executed within a design team aimed at gathering implicit knowledge about product use, exploring relations between use situations and use issues, and analysing gaps in available knowledge. The Envisioning Use workshop is a means to achieve those goals in a team. Another way to explore issues is scenario analysis which can be executed both individually and in a team. Since internal evaluations of solutions and explorations of current use can take place at the same time, as in the Envisioning Use technique, they are placed side by side in figure 7.5. An analysis of use situation aspects can be used as input to internal explorations, for example a literature analysis of certain user characteristics (see the example of team 2, section 6.5.4) can be used as input to scenario analysis or an envisioning use workshop to explore what could happen when these users interact with a certain solution. The methods are further explained in the workbook. The gathered knowledge can be used to update or create the frame of reference of product use.

External exploration and verification

Relations between use situations and use issues for current use can be analysed internally or externally. Internal explorations will mostly lead to a lot of assumptions about product use. However, to be able to make more successful design decisions, it is necessary to base them on facts. These facts can only be gathered by doing external analyses on real end users in real settings. Those analyses can be explorative or focussed. In the latter case the analyses are steered by questions and can include the verification of assumptions that were defined in internal analyses. The questions are drawn from the frame of reference. In the first case the analysis is more open and situation aspects or issues can arise that were not considered before in the frame of reference.

Results from the external analyses can be used to update the frame of reference. Assumptions can be verified and converted to facts and new situation aspects or use issues can be added. External analyses might also lead to new assumptions, when an analysis of use issues of a current solution gives input to assumptions about use issues of a new solution. In that case predictions about future use are based on extrapolations of analyses of current use.

External evaluations

In external evaluations, generated solutions are evaluated on their interaction qualities such as usability, user experience and performance with potential end-users. The frame of reference can be used to set the test conditions. The more realistic the test conditions, the more valid the results will be for predicting future use. The results of the external evaluation can be used to update the frame of reference. The workbook explains how to define objectives and research questions and how to define test conditions or samples.

Internal evaluations

In internal evaluations, no potential end-users are involved, but test are executed by the designers themselves or opportunistically with people in their direct environment such as colleagues, friends or family. Although this type of evaluations is less valid than an external evaluation, it has the advantage of being much faster. Therefore they can be more easily integrated in an iterative design process. In internal evaluations one can distinguish

- evaluations in which the solution representation is compared to the frame of reference in a thought experiment.
- evaluations in which solutions are communicated and discussed with team members or opportunistically chosen respondents by means of scenarios or other representations which connect a solution to its use situations.
- user tests in which the designer or other people use a solution representation like a mock-up. The frame of reference can be used to set test conditions.

In all cases the frame of reference should be used to contextualise the evaluation. This type of evaluations is also very useful for discovering independent use issues. These are use issues that are independent of the use situation. For example, the use issue that a certain user interface might not give enough feedback for people to understand it, can be independent of specific characteristics of those users. These types of use problems occur mostly at the beginning of the design process. By testing internally early in the design process, these types of issues can be discovered quickly (see for example Nielsen (1994)).

Solution generation

The workbook does not give any support on creativity techniques for solution generation. Designers are expected and allowed to use their own design techniques for this purpose. However, the implicit frame of reference (the ideas about use situations in the head of the designer) can be used as a reference throughout this activity. Thus it functions like an internal evaluation or quick reflection tool. These kinds of reflections can occur throughout the creative process. A designer makes a sketch, reflects on it by thinking about its application in the intended use situations, adjusts it etc. In this process it is particularly important that the designer has a valid image of the frame of reference (see the guideline on 'creating a shared vision'). A simplified representation of the frame of reference can be used to inspire the creative process. (see 'representing the frame of reference').

Choosing a target and solutions

Targeting is the act of defining which use situations and use issues the solution will be aimed at. In a decision process, all members of the development team, including the client, should agree on what the target is and which solution should be chosen. Therefore this activity is a team activity. It can be done as part of an Envisioning Use workshop or done separately. As with choosing solutions, to discuss the target it is necessary to have a visualisation of the different options. To ensure overview

Table 7.1: benefits and limitations of the different means of representation of the frame of reference in relation to the design activities.

	Representation	View	Activity	Benefits	Limitations
The implicit frame of reference	No	Always available in the mind of the team member	Solution generation and reflection, choosing target and solutions	Create a shared view, always available	Difficult to share
The simplified target view	Visual icon	Always visible: target/ priorities	Solution generation and choosing/ communication target	Easy to remember, easy to communicate	Not complete
The complete view	Mindmap, table, product use mindmap , structured overview	Hidden: visible on request: evaluative data	Setting external evaluations and external DDUS explorations/ verification Internal DDUS exploration and evaluation	Complete overview, logical categorisation, distinguishes assumptions and facts	Difficult to communicate, complex, difficult to update
Recycle bin	All above mentioned representations	irrelevant data	For reuse after target change	Prevents redundant researches	Can attract unneeded attention from team members

during the discussion a simplified view of the frame of reference might be appropriate. However, when the target needs to be defined in more detail, a visualisation of the complete frame of reference is necessary to go through it. This allows for example to indicate the boundaries of the target use situation aspects, such as defining the boundaries of user characteristics that will be accommodated in the design. Since both choosing a successful target and choosing a solution depends on more criteria than just usability, this activity is not further supported in the workbook.

7.1.9 Means of representation of the frame of reference in relation to the design activities

Section 6.5.7 described the benefits and limitations of the different means of representation of the frame of reference. Those means of representation can now be connected to the above mentioned design activities. The relation between the views and means of representation of the frame of reference and the connected design activity are summarised in table 7.1.

7.2 The revised impact model

From the evaluation of the workbook can be concluded that it is probable that the links in the impact model exist. However, since the evaluation was executed with student teams instead of with practicing designers, the assumed links cannot be verified completely yet. Furthermore, the study gives insight in the occurrence of additional links that need more investigation. The study can therefore be used to revise the impact model which shows the impact of the revised workbook on several design factors. This complete revised impact model can be found in appendix 6 while this chapter shows the simplified relevant parts of that impact model. The revised impact model was used to plan the evaluation of the revised workbook, which is described in chapter 9.

7.2.1 New attributes in the frame of reference and their application

The initial factors with regard to the frame of reference considered its attributes ‘completeness’ and ‘extent to which the frame of reference is explicit’. The results of the study showed that the success of the frame of reference also depends on its consistency, structure of connections, and overview. Therefore these attributes are added to the impact model (figure 7.6). Consistency between different instances of the frame of reference is important because it prevents issues from being forgotten. It therefore assumingly influences the completeness of the frame of reference (link 15). Overview of the frame of reference is assumingly important when it is used for communication purposes in sharing information on product use and as an inspiration tool for solution generation. This attribute is therefore added as a precondition (link 16 and 17) for the explicitness

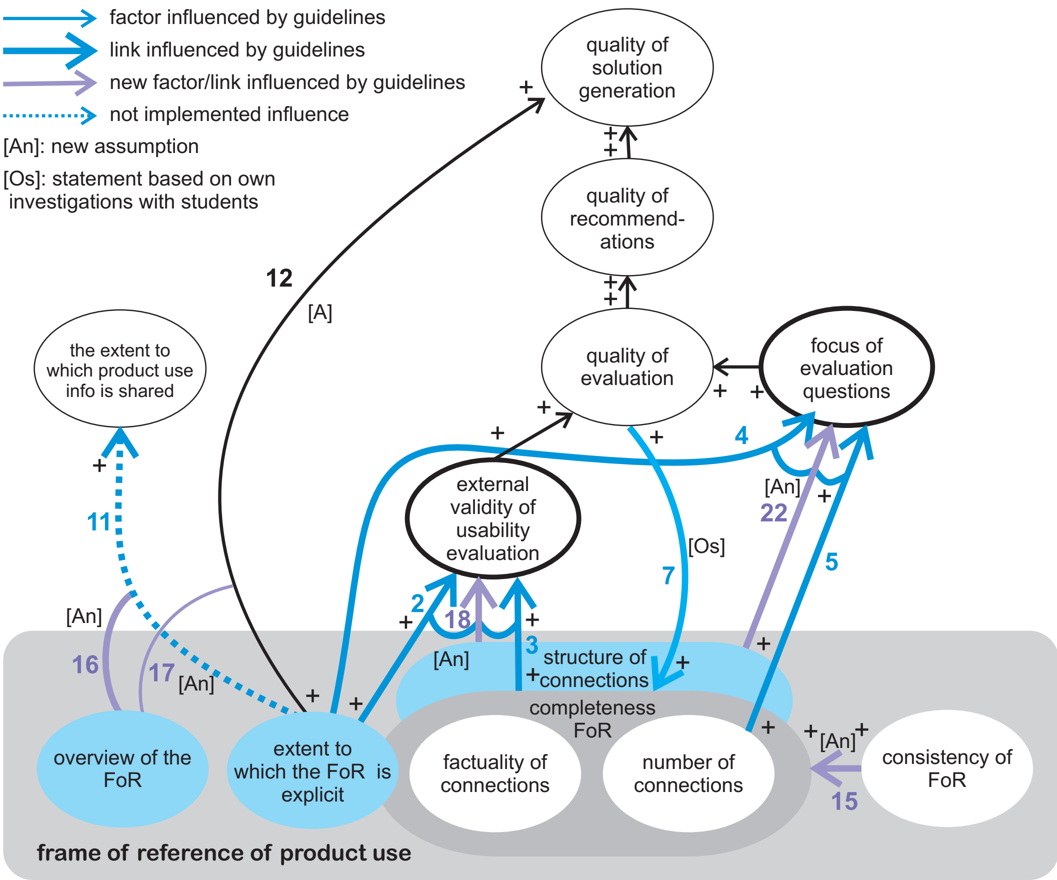


Figure 7.6: part of the revised impact model, showing the different attributes of the frame of reference and their assumed or investigated influences.

of the FoR to have influence on those activities (link 11 and 12). The results furthermore showed that it is important to connect use issues to use situations to be able to use the frame of reference to set relevant test conditions (link 2 and 3) and focussed research questions (link 4 and 5). The extent to which these connections are made is defined as the structure of connections. The attribute structure of connections is added as a precondition for the completeness of the frame of reference to have a positive influence on the external validity of the evaluation (link 18) and the focus of evaluation questions (link 22).The influence of the revised workbook on the explicitness, structure of connections and overview of the frame of reference is indicated in links 1a to 1c in figure 7.7.

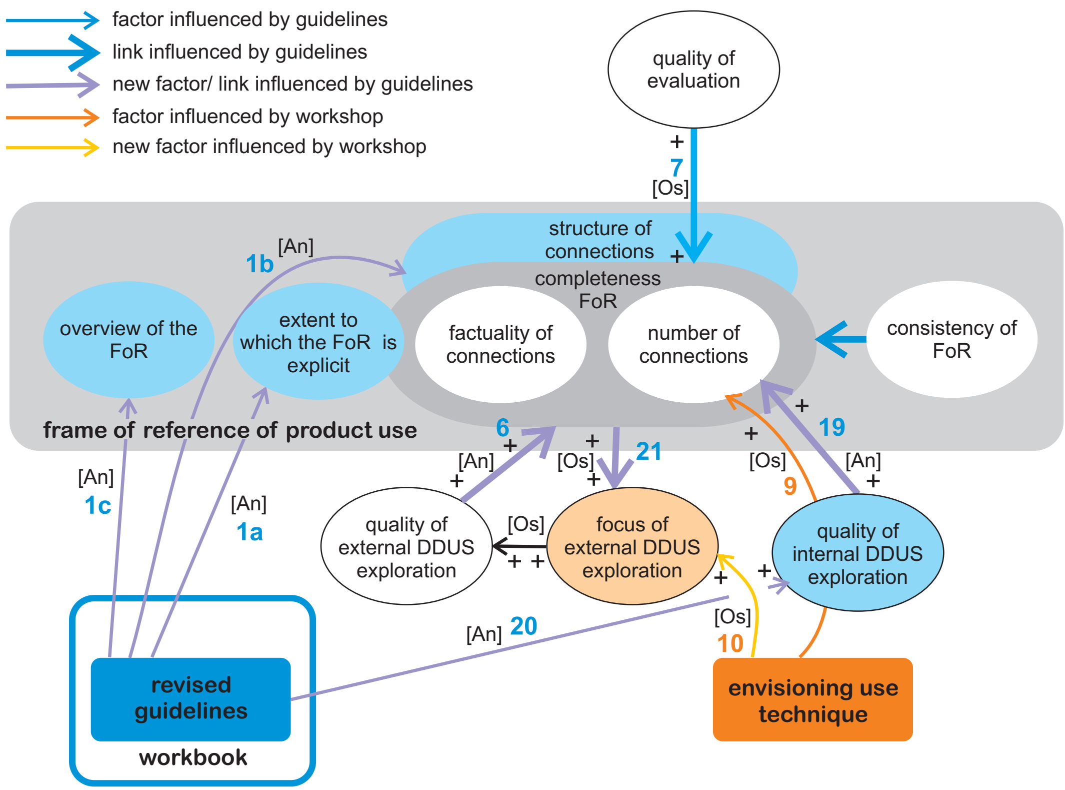
7.2.2 Sources for creating the frame of reference

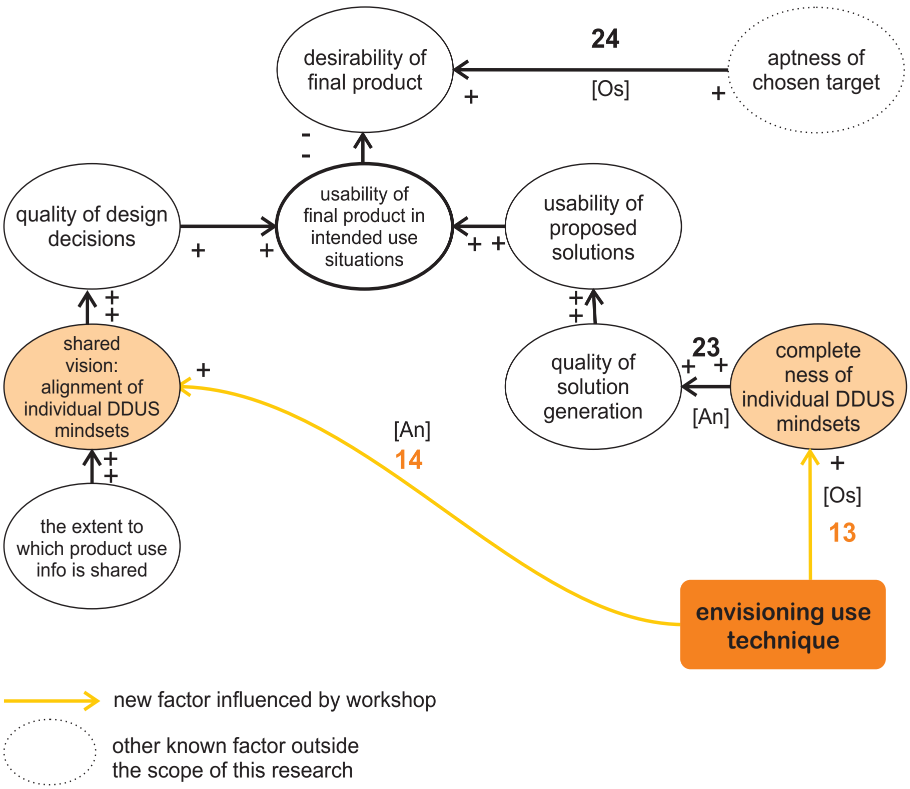
The term 'quality of use situation analysis' is replaced by the term 'quality of external exploration of DDUS, because this term defines better the need for this activity to investigate the relation between use situations and use issues. As concluded in section 7.1.4, use situation analyses which do not connect those aspects cannot directly be used to update the frame of reference. Both external and internal exploration of DDUS influence the completeness of the frame of reference (figure 7.7, link 6 and link 19). However, as discussed, internal explorations will lead mostly to assumed connections between use situations and use issues, while external explorations will lead to facts. Therefore the attribute completeness of the frame of reference is further split up in the attributes 'number of use situation- use issue connections' and the 'factuality of use situation – use issue connections', which is the extent to which connections are assumed or verified. Internal explorations will only influence the number of connections (link 9 and link 19), while external explorations will influence both factuality and number of connections (link 6).

The quality of internal explorations of DDUS can be supported directly by executing the envisioning use workshop (figure 7.7, link 9). Furthermore the workbook gives more insight in how scenarios can be used for this purpose. This link is added to the impact model (link 20).

The influence of the quality of the evaluation on the completeness of the frame of reference (figure 7.7, link 7) was confirmed in the study. The evaluation leads to both verification of assumed issues (factuality of connections) and new use situation – use issue connections (number of connections).

Figure 7.7: part of the revised impact model, showing the contribution of internal and external explorations and evaluations to the completeness of the frame of reference, as well as the influence of the frame of reference and Envisioning Use technique on the focus of external explorations of DDUS.





Focus of external exploration and verification of DDUS

The study showed that formulating questions for external explorations of DDUS led to more useful results. The factor 'focus of external DDUS exploration' is therefore added to the impact model (figure 7.7). This focus can be influenced positively by deducing questions from the explicit frame of reference (link 21) or directly by formulating questions in the envisioning use technique (link 10).

Figure 7.8: part of the revised impact model, showing firstly the contribution of the envisioning use technique to the completeness of individual mindsets of DDUS (link 13) and the extent to which theses individual mindsets are aligned (the shared vision, link 14) and secondly the influence of the appropriateness of the chosen target on the desirability of the final product (link 24).

7.2.3 Additional influences of the envisioning use technique

The study showed the importance of a mindset aimed at DDUS, or an implicit frame of reference. The factor 'completeness of individual mindsets of dynamic and diverse use situations' is therefore added to the impact model. Some quotes of students indicate that this had a positive effect on the quality of solution generation (figure 7.8, link 23). Since this link is not further supported in the actual workbook, it is indicated in black.

This mindset was created by executing the Envisioning Use technique (link 13). Apart from an individual DDUS mindset, the discussion in this chapter leads to the conclusion that doing the workshop together can also align those individual mindsets. This leads to a 'shared vision on product use'. In the original impact model proposed in chapter 4 (figure 4.6 and

4.7), the contribution of the envisioning use technique to this shared vision on product use, was expected to result from the application of the explicit frame of reference created in the workshop (the product use mind map) in sharing information of product use. However, the results of the student projects suggest that this shared vision can be created directly by doing the workshop together (link 14, figure 7.8). This link was evaluated further in design practice, which is described in the following chapter.

7.2.4 Importance of targeting

The results finally showed the importance of setting a successful target. This chapter already explained that although this aspect is important for the desirability of the final product, it will not be further supported by the guidelines, because its requirements stem from beyond usability. The influence of this factor is indicated in black in link 24.

7.2.5 Key factors and links

To set the research questions for the evaluation of the revised workbook it was important to define the key factors that the guidelines influence directly. Link 1a (figure 7.7) which considers the influence of the guidelines on the extent to which the frame of reference is explicit, remained the main goal of the workbook. The initial workbook only partly had this effect. As discussed before, this aspect was stressed more in the revised workbook and therefore the assumed link remained the same in the impact model. It furthermore stresses the importance of structure of connections and overview and explains how this can be achieved. These factors are therefore directly affected by the guidelines as well. In the impact model they are referred to as link 1b and 1c and the concerning factors are indicated in blue. The workbook does not directly influence consistency of frame of reference, since the workbook does not explain how a consistent frame of reference can be achieved, but explains only why it is important to keep a consistent frame of reference. Furthermore the revised workbook directly influences the quality of internal exploration of DDUS by offering guidance on the use of scenarios for this purpose. Finally, the revised workbook directly influences *how* the frame of reference can be created and *how* it can be applied. These 'key links' are shown in bold blue and violet arrows in figure 7.6 and 7.7.

To evaluate the workshop, it was important to define the key factors and measurable success factors which are affected by this part of the support. The main goals of the workshop are to increase the amount of explicit knowledge of product use, particularly the number of new use situation – use issue connections (link 9) and to improve the completeness of individual DDUS mindsets (link 13) and the sharedness of the vision on product use (link 14). These links are indicated in orange or yellow arrows in the impact model (figure 7.7 and figure 7.8).

7.3 Conclusions

7.3.1 Summary guidelines

Based on the results of the study a new set of guidelines was defined and a revised workbook was developed to explain those guidelines. Summarising, the new guidelines are:

- Make all members of a design team aware of dynamic use and create a shared mindset by having members actively work with information about use (Envisioning Use workshop)
- Keep track of a consistent frame of reference with use situations and related use issues throughout the design process
- Keep the frame of reference close to the actual world to stimulate use issue exploration and adoption of the frame of reference by all team members (scenario analysis)
- Structure the frame of reference: connect use issues to the use situations in which they occur
- Explore: explore use issues related to chosen use situations (scenario analysis, Envisioning Use workshop)
- Evaluate: use targeted use situations to set test conditions for use evaluations (external/ internal use evaluations)
- Evaluate: use targeted use issues to set research questions for use evaluations (external/ internal use evaluations)
- Present: use a simplified, visualised representation of the frame of reference to inspire solution generation
- Anticipate: learn about future use situations from analysing the present (external DDUS exploration)
- Verify: verify assumed issues for future use situations (external use evaluation)

The topics that are explained more thoroughly in the revised workbook in comparison to the initial workbook are the different views of the frame of reference, working with scenarios to explore use situation use issue relationships and applying the envisioning use technique in different stages of the design process. Furthermore a new process model is introduced in the workbook which explains how different design activities including internal and external explorations and evaluations of product use can be employed to create and apply the frame of reference of product use.

7.3.2 Objectives evaluation revised guidelines (chapter 9) and envisioning use (chapter 8)

The experiences gathered in this study furthermore provided input for the creation of a revised impact model which shows the assumed and experienced influences of the revised guidelines and the envisioning use technique on the influencing factors of the desired situation. The ultimate goal of the support is to improve the usability of the final product in intended use situations. On the one hand this can be achieved by creating better usable solutions based on recommendations from higher quality evaluations. On the other hand this can be achieved by better quality of design decisions with regard to those solutions by means of an improvement of the extent by which knowledge of product use is shared. Based on the study, an extra key factor was added which concerned the mindsets of the members of the development team. The experiences of the students suggest that these mindsets directly led to better quality of solution generation without the need for a high quality evaluation. Furthermore, the line of reasoning to achieve a better quality of evaluation and a better sharing of information on product use has changed with regard to the initial starting point. This reasoning is explained below.

The new influences of the Envisioning Use technique with regard to the initial impact model concern firstly its influence on the mindset of DDUS. Secondly, it concerns its direct influence on the extent to which a vision on product use is shared, instead of indirectly through the creation of the explicit frame of reference (see figure 7.8). This leads to the hypothesis that **the Envisioning Use technique leads to a shared vision on product use**. This hypothesis was tested in design practice, which is described in chapter 8.

Furthermore the better quality of evaluation was achieved by providing a frame of reference to improve the external validity of the evaluation and focus of the test (figure 7.6). These goals are achieved better when use situations are structurally connected to issues in the organisation of the frame of reference and when it contains more facts about these connections. This leads to the hypothesis that **a better structure of connections and more complete explicit frame of reference leads to more externally valid and focused evaluations**. This hypothesis was tested in the student project described in chapter 9. Additional research questions concern the added value of overview of the frame of reference for sharing information on product use and inspiring solution generation.

Finally the study showed the importance of exploring use situations and issues to achieve a complete frame of reference (figure 7.7). Internal explorations like the envisioning use technique and scenario analysis led to a larger number of assumed connections while external explorations and evaluations can be used to verify those assumptions. This leads to the hypothesis that a **combination of exploring and verifying activities leads to a more complete frame of reference of use situations**. This hypothesis was tested in the student project described in chapter 9 as well.

8

Evaluation Of The Envisioning Use Technique In Design Practice

8 Evaluation of the Envisioning Use technique in design practice

Chapter 6 and 7 described the development and evaluation of an initial workbook aimed at creating and applying an explicit frame of reference of DDUS and related use issues. Part of this workbook concerned the creation of the frame of reference by means of the Envisioning Use technique. The evaluation showed that this technique was applied successfully at different stages of the design process. It was not only used to increase the completeness of the explicit frame of reference and to set questions for external analyses, it also proved successful in creating a mindset of DDUS. These insights led to the hypothesis that the Envisioning Use technique supports the creation of a shared vision on product use. This hypothesis was tested in design practice, which is described this chapter.

This evaluation is conducted in collaboration with researchers Stella Boess and Christelle Harkema. Where needed, insight is given in who was responsible for which parts of the research.

8.1 Set-up workshop evaluation

The application and usability of the Envisioning Use technique were evaluated in the iterations with experienced designers and fictive cases in chapter 5 and in the evaluation in the complete design process and a real case with students in chapter 6. It is now time to evaluate the application and usability of the technique for real cases with practicing dseign teams. This evaluation also allows for a further evaluation of its usefulness, in other words its success with regard to the formulated aims. Blessing and Chakrabarti (2009, page 185) define this as a 'success evaluation', as part of a descriptive study II.

8.1.1 Objectives and research questions

The evaluation criteria or 'measurable success factors' (Blessing and Chakrabarti 2009, page 27) that were studied in this evaluation could be derived from the revised impact model that was introduced in chapter 7. The final success factor is the usability of the final product. However, this factor was difficult to measure as part of this research, since it would take a long time to measure this effect. Only after introduction to the market can the usability of the product in its intended use situation be measured. Another practical aspect that affected the choice for a measurable success factor is the fact that only the workshop itself could be closely observed with each of the participating companies and no subsequent team meetings could be observed. Therefore, gathering sufficient insight in the influence of the workshop on the quality of later design decisions was at this stage not possible. The measurable success factor is therefore the extent to which individual mindsets of DDUS are aligned, also called the 'shared vision' (link 14 in figure 7.8). The main objective of this evaluation was therefore to evaluate the effect of the Envisioning Use technique on this shared vision on product use.

The evaluation was furthermore used to evaluate the application domain of the Envisioning Use technique and the usability of the technique in design practice. Based on these objectives, the following research questions were formulated:

1. What is the influence of the Envisioning Use technique on constructing a shared vision on product use?
2. What is the application domain of the workshop with regard to design phase and type of product?
3. What is the usability of the workshop in design practice?
4. What are unexpected side effects?

The other influences of the workshop that were revealed in the evaluations in the student projects were its influence on the focus of external explorations of DDUS and on the completeness of the frame of reference (link 9 and 10 in the impact model in figure 7.8). These influences could not be further investigated in design practice, since they would require a longer term follow-up study which would require large time investments of the participating firms.

8.1.2 Method

The evaluation needed an approach which could test the hypothesis that the Envisioning Use technique leads to a shared vision on product use. Testing hypotheses referring to changes brought about by the support, such as was the case in this study, requires a comparative study by a control group, unless data about the situation without the support is available (Blessing and Chakrabarti 2009, p207). Comparing the results of the workshop to a control group would require that this control group would need to have the same knowledge of product use and work on the same design case as the experimental group. The uniqueness of the composition of the actual design team and their actual design project made a comparative study by a control group practically impossible. To gather data about the situation without the support, a pre-test and post-test could be used to compare the shared vision before and after the workshop. However, conducting such a pre-test within this research was not feasible. Therefore a non-experimental method was chosen to evaluate the support (Denzin 1978). This approach favours realism over precision and, as opposed to classical experiments, does not include equivalent control groups or repeated observations before and after the experiment. Instead, only experimental groups were included who were exposed to the support, in this case the Envisioning Use technique. A post-test was used to analyse the impact of the support. This post-test included a group interview after executing the workshop and a survey which was used to have participants reflect on the technique and its effects.

An additional evaluation of the application and usability of the support was executed to evaluate the usability of the design support in practice and the suitability of the support for the studied design projects. The method chosen to evaluate usability was an observation of the execution of the workshop and a group interview. To reveal possible usability issues, we particularly observed the oral feedback that participants gave during the workshop on the different workshop tasks. To evaluate the application domain of the workshop, we compared the results of the interviews and observations of the different workshops.

Test conditions

Since the focus of the evaluation was on the success and applicability of the workshop in design practice, an industrial setting was chosen to execute the workshop evaluation. The main advantage of this kind of 'field research' is that results are based on reality. The major disadvantage of the field research is that the activities of the researcher can hardly be planned and defined when starting the research project, and that there is no guarantee that results will be useful, or the observed situation will continue without interruption (Blessing and Chakrabarti 2009, page 254). Indeed we experienced that we depended on the willingness of companies to participate and the extent to which they thought the technique would be of added value to their design project. Also, one planned case was cancelled because of major changes in the product development project. However, finding appropriate cases eventually did not cost a lot of effort, because the participating companies were interested in the technique and participation required relatively low investment and risks. Three workshops were executed with three different product development teams in two different companies. The workshops were executed at a stage in the design process that was found appropriate by both researchers and the contact person of the company. We agreed with the contact person on which members of the product development team would be invited. This included all members who could possibly benefit from the shared vision on product use. However in some cases invited participants were unable to attend. The workshops were executed in meeting rooms at the participants' work site. The 'experiencing' step was executed in two of the three cases. In both cases this role-play was executed in the company's 'kitchen lab' which resembled the actual use environment of the concerned products. In the third case the experiencing step was not executed because of some unexpected delays in the first workshop steps.

Data gathering

To answer research question 1, a group interview was conducted right after the workshop to ask participants about the extent to which they felt the workshop influenced the shared vision on product use as experienced by them. Furthermore a survey was sent to workshop participants, to have participants reflect on the effects of the workshop in the first weeks following its execution. A limitation of using an interview and survey as a post-test is that we could only evaluate the participants subjective opinion on the extent to which they thought their vision was shared and the extent to which this was caused by doing the workshop. This limitation is acknowledged by the researcher.

The questions on application domain (question 3) and usability of the workshop (question 4) were answered by means of observations and the group interview. The observation was executed by recording the workshops on video and observing them afterwards. Question 3 was answered by means of comparing the answers given in the group interviews with regard to the added value of the workshop as experienced by the participants.

Criteria for accepting a factor or link as existing and successful

To assess the extent to which certain assumed influences in the impact model exist, it was necessary to give a definition of the terms used for the measurable success factors. In this study this concerned the extent to which a vision on product use is shared. A positive influence of the workshop on the extent to which the vision on product use is shared was indicated as true if participants indicated that this sharing increased by executing the workshop.

8.1.3 Set-up of the evaluation

As mentioned above, the Envisioning Use technique was evaluated by means of applying the workshop to actual design projects with actual product development teams in their actual work environment.

Introduction of the technique

Since the teams were unfamiliar with the technique and the facilitation of the technique takes quite some time to learn, the workshops were facilitated by the researchers. This prevented that results were influenced by the learning process of the facilitator. The role of the researchers was thus not restricted to that of an 'onlooker' but they were also partially participating (Patton 2002, page 265).

The workshop started with an explanation of the goal and planning of the workshop. Furthermore an introduction was given to the product use mind map structure of dividing use situation aspects and use issues by means of showing an example.

Cases

Cases were found by sending out a case request to contact persons at various companies in our network. In this request, requirements were formulated with regard to the characteristics of the case. The case should concern a product with dynamic or diverse use situations. The project should be in an early development phase and team members should have knowledge about the use of comparable products or it should be possible to involve experts in the workshop to complement knowledge of product use. Based on this request we could select three cases.

The first real case was executed with a company that wanted to explore the adaptation of an existing software product for filing and workflow support to a for them unfamiliar professional market. Since no project team was yet formed, five employees with different backgrounds were involved in the workshop, some of whom had specific knowledge about the new professional market. The initiator of the workshop was the employee who was assigned with the task to explore market opportunities.

In the second real case workshop we applied the technique at a consumer electronics company to the case of a kitchen appliance for a new cultural market. This project was already in the development stage. The workshop participants were the project manager, usability expert, product designer, product development engineer and marketing manager. The usability expert had already gathered user insights in the new market and thus had an expert role in the workshop.

The third real case was executed at the same company as the second case, but concerned a different kitchen appliance and a different product development team. This project was in an earlier development stage than the second case. The project concerned a successor product of a kitchen appliance and was aimed at achieving a better level of usability than its predecessor. A lot of knowledge was available in the team with regard to usability issues. Participants in this workshop were a usability expert, a marketing manager, three development engineers and a system architect. The product designer was invited as well but unfortunately was unable to attend.

Workshop preparation

To prepare the workshops, the contact person was firstly interviewed to get insight in the characteristics of the project and the expectations of the company. When both researcher and contact person agreed on the expected appropriateness of the workshop for the project, agreements were made on the planning and organisation of the workshop. The contact person was asked to invite participants and gather explicit knowledge of product use if available, for example pictures and quotes of user tests. If applicable, the contact person was asked to organise reference products for the 'experiencing' step. In workshop 2 and 3 these reference products were the one or two most important competitor products and a predecessor. The researchers made a plan for the workshop and prepared necessary materials, such as inspirational images for the imagining step. An example of a workshop plan can be found in appendix 7. The allocation of tasks between the researchers is shown in figure 8.1. Data analysis was executed by the author of this thesis.

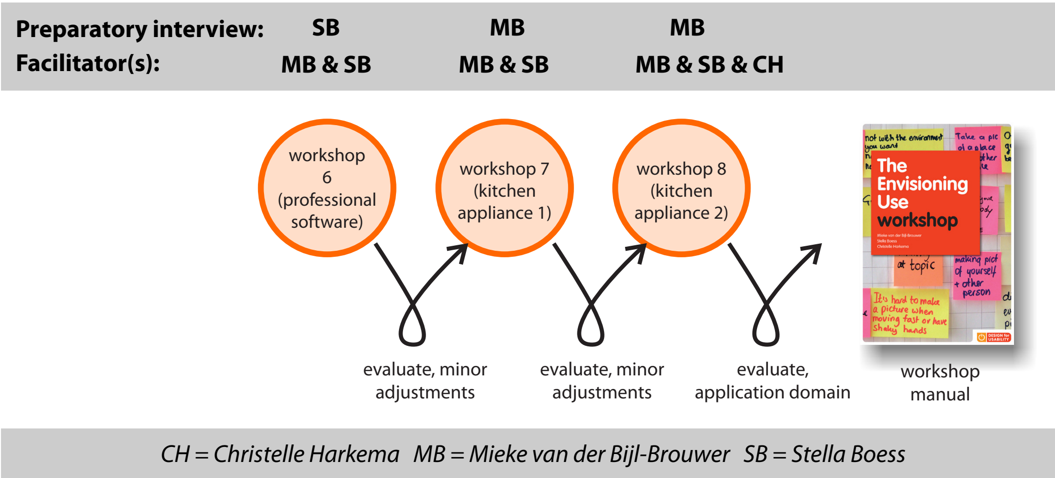


Figure 8.1: evaluation process of the Envisioning Use technique in practice and task allocation between the researchers.

Set-up workshops

Since the cases considered projects in different stages of the development process, the set-up of the workshops was attuned to the needs of the product development team. The case in the first workshop differed from the fictive cases described in chapter 5 in that there was not a product for the new market yet that could be taken as a reference point. More attention was therefore given to the 'imagining' stage. This stage was extended with a technique in which participants could explore different future scenarios in a miniature environment with figurines. This technique is also called 'pivoting' (Urnes, Weltzien et al. 2002).

The other two workshops concerned a product with a predecessor in the market. Therefore all workshop steps were executed in the same way as with the fictive case described in chapter 5. All three workshops were executed within four to five hours.

Interview questions

After the workshops a short group interview (15-20 minutes) was conducted to ask participants how they experienced the workshop. A standardised open-ended interview was applied to focus the interview so that interviewee time is used efficiently and to facilitate analysis by making responses easy to find and compare (Patton 2002, page 346). The interview questions were specified in advance:

1. What is the added value for you of this workshop? (research question 2)
2. What could this workshop add to your general way of working? (research question 3)
3. How easy or difficult was it to fill the mind map in the structure we proposed? (research question 3)

In workshop 2 and 3 additional questions were asked by researcher Christelle Harkema with regard to awareness of known and unknown information about use. These questions are outside the scope of this research.

Survey questions

Six to eight weeks after the workshop, participants were sent a survey with the following main questions. Although the main questions were equal for all cases, some specific questions were added or removed in the second and third workshop, based on the results of the preceding workshops. The detailed survey can be found in appendix 8. The main questions were:

- Do you feel the workshop helped in generating a shared view on product use? (research question 1)
- How did or would you use the information generated on the flip charts in subsequent design activities? (research question 3)
- Do you have any other comments about the usefulness of the workshop?

8.1.4 Data analysis

Based on the observations in the video of the workshop and the experiences of the researchers as facilitator, a workshop report was created which described the time needed for the steps and the most important issues that occurred. For reasons of confidentiality these reports are not presented in this thesis.

The interviews were transcribed completely. Relevant sections were identified in the workshop report, transcribed interviews and surveys and assigned to the appropriate research questions or additional categories.

8.2 Results

8.2.1 General workshop results

Table 8.1 shows the different steps that were executed for each workshop. In workshop 1, more time was spent on remembering, imagining and envisioning in comparison to the other two workshops, because it concerned an unfamiliar target market and it was still completely open which type of product was going to be developed. For time reasons it was not possible to execute the experiencing step in that workshop.

Unfortunately the response to the survey was very low. Of each workshop, one participant filled out the survey completely. One incomplete survey was submitted for the third workshop. Some participants gave short comments on the workshop through e-mail. This low response affects the reliability of the results. Although some of these limitations could be compensated by means of the valuable results of the group interviews, the researcher acknowledges the fact that the reliability of the results with

	Workshop 1	Workshop 2	Workshop 3
Topic	Software product for unfamiliar professional market	Successor product of kitchen appliance for new cultural market	Successor product of kitchen appliance for familiar market.
Participants	Project leader, two usability engineers, one visual designer (expert prof. market), one consumer researcher	Project leader, product (use) researcher, marketing manager, designer, engineer	System architect, product (use) researcher, marketing manager, three engineers
Steps	All, except experiencing	All	All

table 8.1: overview of the characteristics of the workshops

regard to the lasting effects of the workshop on the design process is moderate.

8.2.2 Question 1: a shared vision on product use

The hypothesis was that doing the Envisioning Use technique could lead to a shared vision on product use. This was confirmed in all the three workshops we did. However, we could distinguish different aspects of this 'shared vision' that came forward in all the cases. These aspects considered sharing knowledge of product use in general, creating a shared view on which issues were considered important and creating a shared view on which knowledge lacked and should be gained. Finally, some comments were given on the added value of this shared vision for decision making.

Sharing knowledge of product use

During the workshops we observed several instances at which knowledge about (current) product use or the current situation was explicitly shared between team members. For example, in workshop one, during the imagining step in the miniature environment, one participant would ask the 'expert' participant questions that were related to the unfamiliar professional market such as 'who is making the file?'. And in workshop 3, the questioning step led directly to knowledge transfer. For example, one participant would ask 'did we ever investigate [certain issue]?' and then the other participant answered: 'yes we did, the answer was [..]'. This knowledge transfer was also acknowledged by the participants, as can be concluded from the following quotes:

Project leader (workshop 1): "it is a good means to share knowledge of which you were not aware the others did not know"

Participant (workshop 1) "and I am not in the project, so I know nothing about the [new professional] market, but through brainstorming I feel like after four hours I have an image of what issues are of importance, so I think it has a very good knowledge transfer".

Usability expert (workshop 2): "the information that is in the heads and the assumptions are really captured."

Engineer: "true".

Designer: "yeah, do it together".

Usability expert: "so that is for me also the main advantage of this approach, even though you already know quite a lot."

Participants mentioned that sharing knowledge was stimulated by the interactive character of the workshop:

Participant (workshop 1): "If someone tells you something, do you know it then? Maybe you do not know it exactly. And somehow, this is different than telling. It is more experiencing and therefor for me things now are just the way they are, more than when the project leader told me"

This can also be concluded from the following comments in which participants compare the interactive character of the workshop to more passive group sessions, for example a risk analysis session (here participants refer to an FMEA (failure mode and effect analysis) session):

Usability expert (workshop 2): "In for example a user FMEA it is sometimes really difficult to get the team on this level"

Project leader (workshop 2): "...because, I think therein actually these techniques add a lot of value […]. We sometimes facilitate FMEAs with other companies and always try to have them, to be active instead of staring at a screen, which is usually what happens with FMEAs. That really doesn't work, you never get to this level of thinking".

Creating a shared vision on future use

The second aspect of the shared vision is the extent to which team members agree on what are the most important issues to take into account in the solution or what the desired future use is. This was achieved in all the workshops, as illustrated by the following quotes:

Participant (workshop 1) "By doing the workshop, you get a more common view on what is important within the team.

Project leader (workshop 1): "It is good to bring the higher level goals together. If you have a team and you have collaborated for many years, than you are able to zoom in very quickly, but sharing the higher level goals is seldom done. And now, when you are at the beginning of a project, it is a very good means to get on the same page and complete each other's knowledge ."

However, in the survey, the project leader mentions that although he agrees that the workshop supports creating a shared vision, he would not call it a vision. He mentions it mainly contributed to sharing knowledge with new members of the team. This raises the question what happened to the vision on future use between the time of the workshop and completing the survey (six weeks later). This might also be due to the fact that no project team was created yet at that stage.

The added value of the workshop for the shared vision on future use can also be derived from a comment of the system architect of the second workshop who mentioned that he regretted that the product designer did not attend, because they would now have to convince him of some of the decisions that were made. For example, they reconsidered the appropriateness of a certain sub solution about which some use issues emerged during the workshop. From this can be concluded that a shared vision is created within the workshop, but is expected to be difficult to transfer to team members that were not present.

The content of the vision on future use was not only shared, but also adjusted during the workshop, as can be concluded from the following quotes:

> *Usability expert (workshop 3): "What I found funny is the discussion about [feature X]. With our predecessor product we said [feature X should work like this]. But if you think, well, the scenario we envision is [scenario Y], and then [feature X] might not be that useful anymore."*

> *System architect (workshop 3): "What I find annoying is, before we all said, we need to have [feature Y], that is nice. But now, if you use it [in the role-play with competitor product] you think, oh no"*

In that particular role-play it was observed that the mentioned feature led to unexpected usability problems. This implies that new issues were found or that some issues with regard to future use gained priority.

The way in which the vision on future use was created varied per workshop. Since the first workshop concerned a case for a new market without a predecessor product, participants were asked to create ideal future scenarios together in the 'envisioning' stage instead of creating product ideas. Participants were particularly satisfied with this activity:

> *Participant (workshop 1): "I liked creating the future scenario and then go back to the basis and try to achieve the scenario step by step. Then you know where you eventually want to go".*

> *Participant (workshop 1): "Even though we indicated that the scenario we created was fictive, it is just like we experienced it as a group. And that is different than when somebody says: well, I know a story and it goes like this".*

A participant of workshop 2 indicated that he missed that kind of higher level envisioning:

> *Participant (workshop 2): "Maybe you should have been ehm maybe more strict about ok, now forget about the product but really think about usage scenarios and then start to think about it from that angle. Because [...] we immediately started talking about our product".*

This suggests that the creation of the shared vision on what is important in future use could benefit from the ideal scenario approach, even when there is a predecessor product.

Creating a shared vision on important questions

The third part of the shared vision was the sharing of what was not known and prioritising these knowledge gaps to decide on necessary research activities. This is illustrated by for example a quote of the usability expert of workshop 2:

> *" [the workshop stimulated] to come to one page with everybody, to what do we know, what don't we know and how important is it to find out, to get answers for things we don't know."*

And by the following quote of one of the development engineers of workshop 3

> *"Doing it together results in that it becomes apparent what you do not know together. This works better than just telling each other."*

Added value of the shared vision in decision making

The former paragraphs described the different aspects of the shared vision. The impact model (figure 7.8) indicates that a higher level goal of the shared vision on product use was the influence it would possibly have on making design decisions with regard to product use. Although it was expected that this could not be analysed within this study, several comments of participants suggest that this is indeed true:

> *Participant (workshop 1): "If you would do this with ten people, then after one afternoon you would have the idea of, this is what we are going to make, this is the problem we are dealing with. And somehow I think this will often play a role in future decision making. You get a more common view on what is important."*

> *Usability expert (workshop 2, in survey): "Targeting helped setting the mindset and influenced decision making in value engineering sessions."*

> *Usability expert (workshop 2, in survey): "We now have a shared experience (role-play) to fall back on in discussions."*

Conclusion shared vision on product use

The hypothesis that doing the workshop leads to a shared vision on product use is confirmed. The analysis of the results showed that this vision consists of shared knowledge of current product use, a shared idea of desired future product use and a shared idea on which knowledge lacks and what should be done to fill the knowledge gaps. The vision on future product use was not only shared, but also adjusted during the workshop, based on experiences in the role-play. How long the complete shared vision on product use lasts could not be concluded because of the low response rate to the survey and contradicting answers to the concerning question.

Several participants suggested that the workshop stimulates the transfer of knowledge between members by means of its interactive character and by making explicit what is not known. The use of scenarios could be stimulated more to get to a higher level definition of product use and prevent fixation to current solutions. Finally some comments were made that suggest that the shared vision on product use has a positive effect on decision making.

8.2.3 Question 2: application domain

All the workshops were held in a different development stage of the design project. The first case was done in an early phase as an exploration of a possible project. The second case concerned a project which was already in development and had a proposition with fixed focus points. The third case was in a predevelopment stage in which there were still possible directions for concept development. In the iterative evaluations of the workshop described in chapter 5, participants indicated that they thought it would be useful to do the workshop in an early design phase. In the cases described in this study we observed indeed that in the second workshop, which was the furthest in the design process, we experienced some problems with regard to this issue. The project leader of that team indicated that in this stage of the development process doing the workshop risks making team members frustrated, because they are made aware of questions that cannot be answered and no large adjustments can be made to the concept anymore:

> *Project leader (workshop 2): " This is more something for predevelopment than for, because we are now basically in product development, we're in execution. So basically what we have is what we get […] There are some things we can do in details, but we cannot all of a sudden change the whole idea around"*

> *Project leader (workshop 2) "But i think some of these questions you can only answer with let's say predevelopment. So, what might happen now, is that we have these questions and we cannot solve them. It can happen. And then we have to just take the risk along or we just have to decide, ok, the best we have. But now we have the questions on the table, so that can be quite frustrating maybe for the team."*

However, they also indicate that it is better to make them explicit at this moment, than not at all.

> *Usability expert (workshop 2): "But I think then it is better to have them on the table than in everybody's head. It just revealed them […]. The questions would have been there anyway […], maybe even come up later. At least they are now on the table. The worst thing that we can do is put them aside but know that we cannot do anything about it anymore. But it's not I think, we did not create any new questions or uncertainties."*

> *Project leader: "That is true. Then you can consciously decide not to pursue it."*

Furthermore in all the workshops, the level of detail of issues and questions was discussed with regard to the design phase. In workshop one, there was no possibility to do a role-play with a comparable product, because of its early development stage. One participant explicitly indicated that now it did not become clear which issues play on product level. He also indicated that this would not be desirable at this stage:

> *Participant (workshop 1): "I think it is good not to zoom in on product level right away. Because now you have to come loose of this solution that was chosen kind of randomly. Now you are focusing on what is really needed and what these users have to deal with and what they need. What the real problems are."*

And for the later workshops participants indicated:

> *Engineer (workshop 2): "On the one side you would have done it a bit earlier because some questions are now too late to answer, possibly. But also if we would have done it earlier we would have had less knowledge so we wouldn't have had those questions. So it is always a give and take when do you do it, and it has to grow maturity."*

> *Engineer (workshop 3)"I think a better timing would have been to execute the workshop with our first predecessor. This is already a third successor product"*

>> *Usability expert (workshop 3): "On the one hand I agree. On the other hand the second successor was executed differently and if we would have done it earlier in the process, than you could not have done it on this level. So we attuned the choice for doing the workshop now to the fact that we already somehow chose a concept direction."*

Chapter 5 showed that participants had contradicting opinions with regard to what appropriate projects would be to apply the workshop to (see section 5.5.2). They questioned the novelty of the product and the familiarity of designers with the product. In the workshops described in this chapter, none of the participants thought that their project was inappropriate for the workshop. The familiarity turned out not to be a problem. In both workshop 1 and 2, at least some of the participants were not familiar with the target market (both cases) or the design concept (software case). The knowledge transfer function of the workshop resulted in that a lot of information about those unfamiliar topics was shared between the 'experts' and the other participants. Therefore unfamiliarity is not a problem, as long as participants with expert knowledge are involved. The novelty of the to be developed project did neither influence the usefulness of the workshop. The first case considered a non-existing product, while the second and third case considered successor products. Since all workshops led to valuable results, it can be concluded that the novelty of the product does not influence the appropriateness of the workshop.

From this can be concluded that the workshop is useful at any stage of the development process in which the results of the workshops can still be used to improve the design or to steer research activities with regard to the design. In the earliest stage, when there is no concept or design brief yet, the results will be high level, while later in the development process, issues and questions will be more detailed. The workshop can be applied to both novel and successor products.

8.2.4 Question 3: workshop usability

The usability of the workshop was analysed on two levels. Firstly we analysed the effectiveness and efficiency of the (combination of) steps within the workshop. This means we observed the general progress of the workshop and asked participants how difficult or easy they found the workshop steps. Secondly we investigated the usability of the workshop within the actual design process, by asking participants about how they used or would use the information gathered in the product use mind map.

Usability within the workshop: the division in use situations and use issues

Chapter 5 showed that in some workshops participants experienced difficulties with the proposed use situation- use issue division. The iterations showed that the division supported 'going back and forth between stories and scenarios' and thus revealing more knowledge of product use (section 5.5.4). In the second workshop of this study this problem emerged again. Both the designer and engineer admitted that they found the use situation – use issue structure difficult. The usability expert indicated that this was also due to the fact that they had to learn that way of thinking. The engineer commented on that as follows:

Engineer: "The question is, what does it add? If I now all see this, we did not use or the yellow or the pink. Where is the added value of all that thinking?"

Apparently it was not clear to them why they had to make the division in use situations and issues. Therefore, in the third workshop, we tried to make the added value of that way of thinking more clear in the introduction. However, we then experienced a similar problem, when the marketing manager asked in the remembering step why he could not just describe his complete lists of user insights, which is essentially a list of use issues only. Eventually the participants indicated after the workshop that they did appreciate this division. They mentioned that a strong added value of the division, in comparison to lists of user requirements or user insights, is that it adds context to those requirements.

Participant (workshop 3): "We are polluted with lists. When you have an existing product, there is always someone who says: this is the top ten complaints, this is the call rate and we have all those lists in our heads. But now we have to step back and say when these issues occur. Someone runs in to something and then things happen."

Participant (workshop 3): "And that was what was strong about the division in use issues and use situations. Particularly the use situations lack in those lists and then you just see the issue, but not the background of it."

This added value of adding context to the vision on product use can also be derived from the following comment of the usability expert of workshop 2 in the survey:

Usability expert (workshop 3 in survey): "Priorities did not change in the workshop, because the product proposition is already fixed and the focus points are known. However it made more explicit what is meant by these priorities".

Therefore it can be concluded that it remains very important to explain why the division in use issues and use situation aspects is made. The added value of that way of thinking in comparison to lists of requirements can then be used as an additional argument.

Usability within the workshop: kick-off and wrap-up

A second usability issue that emerged was related to the starting point and wrap up of the workshop. In the first workshop the kick-off did not go smoothly because it was not clear to everyone what the ideas for the desired functionality of the to be developed system were. It turned out that we also had a wrong idea of this desired functionality. Therefore we had a long discussion on the relevancy of for example the division in use phases. Although we did have the project leader explain the ideas on the system in words, next time it might be a good idea to have the responsible person prepare a high level scenario that describes the future situation. In the other workshops we did not experience this problem, because the teams had been working together for quite a long time and had a clear project objective, which was also discussed before the workshop with the researchers. From this can be concluded that it is important to have the project leader share the project goals with the other participants at the start of the workshop, particularly when the project is in a predevelopment stage.

In the second workshop, we did not have time to wrap up the questioning step. Therefore the workshop ended with just a list of questions, without an addition of priorities and steps to take to get them answered. The project leader then said:

Project leader (workshop 2): "I don't feel happy with it but I don't know why. That is what I think good, that it is put on the table […], but we still have to conclude on the questions […]. There are only more questions, that is good, but what is next. That is what I miss in the process."

This indicates that it is very important to plan the workshop in such a way that it always includes a clear wrap up in which decisions are made on subsequent activities.

Usability of the information gathered in the product use mind map

As in the workshops described in workshop 5, we discussed with participants how to use the information in the product use mind map. We did not get insight in how the information was actually used after the workshops, although the usability expert of the second workshop indicated that she planned to add the results of the product use mind map to the presentation format which is standardly used by the company to represent user experiences. Other means of representation that were suggested by participants are similar to the ones suggested in chapter five and include for example a visualisation of the results in an animation of the desired scenario in which the use issues are explicitly annotated. In the second workshop, participants mentioned that they found it important to add the workshop reasoning to the results. This reasoning does not become clear from just the list of target issues and the list of questions.

Project leader (workshop 2): "Basically we went through a couple of steps, and if only a summary of six lines after all these steps, I don't see them in the background of what is done before."

Marketing manager (workshop 2): "I think a logical approach that I would take the results and put them indeed […] into context of what we have done. So where does this come from. Then from all this information we derived several attention points and then those left us with some questions. And if we have these questions related back to the context where they came from, we can decide, is it worth it to really investigate them and provide answers to them or can we just make a decision to leave it or to just do a or b without investigating"

From this can be concluded that the reasoning within the workshop is found important as background to the questions and target use situations and issues, but that it is not clear yet how this reasoning can best be captured to be able to communicate it.

Conclusions question 3

Although some participants experienced the thinking in use issues and use situations as difficult, they eventually all managed to apply that division successfully. However, participants should be explained clearly what the added value of this division is. An additional benefit of the use situation-use issue division to the earlier mentioned value of going back and forth between stories and scenarios, is the fact that it adds context to the use issues, as opposed to lists of requirements or user insights. Another conclusion that can be drawn with regard to the usability of the workshop is that the starting point of the workshop should be made clear by means of alignment of workshop expectations and the wrap up of the workshop should always be included to make a connection between the workshop results and subsequent activities. When the results of the workshop need to be communicated it is important to add the reasoning which was done in the workshop to the representation. Although some suggestions were done on visualisation formats of these results, there is no insight yet in what an appropriate means for this representation is.

8.2.5 Question 4: side effects of the workshop

Question 4 concerned the new 'side-effects' of the workshop. These unexpected results concern the influence of the workshop on the dedication of participants to usability and the added value of the workshop for the factuality of the frame of reference of product use.

Dedication to usability

One important effect that came forward and which was not directly related to the creation of a shared vision on product use, was the extent to which the workshop made participants more 'dedicated' to usability in general. This is illustrated by the following quotes:

Usability expert (workshop 2): "It is sometimes really difficult to get a project team really think about the use and what it means. And not related to the product in a technical sense. I think, maybe you don't see it. These post its are really on a level of getting into the skin of a user that I don't often see"

System architect (workshop 3): "Now you clearly have a refreshed mindset of what product use is about"

Pre developer (workshop 3 in survey): [Question: what was the added value of this workshop for the development process?] "Insightful, being put into the role of user helps to open your eyes to more day to day experiences users may face"

This suggests that the participants feel they become aware (again) of the need of usability and start looking (again) at the product from the perspective of the user. However, one engineer of the third workshop indicated he still found usability a very difficult subject, because 'you can never do it right'. This suggests the workshop stimulates, but does not guarantee dedication of team members to usability.

Factuality of the created frame of reference

Participants furthermore commented on the content of the frame of reference with regard to its factuality. In the impact model introduced in chapter 7, it was assumed that the workshop could only influence the number of use situation- use issue connections (link 9 in figure 7.8), but not their factuality. This lack of influence of the Envisioning Use technique on the factuality of the frame of reference indeed came forward in the workshop evaluation and participants had several recommendations to increase this factuality. The project leader of workshop one indicated that it would be interesting to do the workshop with experts:

Project leader (workshop 1): "I think it would be good to do the workshop with clients, with the users, because we are imagining this, but we are not the [professionals]. What can we say about that? We don't know anything about it, do we?"

From this can be concluded that in order to achieve a satisfying level of knowledge transfer, one should make sure to include enough 'experts' in the workshop, be it team members with expert knowledge or external experts.

Furthermore some participants indicated that they should be aware of the bias in the data, as mentioned in the second workshop:

Marketing manager (workshop 2): "We are working for a while together now. Unconsciously and consciously we are influencing each other. We now have a group opinion, which is a good thing but might be dangerous as well.

The marketing manager of the third workshop mentioned during the workshop that they are biased, because they know the product too well. He indicated that he needs consumer data to realise that sometimes things go wrong. This suggests that involving external experts could limit the level of bias of the frame of reference.

The results furthermore showed that additional activities are needed as a foundation of priorities in usability issues:

Marketing manager (workshop 3): "We can now imagine a lot of situations that lead to those issues. But if you want to get to the core, you have to know the most important and most occurring issues."

Project leader (workshop 2): "So, I think what we can do as a summary and conclusion of this session is to take the open questions to the risk assessment, user FMEA whatever and there rank, if we really think it is a high risk than we need to action it. We have to do that anyway in risk management. When we think as a team it is a high risk what action do we put behind it and who does it, etcetera"

The added value of these additional activities for this purpose was confirmed by the engineer of workshop 3 in the post-workshop survey:

Engineer (workshop 3 – in survey): "The workshop itself did not clarify the target, the work afterwards did."

Concluding, the factuality of the created frame of reference depends on the expert level of the participants with regard to the topic, for example by means of preceding design team activities with regard to product use. Participants furthermore indicated the need for inclusion of real user-data to compensate the bias of the team. Finally, additional research or risk assessment activities are needed to further analyse priorities in the frame of reference.

8.2.6 Evaluation of the research method

The observation and group interview gave sufficient insight to answer the research questions with regard to the direct effects of the workshop. A survey approach was used to analyse the effects of the workshop on the design process following the workshop. This approach was unsatisfying, because the response level was low. Furthermore, some participants indicated that the workshop was too long ago for them to remember what they did with it. The research approach therefore might be improved by an adjusted timing of the survey or choosing another means of data gathering.

8.3 Discussion and conclusions

The evaluation of the workshop in three real design cases in practice showed that the hypothesis that the Envisioning Use technique positively influences a shared vision on product use could be confirmed. This vision includes sharing of available knowledge of product use, creating and sharing a vision on desired future use and creating and sharing a vision on which knowledge lacks and which are the most important questions to investigate further. The evaluation did not give insight in the lasting effects of the workshop on the shared vision.

With regard to the process of creating a shared vision, we can conclude that the knowledge transfer seems to be stimulated by the interactive character of the workshop. Furthermore the ideal scenario approach such as executed in the first workshop could be exploited more to support the creation of the shared vision on desired future use.

With regard to the vision on future product use, participants appreciate the addition of knowledge of use situations in comparison to lists of user requirements. However, the results also showed that participants want to capture this ‘context’ of both the target use issues and questions in such a way that it could be taken into the design process. More research is needed to investigate if and how the vision can be communicated and can last in the design process.

Finally some comments were made which suggest that the shared vision supported later team decision making processes. However, this suggested influence needs further research to have it confirmed, for example by means of observations of group meetings and interviews with those concerned.

The evaluation furthermore showed that the workshop is useful at any stage of the development process in which the results of the workshops can still be used to improve the design or to steer research activities with regard to the design. This includes the phases design brief formulation and the stages analysis and synthesis of the strict development phase in the Delft Innovation Model (Buijs and Valkenburg 2005). This suggests that it is useful to do the workshop as early as possible in the development process and repeat the workshop in later stages of the design project. This appropriateness of the workshop for these design stages already became apparent in the student projects discussed in chapter 6 and 7.

With regard to the usability of the workshop, the results show that the current workshop set-up is usable, but that it remains important to clearly explain the goals of the workshop and the goals of the use situation- use issue division to participants. As explained in chapter 5, the goal of the latter is to support revealing knowledge by going back and forth between stories and scenarios. An additional motivation to employ the division came forward during the study described in this chapter. This concerns the added value of the use situation – use issue structure in adding context to use issues, as opposed to user insight lists or user requirement lists. Finally it became clear that the wrap up of the questioning step is very important to be able to take the results of the workshop into the design process.

A side-effect of the workshop is its possible – but not guaranteed - effect on the dedication of team members to usability in general. This assumingly influences the empathy of team members for the end-user. This kind of 'empathic design' increases the likelihood that the product designed meets the user's needs (Koskinen, Battarbee et al. 2003).

To increase the gathering of factual knowledge of product use, participants suggested to involve experts. Including experts could also possibly compensate the mentioned bias of the team with regard to product use. As discussed in chapter 3, these experts should have a broad knowledge of product use, such as the bicycle dealers for the bicycle carrier case. In general, end-users will not be able to provide this broad view, because they can only relate to their personal experiences or to what they have observed in their close environment. Therefore we recommend to carefully consider the selection of participants with regard to their expected breadth of knowledge of product use.

Summarising, the study showed that the workshop is successful in creating a shared vision on product use in design teams. The indications that were found with regard to the effect of the shared mindset on decision making were further investigated in the study which is described in the next chapter. This study also evaluated the revised guidelines which were introduced in chapter 7.

9 Evaluation Of The Revised Guidelines

9 Evaluation of the revised guidelines

Chapter 6 and 7 described the development and application evaluation of a workbook with guidelines which designers can use to develop an approach which integrates knowledge about DDUS in the design process. The core functionality of the initial support was aimed at building an explicit frame of reference of product use which could be applied in use evaluations, for communication purposes in decision making and as inspiration for solution generation. The first iteration showed firstly the importance of a shared implicit mindset of use situations and issues and the assumed influence of the Envisioning Use technique on this issue. This hypothesis was confirmed by the study in chapter 8. Secondly, the first study led to the hypothesis that a better structure of use situation – use issue connections, and a more complete frame of reference leads to more externally valid and focused evaluations and thirdly it led to the hypothesis that a combination of exploring and verifying activities leads to a more complete frame of reference of use situations. These hypotheses were integrated in a revised workbook which was further evaluated in a design project which is described in this chapter.

According to the Design Research Methodology Framework of Blessing and Chakrabarti (2009, page 18) this chapter describes a comprehensive descriptive study II. This type of study is aimed at evaluating the developed design support, in this case the revised workbook presented in chapter 7. This chapter firstly introduces the evaluation focus, including the objective and research questions. Secondly it describes the evaluation plan including the research method. Thirdly the research questions are answered based on the result of the evaluation. Finally, it concludes with a description of adjustments that are made to the revised workbook based on the evaluation. These adjustments are integrated in a final workbook, presented in appendix 10.

9.1 Evaluation objectives

It was chosen to conduct another evaluation through a student project. This type of evaluation can give more insight in the usability of the revised support and how the revised guidelines are applied. In that sense it is closer to an 'application evaluation' than a 'success evaluation' according to Blessing and Chakrabarti's definition (2009, page 184). As Blessing and Chakrabarti state 'success can only be truly measured in the intended situation, i.e. in practice' (2009, p207). Although the guidelines are now in a less explorative state than the initial guidelines were, a true success evaluation of the guidelines in practice at this point is still not desirable. It would require considerable risk-taking from participating companies, based on the needed investments in proportion to the uncertainty of the expected success at this stage. An 'application evaluation' is aimed at testing the direct influences of the support with regard to the key factors. However, in comparison to the study described in chapter 7, higher level influencing ‘success’ factors are considered in this study as well. The study therefore has the aim of both evaluating the usability and application of the revised workbook with regard to the key factors, as well as measuring the success of the application of the guidelines in student teams.

9.1.1 Research questions

This section describes the research questions which were formulated for this study. These questions concern on the one hand the evaluation of the assumed influences of the revised guidelines and on the other hand they concern their application domain. The research questions that concern the desired effects of the support were derived from analysing the key factors and links in the revised impact model which was introduced in chapter 7(see appendix 6). In this section, these relevant links and factors are mentioned for each concerning research question. The research questions concern: the application and effects of the means of representation and attributes of the frame of reference (section 9.1.2); the different sources that were used to complete the frame of reference and their success in doing so (section 9.1.3); the effects of the application of the frame of reference in usability evaluations (section 9.1.4); the creation and application of the shared vision on product use (section 9.1.5) and finally, the application domain of the guidelines (section 9.1.6).

9.1.2 Question 1: means of representation and attributes of the frame of reference

In the revised workbook, new attributes for the frame of reference were introduced to improve its success. These attributes concern overview and structure with regard to connecting use situations to use issues. Furthermore the limited success of the first workbook with regard to stimulating the creation of an explicit frame of reference, resulted in additional guidance on this issue in the revised workbook. To evaluate these adjustments the following research questions were formulated:

1. What characteristics do the explicit frames of reference of product use have? To what extent is this caused by the support? What are their benefits and limitations? More specifically:
    a. Is the frame of reference made explicit and which means of representation is used to make this frame of reference explicit? (link 1a: the extent to which and how the frame of reference is made explicit)
    b. What is the level of overview of the frames of reference? (link 1c: the extent to which the guidelines lead to better overview of the frames of reference)

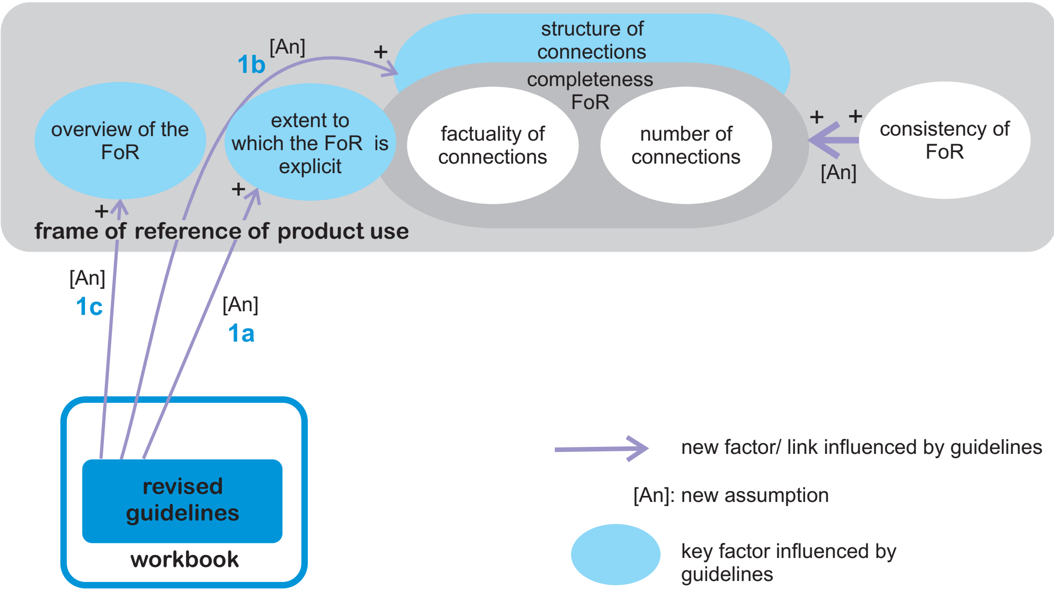


Figure 9.1: part of the revised impact model, showing the assumed influences of the revised guidelines on the attributes of the frame of reference.

c. To what extent do the frames of reference connect use issues to use situations? (link 1b: The extent to which the guidelines lead to better structure in use issue-use situation connections in the frame of reference)

d. What are the benefits and limitations of the general means of representation, level of overview and proposed structure of connections?

The influence of the consistency of the frame of reference on the completeness of the frame of reference was not evaluated in this study.

To be able to judge the results, it is necessary to define the criteria for accepting a factor or link as existing and successful (Blessing and Chakrabarti 2009, page 203). The criteria for answering this first research question concern the attributes of the frame of reference and the influence of the support on the different attributes of the frame of reference.

The influence of the support mentioned in this research question and some of the following research questions is difficult to assess, because no comparative study including a control group can be conducted. Therefore, to analyse the added value of the new guidelines, the results regarding the concerning questions within this study are compared to the results of the previous project

The extent to which use situations and use issues are made explicit can be assessed by comparing the evolution of the frame of reference to the actual relevant target use situations – issues reflected in the design materials (see next section, the evaluation plan). The structure of connections can be assessed by investigating if use situation aspects and

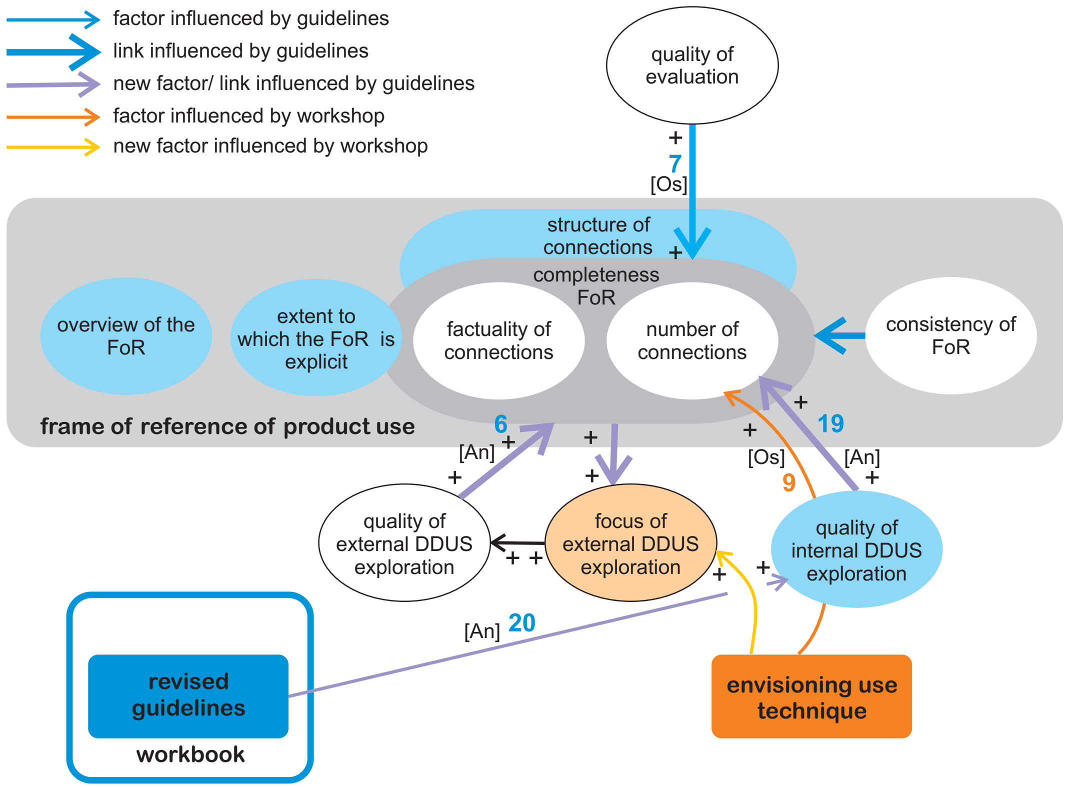


Figure 9.2: part of the revised impact model, showing the assumed influences of internal and external explorations and evaluations of DDUS on the completeness of the frame of reference.

use issues are connected. Finally, the overview of the frame of reference is assessed by asking participants about the extent to which they think their representations of the frame of reference provide the needed overview.

9.1.3 Question 2: sources for the completion of the frame of reference

The first study showed the added value of explorations of DDUS with regard to the creation of the frame of reference. This was translated in a new process model of design activities surrounding the explicit frame of reference (figure 7.5). With regard to the success of these activities in the creation of the frame of reference the following research question was formulated:

2. How is the frame of reference completed and to what extent is this caused by the support? More specifically:

    a. Which types of internal explorations are executed and to what extent is this caused by the support? (link 20: the extent to which the guidelines stimulate the quality of internal DDUS explorations)

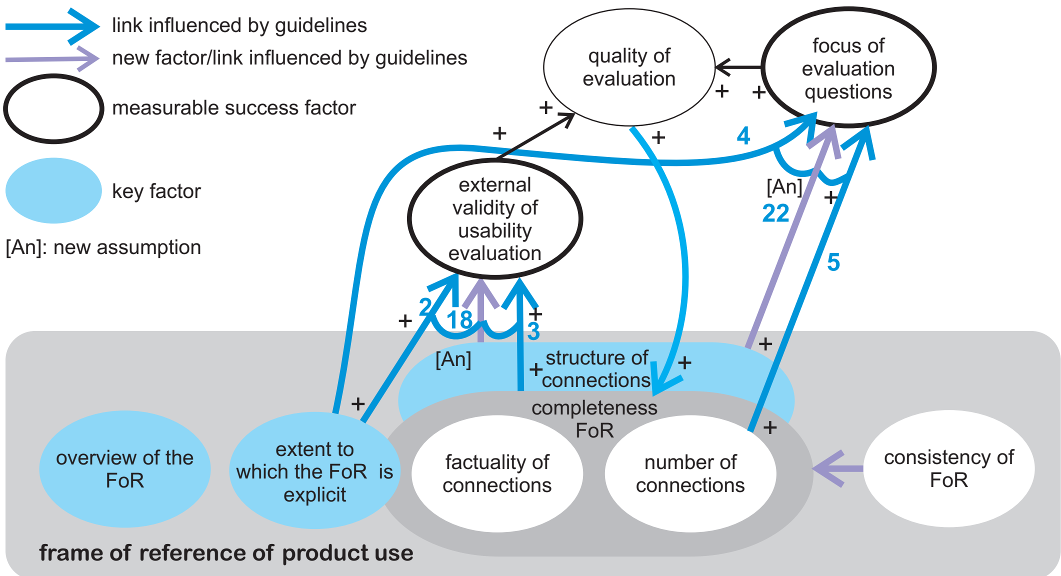
b. How and to what extent are internal and external explorations and evaluations applied to increase the completeness of the frame of reference? (link 6,7, 9 and 19: how internal and external explorations of DDUS and evaluations influence the completeness of the frame of reference)

The completeness of the frame of reference can only be truly measured after the product has been introduced to the market. This was already explained in the evaluation plan of the initial workbook in chapter 6 (section 6.3.2). In this study, the same measurement of completeness will be used as in chapter 6, namely the relative completeness in comparison to previous frames of reference. As for the previous research question, the added value of the new guidelines is assessed by comparing the results of this question to the previous project.

9.1.4 Question 3: application of the explicit frame of reference

The first study showed the added value of the explicit frame of reference in applying it in evaluations of solutions. The structure of use situation – use issue connections was assumingly an important attribute in determining the success of this application. Since the application of the frame of reference in usability evaluations was defined as the most important goal of the explicit frame of reference, this influence was not only assessed with regard to the key links (2,3,18 and 4,5,22), but also with regard to the measurable success factors 'focus of evaluation questions' and 'external validity of the evaluation'. The concerning research questions are:

Figure 9.3: part of the revised impact model, showing the assumed influences of the completeness of the explicit frame of reference and structure of connections on the external validity and focus of usability evaluations.

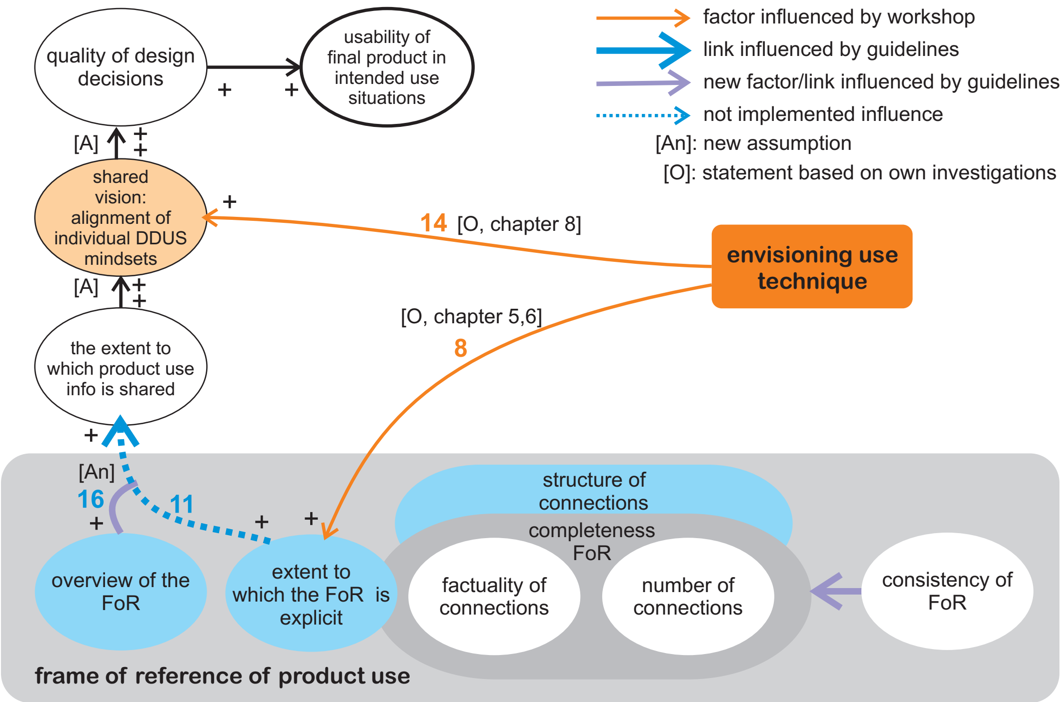


3. How is the explicit frame of reference applied? More specifically:
    a. How and to what extent do completeness of the frame of reference and structure of connections influence the external validity of evaluations (link 2,3 and 18)
    b. How and to what extent do completeness of the frame of reference and structure of connections influence the focus of evaluation questions? (link 4,5 and 22)

The external validity of the solution evaluations is a factor that is difficult to assess. External validity is the extent to which test conditions represent real world situations. Since real world situations will only become completely apparent after the product has been introduced to the market, external validity of the test can only be assessed afterwards. The external validity of the test is therefore estimated by comparing test conditions to use situations that seem relevant, based on an analysis of the explicit frame of reference and other documents that give insight in relevant use situations. The resulting limitations of this measurement with regard to reliability and objectivity are acknowledged by the researcher.

The focus of evaluation questions can be assessed by analysing the aggregation level of the questions in the setup of the usability evaluations.

Figure 9.4: part of the revised impact model, showing the assumed influences on and of the shared vision on product use.



9.1.5 Question 4: creation and application of the shared vision

In chapter 8, the influence of the envisioning use technique on a shared vision on product use was assessed. That evaluation did not give insight in the lasting effects of the workshop. Therefore these effects were measured in this evaluation, resulting in the following research questions:

4a. How is the shared vision created? (figure 9.4, link 11 and 14)

4b. What are the lasting effects of the shared vision with regard to decision making?

The criterion for assessing if these influences exist is if participants indicate that they experience this influence of a shared vision.

9.1.6 Question 5: application domain of the guidelines

While chapter 8 gave insight in the application domain of the Envisioning Use technique, the study described in this chapter was used to investigate the application domain of the guidelines. This part of the evaluation concerns the types of products that are appropriate to design by means of the guidelines. The last research question therefore is:

5. What is the application domain of the guidelines with regard to types of products?

9.2 Evaluation plan

The study concerns a comprehensive descriptive study II following the methodological framework of Blessing and Chakrabarti (2009, page 14). In this stage researchers investigate the impact of the support and its ability to realise the desired situation. A qualitative approach was chosen because the focus is not only on whether, but particularly on why and how the support is successful and applicable.

9.2.1 Test conditions

As described above, applying the workbook to a design project executed in design practice was at this stage not possible. The guidelines were therefore applied by students to a design case. As with the study described in chapter 6, the project was executed in design teams for a real client to simulate a realistic design context as much as possible. The project was executed within the same elective master course as the previous study.

9.2.2 Data gathering

The results of the design projects executed by the students were used to answer the research questions. Questions 1a-1c relate to different attributes of the frame of reference. Insight in the developed frames of reference was therefore needed. From the first study was learned that most insights in the development of the frames of reference were gathered from the portfolios. Furthermore, using the online file storage of the teams had practical limitations. Therefore only the portfolio was used in this study to answer these questions.

Questions 1d, 2 and 3 relate to the design process. Insight in the design process could partly be derived from studying the results of the design process in the portfolio. However, insight in the actual activities was also needed. Therefore students were asked to describe each explorative or evaluative activity briefly in the appendix of their portfolio and they were asked to write an extensive evaluation of their approach. Furthermore teams were asked weekly in a progress meeting which activities they conducted and the researcher kept a log of these activities for each team. Having the students log their own process was undesirable because of the observed overload of documentation activities in the previous study. An additional group interview after the project was conducted to confirm and complete insights from these studies. Thus, like the previous study, 'data triangulation' was used to answer the research questions (see section 6.3.2).

Question 4 was answered partly by consulting the written evaluation of the approach. The additional group interview could be used to further discuss the resulting issues. Question 5 was answered by comparing the results from the case described in this chapter to the carrier bike case described in chapter 6.

As discussed before, the statements that were formulated with regard to the success of the support have restricted external validity since the evaluation is executed in a simulated design context. This restriction in validity is acknowledged by the researcher.

9.2.3 Plan of the design project

Introduction

The introduction of the course was executed similarly to the previous course. The differences are that now a complete workbook was offered, including examples from the previous course and one extra lecture was added to better explain the application of the guidelines. The students again received weekly coaching by the researcher. No additional instructor was involved this time.

Case

Three teams of five students participated in the project. A different case was chosen to further explore the application domain of the guidelines. In the first study, it was decided deliberately to choose a mobile product with many dynamic and diverse aspects. The application of the Envisioning Use technique in practice showed that cases with less obvious dynamic and diverse aspects also revealed many use situation – use issue relationships. Therefore a less obviously dynamic product was chosen as a case. This product is the Philips Airfryer (figure 9.5). This is a deep fryer

Figure 9.5: the Philips Airfryer

which uses air instead of oil to fry food. The dynamic and diverse use aspects of the product concern the different kinds of food that can be prepared using the fryer and the different needs of users. A representative of Philips Consumer Lifestyle (group leader of the product research centre) introduced the brief and was available for feedback. The final results were presented to ten members of the Airfryer development team. The participation of the product researcher had the advantage that a lot of knowledge of use situations and usability in general was already available, as opposed to the first study in which the client had no knowledge at all about these issues. The students could therefore spend more time on applying the knowledge instead of on gathering the knowledge.

Assignment

The assignment that was given to the students was: "analyse the dynamics and diversity of the use, users and context of the Airfryer. Based on these analyses, develop a new version of (a part of) the Philips Airfryer or an accessory that is appropriate for a broad, specified part of the analysed use situations." As described in section 9.2.2, students were asked to create a portfolio of the evolution of the frame of reference and of the design representations and to write brief reports of their evaluative and explorative activities, and a process evaluation. They were free to choose a means of representation for the frame of reference.

9.2.4 Data analysis

Data analysis design process

The portfolios generated by the students gave sufficient insight in the evolution of their frame of reference. To get insight in the design process (questions 2, 6, 7 and 8), the results from the research log, the portfolio and the process evaluation were used to create a summary of the approach of each team. The summary contains a description of the steps that were executed, the related relevant use situations and issues and the related representation of the frame of reference (see table 9.1). Inconsistencies between log, portfolio and process evaluation were indicated by means of shaded cells as input for the group interview.

Set-up interview

Based on an analysis of the design process and the frames of reference as described above, a group interview was set up to confirm the analysis and where necessary fill in gaps in the information. Furthermore the interview was used to discuss issues resulting from the written process evaluation concerning the shared vision on product use (question 4). As with the previous study a standardised open ended interview was applied

Activity	Use situation	Use issues	Representation FoR
Consult online reviews	Random	Advantages and disadvantages of current Airfryer	List of issues and quotes
Brainstorm target groups	Families, YUP		Mood boards for each target [log]
Choose target	Health conscious families, Diverse target group (parents, children, other caregivers)	Health oriented; cooking and eating is important; airfryer not well known	
Collecting information based on CBS and Philips site, 'literature analysis'	Families; varied cooking skills; eat fries once per one or two weeks; not a lot of time for cooking	Healthy food is very important; product safety, easy to use, clean and store	Visual in report + word cloud [portfolio]
Online survey to collect broader data [in log mentioned after intermediate presentation]	20 Families; children often in the kitchen; different ages; cooking and eating habits;	Children can be distracting, sometimes help cooking; serving the food	Graphs

Table 9.1: example of a part of an approach summary, based on log, document analysis of report and evaluation essay; shaded cells indicate inconsistencies between different sources.

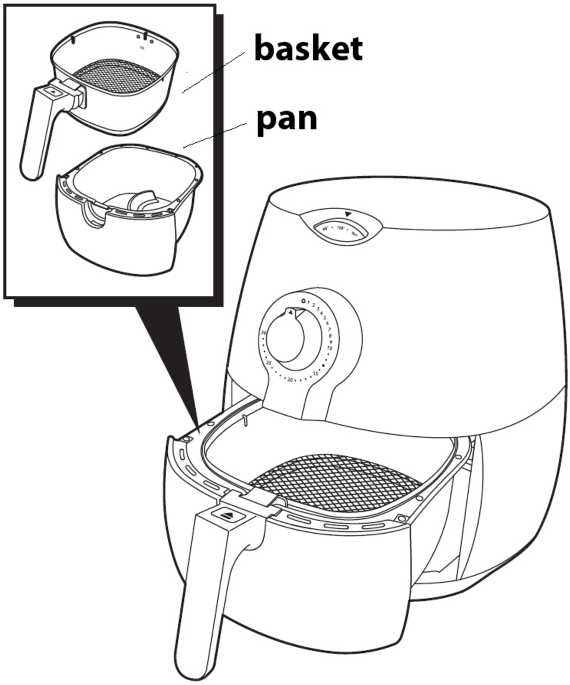
to set up a 30-minute interview. Apart from the specific questions with regard to the inconsistencies and gaps in abovementioned summaries of the approach, the following general set of interview questions was posed. This list was kept short due to the short time available for the interview:

1. According to you: what is a design approach aimed at DDUS?
2. Did the followed approach help you in getting a view on the use situation(s) of the product and taking that into account in the design process?
3. What are the benefits and limitations of your approach?
4. What would you do differently in your process a next time?
5. Which parts of what you did would you apply in a future project?

Data analysis interview

The group interview was transcribed completely. Subsequently relevant sections of the transcripts and written process evaluation were identified and assigned to the research questions.

Figure 9.6: an explanation of the Airfryer parts



9.3 Results

9.3.1 Summary of the project results

For clarification of the team results a short description of the Airfryer features is given. The Airfryer is a kitchen appliance which can be used to fry food with hot air. The current product contains a basket, connected to a pan which collects excess fat. The pan and basket have to be removed from the device halfway cooking time to shake the prepared food and after cooking time to serve the food. The basket can be removed from the pan for cleaning purposes and to serve ingredients (see figure 9.6). Two rotation buttons on the appliance can be used to set cooking time and temperature.

Team 1 extended their initial target of families with children, with elderly couples of 55+ years old who want to prepare a meal for two persons at once. Their main concerns are health and convenience. The most important issues the team worked on were the needed shaking of the basket which is quite heavy, particularly for elderly; difficult to read settings and problems of space with regard to the different parts that need a place on the kitchen counter. They designed a top-loader concept with a clear interface, no need for extra space, a familiar way of opening compared to traditional cooking pots and a light weight basket (see figure 9.7).

Team 2 chose a target based on the mentality model of Motivaction (2012), which divides populations into separate segments by plotting status and values against each other in a diagram. The team chose the

Figure 9.7: results of team 1, an Airfryer for elderly: the final design and two photos of a usability evaluation with elderly.

so called ‘social climbers’ as a target. In the Motivaction model this class consists of relatively young people who are individualistic, materialistic and status-sensitive. The main issues that they worked on in the project were convenience (food needs little attention), a luxury look and inspiration for cooking. Half way they found out the target group was not interested in the Airfryer because they perceived the device as a deep fryer whereas they preferred healthy food. The group then tried to remove the associations with unhealthy food by means of a new design. Their final design consisted of a new design Airfryer (they changed the name to Aircooker) with different compartments which allows cooking different ingredients in equal amount of time, recipe support and an App for more recipe and shopping support (see figure 9.8).

The target group chosen by team 3 consists of health conscious families with children. They focused on problems with controlling the device because of distraction of children in the kitchen, safety of small children and storage of the parts. Their main objective was to design a product which keeps usability of parents intact while giving parents the idea that the product is safe. The main use situation aspects they considered were the level of perception of safety of parents and different cooking and eating rituals of the families. Their final solution is an Airfryer with a child lock and space on top to store the basket (see figure 9.9).

Figure 9.8: results team 2: a ‘convenient and luxurious Aircooker’ for social climbers: ‘tasty, easy, quick and healthy’

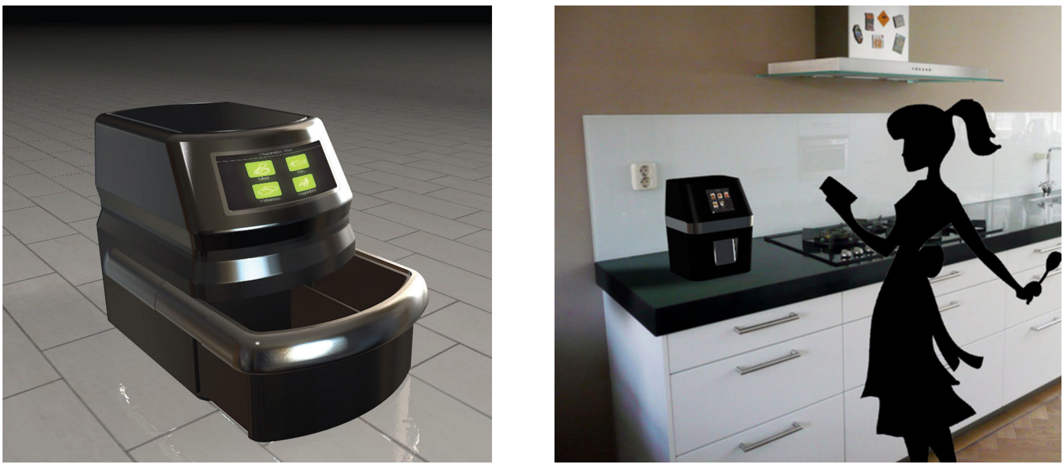


Figure 9.9: results of team 3: Airfryer for families with children with a high level of child safety

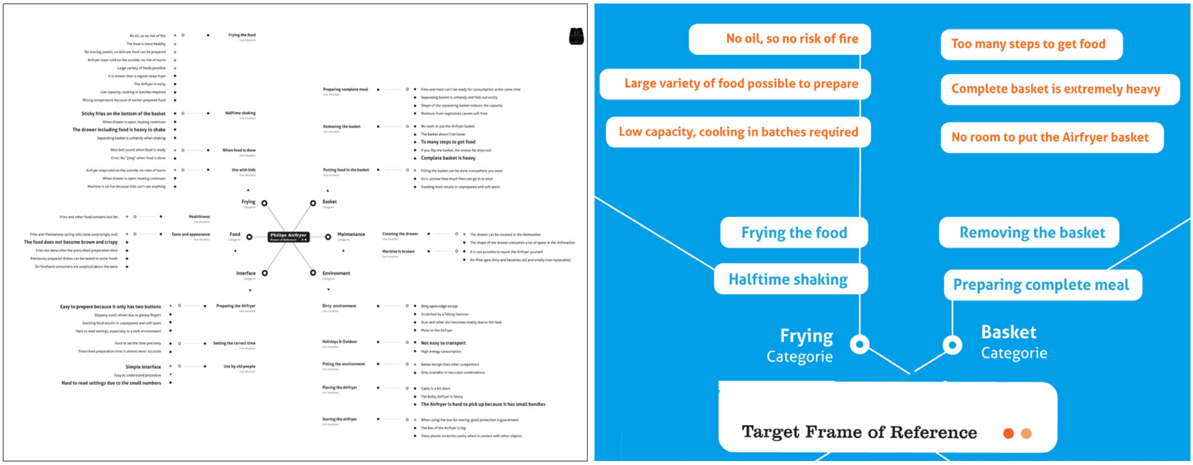
9.3.2 Question 1: the attributes of the frame of reference

The first research question concerned the extent to which and how the frame of reference was made explicit; the extent to which the frames of reference include overview and a use situation - use issue structure; and the benefits and limitations of these means of representation and attributes. To answer this question this section will firstly report the different types and means of representation of the frame of reference that were created by the teams. Based on the first study, the workbook mentions the benefits and limitations of the means of representation that were used in that study. Since this concerned a limited amount of means of representation, students were free to explore other means of representation if they wanted to. Appendix 9 shows an evolution of the frames of reference for each team in relation to the most important design activities connected to those frames of reference.

Evolution of the frames of reference of product use.

Team 1 created one complete frame of reference in an A3 mind map format, based on a first general Envisioning Use workshop and distilled a target mind map from this complete mind map (see figure 9.10). This target mind map was only focused on the extension of the target group – the elderly – and not at the original target group: the families. For communication with the client a simple visual representation was used

Figure 9.10: the complete frame of reference of team 1 and a part of the target mind map of team 1



with the main issues in the target group, a word cloud and two concept presentations in the use context. They updated the target mind map once, based on a brief Envisioning Use technique that was executed right before their final user test to set questions.

Team 2 created a complete frame of reference in a web site format after their first Envisioning Use workshop. The website is a hierarchical representation of information on product use in categories which are connected through hyperlinks. After verification of some of the issues they added a goal definition in words and main issues to the website (figure 9.11). After another target specific Envisioning Use workshop they created a third target frame of reference in a table format which connects use issues to ‘requirements’. Three narrative scenarios were generated for the final concept to show how it could work in different ‘shopping’ situations.

Team 3 created a complete frame of reference based on their Envisioning Use workshop. They used a ‘Prezi’ format which is a zoomable digital presentation format (Somlai-Fischer 2012, see figure 9.12). They updated this frame of reference after the first family observations. A

Figure 9.11: the website main page of the second frame of reference of team 2 and the sub category ‘target group’ of the category ‘clusters’

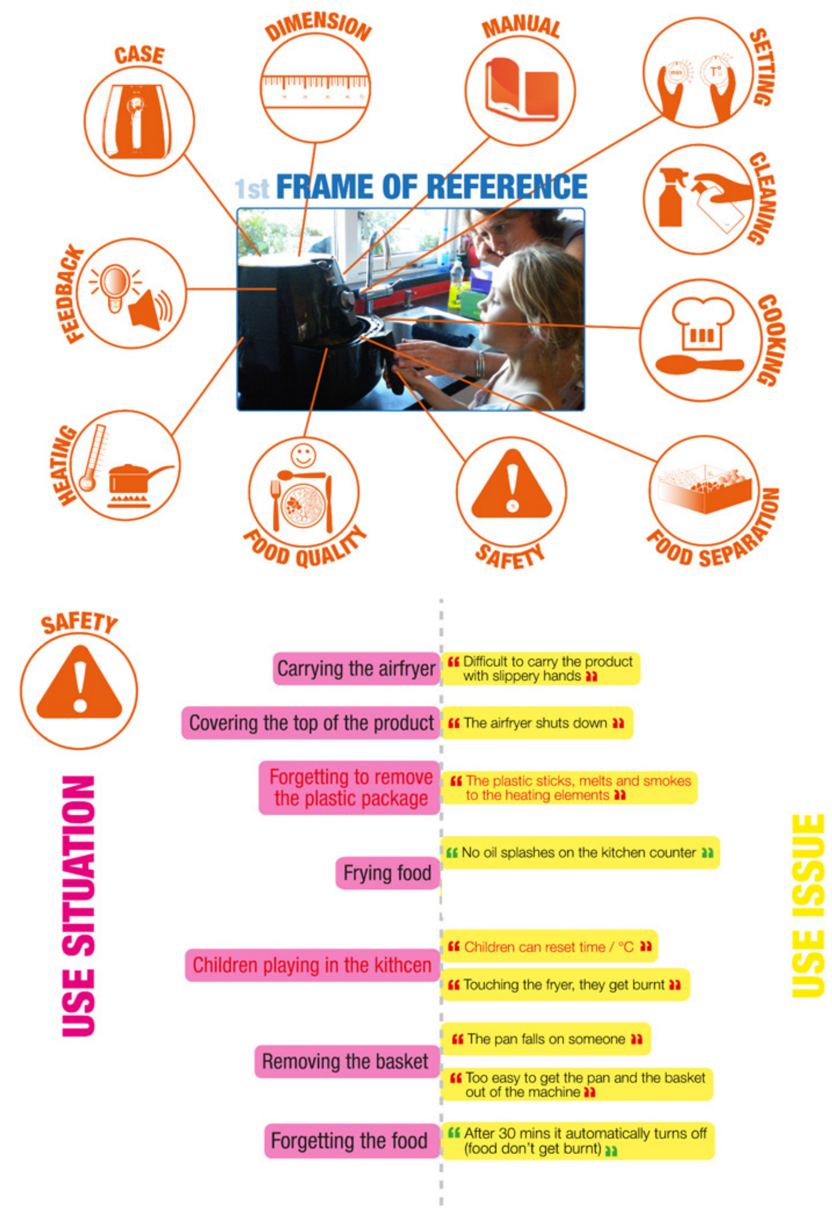


Figure 9.12 the main page of the Prezi presentation (above) and a view after zooming in on the safety icon (below)

simplified target frame of reference, based on this updated frame of reference was created of nine use issue – use situation connections. For communication purposes they created a simple visual of the target and their main issues and a word cloud which mentions the main issues. They used graphs to show diversity within the target group with regard to specific use issues. The final concept was presented in a storyboard which showed the current and future scenario for each target issue. Finally the Prezi was updated after the final user test to show solution specific issues.

All teams worked with an evolving frame of reference in two (team 1) or three (team 2 and 3) versions and different views. Compared to the first study, the number of complete frames of reference was lower on average. This is partly due to the fact that none of the teams chose to

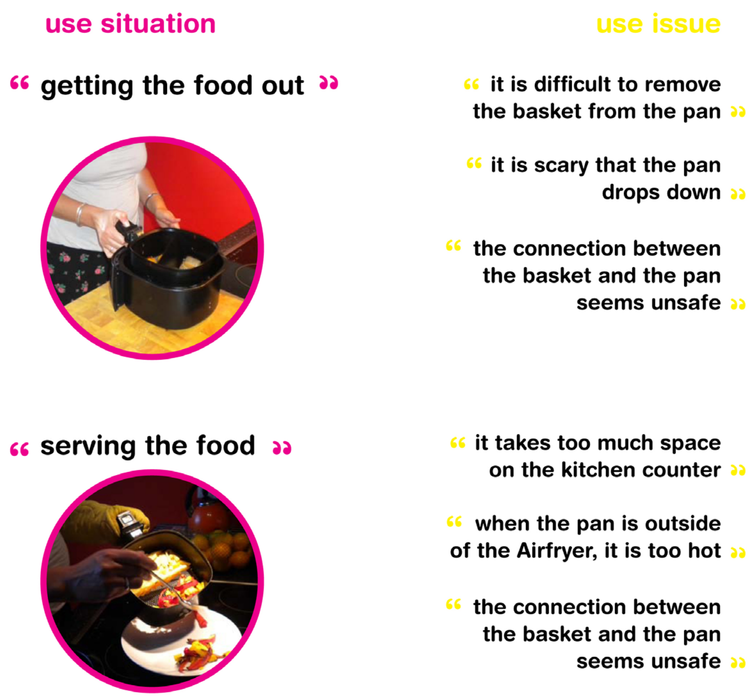


Figure 9.13: Part of the target representation of team 3

reformulate their target, while in the first study three of the four teams had to choose a new target user group. In this study all use situations and issues that were mentioned as being relevant in other documents were made explicit in at least one of the frames of reference in all the projects, while in the first study two teams (team 3 and 4) did not show an explicit frame of reference for each target. It can therefore be concluded that the guidelines positively support making the relevant use situation aspects and connected use issues explicit.

The second part of this research question relates to how the frame of reference was made explicit, in other words the means of representation of the frame of reference. The structure of connections and overview of the different means of representation will be discussed in the corresponding question sections.

9.3.3 Means of representation of the frames of reference

In comparison to the first project new means of representation were explored. No mind mapping software was used this time, although a mind map was used as the basis for the frames of reference of team 1. They only used an A3 print of those frames of reference. The website representation of team 2 and the Prezi representation of team 3 both concern a hierarchical digital representation of use situations and issues. All could be considered structured textual representations although the Prezi and website also contained some pictures to illustrate the categories.

Target representations

Both team 1 and 3 created a textual target representation based on their complete representation, team 1 in one mind map (figure 9.10) and team 3 in a sequential format with pictures (figure 9.13). Team 2 created a target presentation in a table format (see 'structure of connections', figure 9.20).

Visual representations for communication purposes

Team 1 and 3 used visual representations with connected quotes and word clouds to communicate the target use situation and related issues (figure 9.14). They also used graphs to show the heterogeneity of the target group with regard to user characteristics that were relevant for the product. Team 2 did show a collage and some data on their target group, but the group was represented as homogeneous.

Solutions connected to use issues

Team 2 used scenarios to show the future product in context in a narrative format (figure 9.15) and team 3 used a simple storyboard format for the same purpose. Team 1 only showed the general idea of their initial concepts in a visual representation of one use situation (figure 9.16).

Figure 9.14: visual representations of team 3 to communicate the target user group and related issues.

Scenario 2

Loes is travelling homewards by train after a long day of work. She is too tired to put much effort in cooking for herself only, but she still wants to cook something healthy and delicious. So she gets her laptop and looks at the AirCooker recipes on the internet and selects one with chicken, potatoes and cauliflower, together with a cheese sauce which she can put in the microwave. When she arrives at the train station, she goes to the local supermarket on her way home and buys the ingredients. At home she takes the AirCooker from the shelf, puts it on her countertop and looks at the recipe again for the preparation time and which compartments to use for the food. When she is done, she starts the machine and finds herself ending up watching Sex and the City on television. When she hears the signal she shakes food and continues to watch television. The food is ready and she puts the sauce in the microwave before putting the food on her plate. When she finishes the plating, she gets the sauce out of the microwave, pours it on her food and eats the dinner in front of the television. When she is done, she puts the dirty stuff in the dishwasher and puts the AirCooker on the shelf again.

Figure 9.15: the scenario format of team 2

It can be concluded that similar means of representation for the frame of reference were used as in the first study. However, the Prezi and website representation are new and no digital mind mapping software was used to refer to during the design process. Furthermore graphs are introduced by students to show the heterogeneity of the target group. The benefits and limitations with regard to overview and structure of all the representations will be discussed in the following question sections.

Figure 9.16 concept presentation in a visual representation of one use situation by team 1

9.3.4 Overview of the frame of reference

The second research question was: what is the level of overview of the frames of reference and what are the benefits and limitations of this overview? The workbook explained to use different views on the frame of reference: a complete view for use in evaluations and a simplified target view with better overview for decision making and solution generation. Furthermore a 'recycle bin' was proposed for reuse of information. Since the level of overview is particularly important for the simplified frame of reference, this section will discuss how this overview was achieved and how it was applied in communication and solution generation (the expected influences of the overview in the impact model).

Simplified view for communication within the teams

The target views are easily recognisable in all of the projects. Team 1 and 3 created a target representation early in the design process. Team 2 initially had the idea to only work with the website, because they thought the hierarchy of the website would lead to better overview. However, hiding specific issues in categories did not lead to the intended overview, because the main screen only shows categories and not specific target use situation aspects and issues. Team 1 deliberately chose a view which could be printed on A3 so it could be kept close to the design process.

> *Student (team 1): "We thought it was important to print the frame of reference on an A3, because when you use it during the design process you don't want to look back on your computer all the time [..] but you want it on the table so everyone can see it and write on it."*

Team 3 also mentioned the benefits of a 'one page overview'. From this can be concluded that overview is indeed important in communication and that an A3 print or one page overview of target use situations and issues can give this overview.

Since no observations of communicative activities were conducted it is not clear at this point how this overview influences this communication process within the team. The assumption was that the simple frame of reference would be used particularly to make decisions on the target use situations and the solution to choose. However, results from the interview gave indications that the overview also influenced decisions with regard to the design process. Team 2 got stuck in their design process at a certain point, because they did not know what to do anymore. They explained:

> *Researcher: what would you do differently a next time in your process?*
>
> > *Student A (team 2): focus earlier [...] and make the end result in one page overview of the frame of reference which is easy to access and understand.*
> >
> > *Student B (team 2): yes, and with a quick look you can understand where you are and what to do.*

Team 3 also indicated in their article:

'creating a general vision with the main issues and always referring to the simplified frame of reference during the redesign was really useful for proceeding in the design process.

This shows that the simplified frame of reference can be used to support decision making with regard to the next steps to take in the design process.

Simplified view for solution generation

Both team 1 and 2 indicated the importance of the target frame of reference for solution generation and the limitations of the complete frame of reference with regard to this issue. As one student of team 1 indicated:

"The complete frame of reference contains too much information to deal with. You do not get any new ideas from this complete frame of reference."

From this can be concluded that a target frame of reference is indeed necessary to inspire solution generation. The results do not give insight in what the optimum level of overview and connected means of representation is to inspire solution generation. Team 1 and 2 both created target representations with 21 target issues, while team 3 worked with only 8 issues. The study does not show which of these types of representations was most inspiring.

Conclusions overview of the frames of reference

Since all the teams eventually achieved a frame of reference with sufficient overview to use in their design process it can be concluded that the guidelines positively influence this factor. However, since team 2 achieved this rather late in their design process, better guidance should be given on the means of representation of this frame of reference and the importance for proceeding in the design process. A one page overview of the target use situations and issues proved valuable for this purpose as opposed to the hierarchical website and Prezi representations.

It can be concluded that overview is important for communication within the design team, assumingly to make decisions on solutions and target use situations, and particularly with regard to the continuation of the design process. Furthermore the comments of the students suggest that there is also a positive influence on solution generation.

9.3.5 Structure of use situation – use issue connections

The third question is to what extent do the frames of reference connect use issues to use situations and to what extent is this caused by the support? The guidelines explain that to be able to use the frame of reference in evaluations, it is important to connect use issues to use situation aspects. Each of the frames of reference was analysed with regard to this structure. Figure 9.17 to 9.20 show examples of each team that are representative for the structures of the frames of reference.

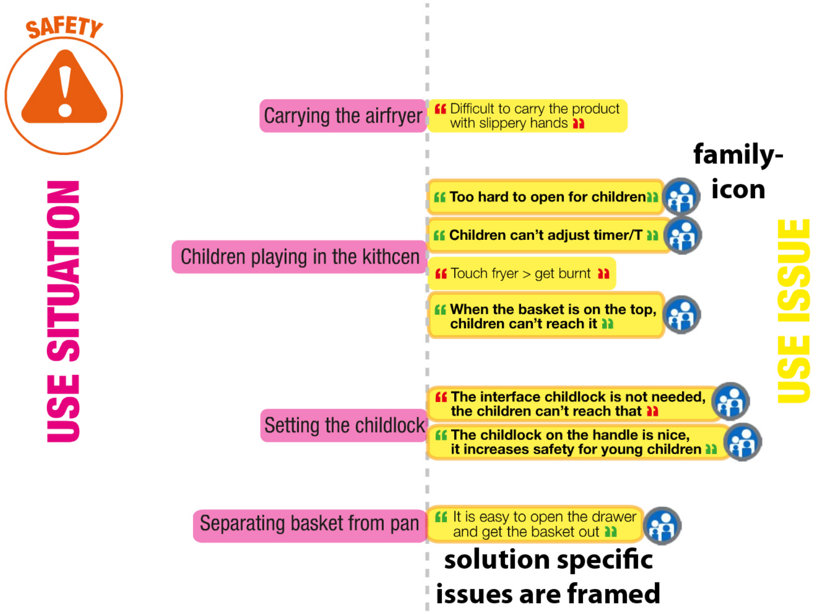
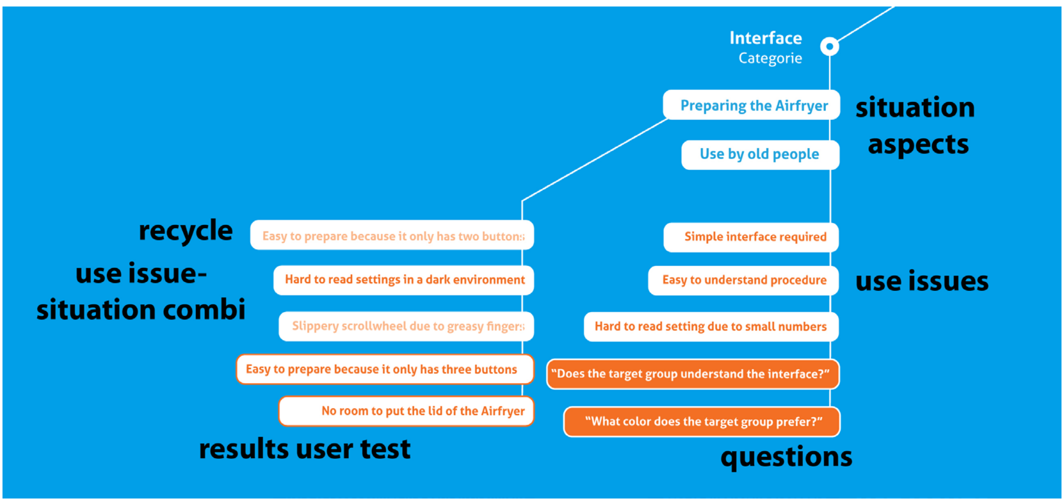


Figure 9.17: structure of connections in the Prezi format of team 3

Figure 9.18: structure of connections in the A3-mind map format of team 1. Different colours are used for use situation aspects (blue) and use issues (orange). Irrelevant issues are made transparent (recycle bin view)

The most clear structure is seen in the Prezi format of team 3 (figure 9.17). They make explicit what use issues and use situation aspects are and how they are connected. They furthermore added a 'family icon' to make more clear which issues are specific for the target user group. Solution specific issues are framed with an orange line. However, the structure was only achieved after getting feedback from the researcher in the progress meeting. Their initial target that resulted from the Envisioning Use technique was aimed at product parts (e.g. 'improve the food separator') instead of on use issues.

Team 1 distinguishes use situations (blue) from use issues (orange) by means of a colour code (figure 9.18). However, when analysing the use issues in more detail some 'issues' include situation aspects that are not



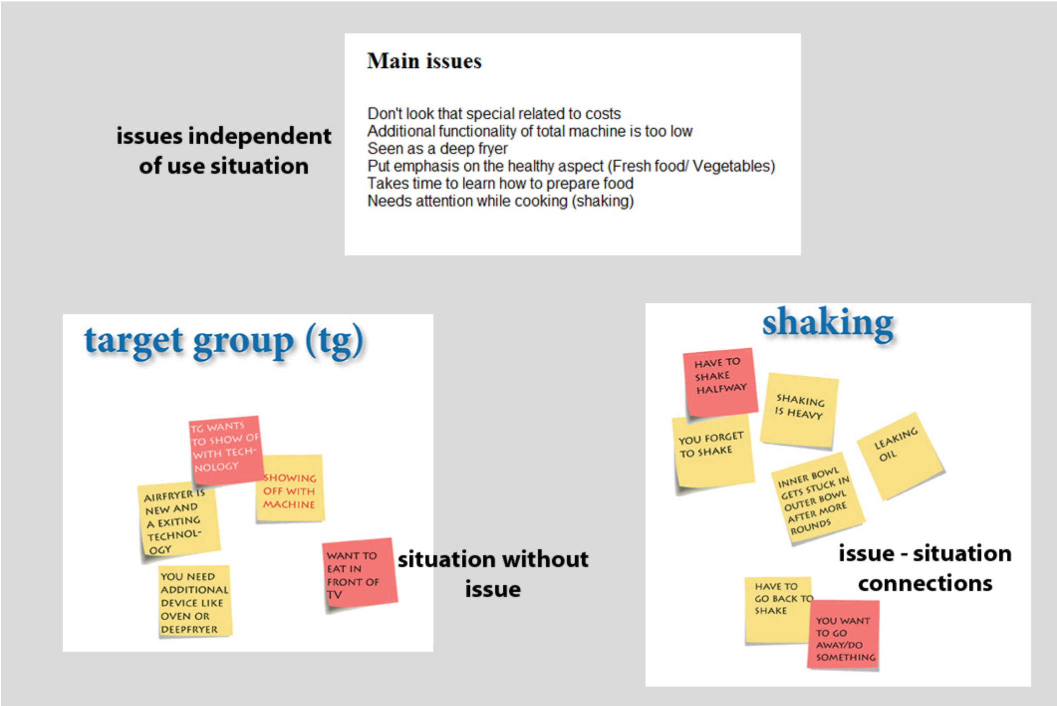


Figure 9.19: structure of connections in the website format of team 2

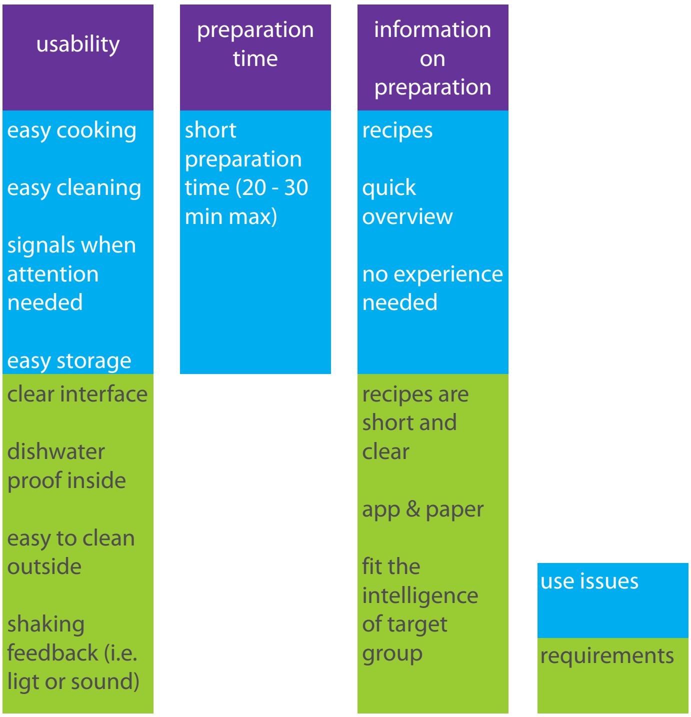


Figure 9.20: part of the 'target' format of team 2 created later in the design process, connects use issues (top cells) to requirements (lower cells), but the difference between the two is not very clear.

mentioned elsewhere (dark environment, greasy fingers). Like team 3, they indicate solution specific issues based on the user test with an orange frame.

The website format of team 2 contains least structure (figure 9.19). The first website consisted of four categories: user, context, use phases and clusters. The former two categories describe the target group, the latter categories describe use situation – use issue connections, of which two examples are shown in the figure. One 'sticky note' is shown without a relevant use issue. After verification of some of the issues they added a goal definition in words and main issues (above in the figure) to a second version of the website. They were added as two separate categories. It is not made explicit how these connect to their chosen target, the social climbers. Later they created the third frame of reference as shown in figure 9.20. This representation connects 'use issues' (top cells) to 'requirements' (lower cells). This categorisation is not applied completely consistent, for instance 'signals when attention is needed' is mentioned as an issue but could also be defined as a requirement.

None of the 'visual' representations of team 1 and 3 (see for example figure 9.14), clearly connects use situations to issues, although some are more clearly related to the Airfryer than others. These results and the struggle of team 2 with the structure of the frame of reference, the inconsistencies in structure of team 1 and the necessary support of the researcher with regard to the appropriately structured frame of reference of team 3 indicates that the guidelines do not directly positively influence the structure of use situation- use issue connections in the frame of reference. This could be caused by the fact that the guidelines do not clearly make a difference between issues, requirements and solution specific issues. This aspect needs more explanation in the workbook and will be further discussed in the recommendations for the final workbook (section 9.4.1).

9.3.6 Question 2: completing the frame of reference

Question 2a concerns which kind of internal explorations are executed and to what extent the quality of those explorations is influenced by the support. Questions 2b is: what is the extent to which internal and external explorations of DDUS and evaluations influence the completeness of the frame of reference? From the first study could be concluded that internal explorative activities resulted in a large addition of new issues, while external evaluative activities mainly were used to verify use situation – use issues aspects. External explorations could lead to both new issues (explorations) and verification of issues for current use. This section firstly summarises the activities aimed at the creation and update of the frame of reference of each of the teams (see appendix 9 for a visualisation of this process). Then it discusses the answers to research questions 2a and 2b, and the factuality and heterogeneity of the gathered information.

Summary of activities aimed at completing the frame of reference

All teams started the project with a baking session executed together with the Philips representative. This meant that after the presentation of the brief, they could try out the current Airfryer with different types of food. This activity can be considered an internal exploration since an existing product was tested without end-users. Team 1 then used online reviews [external exploration] to gather insights related to current experiences of the end user and further explored the use situation internally in the envisioning use workshop. An observation of the current use of the Airfryer by elderly [external exploration] was executed to verify issues from this internal exploration. New issues were also discovered and concerned for example the lack of space on some kitchen counters to put all the different parts. A literature analysis of the composition of the target group was executed with regard to movement restrictions and the age of couples whose children have left home, but it is not made clear how these aspects connect to use issues. After concept generation another Envisioning Use workshop was executed which resulted in specific issues related to the concept, for example if the designed lid would not be too heavy. This second workshop consisted of imagining and questioning and resulted in focused questions for the final user test (see also figure 9.23, 2nd target FoR of team 1). A survey and user test with a partly functional prototype were then executed to have the most important issues with regard to preferred appearance and handling verified. These evaluations did not lead to any new issues. The verified issues were adjusted in the final frame of reference.

Team 2 used online reviews [external exploration] as input to an initial envisioning use workshop with a separate 'self-test' at home to explore the current solution and the target of social climbers [internal exploration]. They conducted literature analysis on the target group based on the Motivaction model, but the results did not connect use situations to issues. Based on questions formulated in the Envisioning use technique an online questionnaire (60 respondents) [external exploration] was executed to further analyse the target group and how they thought about the current Airfryer, based on a picture and explanation of the appliance. The results are shown in a separate report which shows the distribution in answers with regard to for example preferred time needed to prepare frozen food. Additional interviews by phone [external exploration] with six people of the target group were conducted to find out more about the motivation behind the answers. This led to new issues such as their scepticism with regard to the performance and convenience of the device and more detailed issues such as if they would mind shaking the food halfway. Then the team started generating concepts but got stuck in their design process as explained earlier. They described a second session which they call a 'focus session' which is aimed at regrouping the website frame of reference issues and connecting them to 'requirements' as described for question 1b. Since this session only considered 'clustering' and 'targeting' in workshop terms, it is not considered an explorative activity. After their ‘focus session’ they explored the concepts further in three scenarios for different shopping situations (e.g. create shopping list based on recipe, or create recipe based on available products in the fridge) [internal exploration], but this was not connected to their frame of reference or their final usability evaluation. In this evaluation a paper prototype of the App and 2D representations of the appliance were shown to people from the target group for feedback. These results were not transferred to the frame of reference, but the evaluation report shows many new issues that could potentially be added to the frame of reference. An interesting insight is that the interviews show that the preparation time of 20-30 minutes is seen as a major limitation of the Airfryer by the three respondents and the main reason why they would not buy the device.

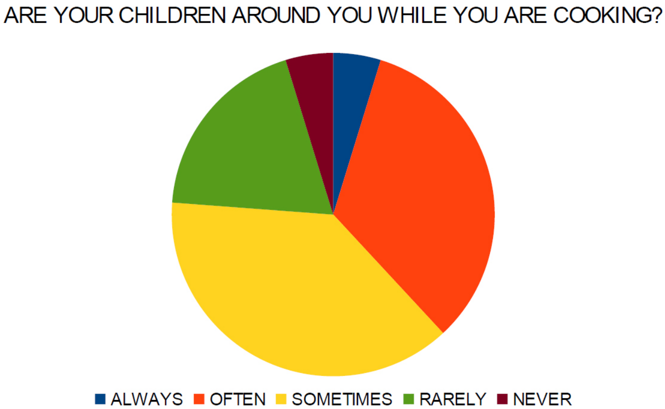
Apart from the initial Envisioning Use workshop to gather and explore issues for the family target group and for different kinds of food, team 3 mainly used external explorative activities to add new issues to their frame of reference. Valuable sources were consulting online reviews, an online survey, family observations of the use of the current Airfryer and face to face interviews. Not all external activities explicitly connected use situation aspects to use issues. For example, the online survey and face to face interviews were aimed at cooking habits and level of attention for children, but were not conducted with parents who had experience with the Airfryer. However, the preceding envisioning use workshop already had connected those situation aspects to assumed issues, for example, the supposed distraction of children while using the Airfryer. The interviews therefore were mainly used to check homogeneity of the target group with regard to specific use situation aspects, such as if parents let their children in the kitchen while cooking (see figure 9.21a). The concept was presented in a storyboard which contained some new issues [internal exploration]. Later usability evaluations were used to check the resulting assumed issues. As expected these evaluations mainly led to verification of issues and some new issues such as “since a young child cannot see the child lock on top of the handle, it will not manage opening it” (see figure 9.21b).

Conclusion internal explorations

In comparison to the first study a lower number of internal explorative activities was executed. The Envisioning Use technique was applied by all teams in initial stages, but only one team explicitly applied it a second time later in the design process to explore use issues. Scenarios were used by two teams, but only in one case is clear how they were actually explored. So, less clear explorative sessions were executed than in the first study. From this can be concluded that the guidelines do not better support these kind of activities than the initial guidelines.

In the first study, three teams applied the workshop in later design stages again to share newly acquired information and link it to case specific issues or to imagine issues for a newly defined target. In this study, as mentioned before, none of the teams changed their target, so in that

Figure 9.21a: representation of the heterogeneity of the target group 'families' with regard to one relevant use situation aspect: having children around you (connected to distraction while using the Airfryer) and figure 9.21b: photos of the evaluation which revealed the importance of the visibility of the child lock.



sense explorative activities were less needed. This study shows that the workshop can also successfully be used to explore issues for developed solutions, as team 1 did. In the first study this goal was only achieved by applying scenarios. To better stimulate the application of internal explorative activities to explore a new target, a new solution or to connect new use situation information to issues, these purposes could be explained better in the workbook. The next section further explains what the added value of those explorations is.

Conclusion combining exploration and verification

The results confirm the results of the first study: internal explorative activities led to new issues, external explorations led to both new issues and the verification of existing issues, while evaluations mainly led to verifying these issues. Analyses that did not connect use issues to use situations did not lead to new issues in the frame of reference, such as the literature analyses of team 1 and 2 with regard to the characteristics of the target group. Preceding an external exploration or evaluation with an internal exploration - such as team 1 and 3 did for their final user test - led to more focus in those activities and thus made them more effective with regard to the completeness of the frame of reference, in comparison to research activities which were not preceded by such an exploration, such as the usability evaluation of team 2.

Since there was no observable difference between the application of the guidelines in the two studies, even though the guideline was only explicitly part of the second workbook, it is likely that the success of combining the two types of activities in the first study was caused by the introduction to the envisioning use technique and the clear connection of that technique to subsequent activities by means of formulating questions.

Validity of explorations and verifications

As in the first study, this project showed that it was important to have issues verified in external explorations of current use or evaluations of newly generated solutions. Although team 2 conducted surveys and phone interviews with the target group, they found out only at the end of their project that the necessary time for preparing food with the Airfryer was seen as an insurmountable issue by the social climbers. Apparently the type of external exploration has a large influence on finding and verifying issues. This team was the only team who did not conduct observations of target users trying out the current Airfryer. The results from the survey and interviews were completely based on how the respondents imagined they would use the appliance. Therefore the results are less factual or valid than when respondents actually use the product. The user observations of team 1 and 2 are more valid but still include some imagination because it was the users first encounter with the Airfryer and they still needed to imagine how the daily use would be. In the carrier bike study it was more easy to find users who already had experience with that kind of bike to gather valid information. This illustrates that the border between a 'fact' and an 'assumption' is rather vague. Team two states in their article:

> *"During the Airfryer project there was no awareness of missing important use situations, because it looked like all the issues were covered. Missing situations might become clear during use tests and should be addressed at that moment. "*

This quote leads to the question if a frame of reference built on assumptions does not lead to a false feeling of certainty. In the first study team 3 worked for quite a long time with such a broad frame of reference based on assumptions about the holiday park employees and also found out late in their project that these assumptions could not be confirmed. Comparing their process to the process of team 2 of this study leads again to the conclusion that the importance of early verification should be made very clear in the support.

Heterogeneity of use situation – use issue connections

The results of this study furthermore showed one important issue with regard to the diversity of use situations that was not considered in the previous study, namely the heterogeneity of the target use situations in relation to specific use issues. In the previous study differences in use situation aspects were often indicated as separate use situation aspects connected to separate issues, for example different weather conditions led to different comfort issues for the carrier bike and different ages of children led to different needs. In this study, all groups gathered insight in the heterogeneity of the target group by means of literature analysis (team 1) or surveys (team 2 and 3). Since team 1 considered general

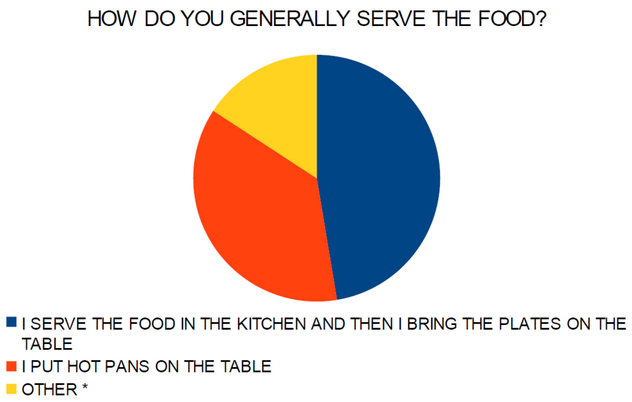


Figure 9.22: the graph that shows the heterogeneity of the target group with regard to the target group and the related part of the frame of reference which does not reflect this heterogeneity.

data of the target group, their analysis resulted in aspects that were not related to the Airfryer and could therefore not be added to the frame of reference. In the cases of team 2 and 3 specific questions were asked with regard to cooking rituals and the Airfryer. However, the variety in answers does not come back in their frames of reference. For example, team 3 asked if dinner was served at the table or in the kitchen to twenty families. As seen in the graph in figure 9.22 about half of the families serves the food in the kitchen and then brings the plates to the table and the others do it differently. However, when they visited the two families to observe how they would use the Airfryer, the families indicated they both serve the food in the kitchen because of safety reasons. The issue was then indicated as such in the frame of reference, even though this would be true for only a part of the target user group. It was not further referred to in the target frame of reference in the rest of the design process. If they would have aimed their design at families who do prefer to serve food on the table, they might have created a different solution. Therefore, it is recommended to represent this heterogeneity in the frame of reference.

Conclusion question 2

The study again confirmed that explorative activities mainly lead to new use situation – use issue connections while external exploration of current use and evaluation is needed to verify issues. From this can be concluded that the hypothesis that a combination of exploring and verifying activities leads to a more complete frame of reference, can be confirmed. The revised workbook did not lead to more explorations and verification in comparison to the initial workbook. The results also again confirm the importance of early verification of use issues. Although the added value of combining explorative and verifying activities was a new guideline in the workbook and although early verification was explicitly recommended, the guidelines were not applied by all teams. This might be due to the flexibility of the guidelines and the usability of the workbook, which is further discussed in chapter 10.

From the study can furthermore be concluded that the type of external exploration influences the level of factuality of the resulting 'verified' use situation – use issue connections. Additional support is needed to make designers aware of the level of factuality of use situation – use issue connections.

Finally, it can be concluded that the heterogeneity of how the target use situation is connected to use issues does not become clear in the frames of reference presented in this study, but could provide a useful addition to the frame of reference, to indicate the importance of use situation – use issue connections. More research is needed on how this issues can be integrated in the frame of reference.

9.3.7 Question 3: external validity and focus of evaluations

Question 7 is how and to what extent do completeness of the frame of reference and structure of connections influence the external validity of evaluations and the focus of evaluation questions? This question is based on the hypothesis that when use issues are connected to use situations, this structure will support setting up externally valid test conditions and asking more focused evaluation questions. To answer this question the plans of the different final user tests were compared to the structure and completeness of related frames of reference. Unfortunately, none of the teams explicitly mentioned the test conditions in their plan, other than that the respondents should be part of the target research group and the tasks that respondents were asked to perform. However, photos of the user tests revealed relevant information with regard to the actual test environments. This section firstly gives a summary of the test conditions and questions of the usability evaluations of the different teams in comparison to the structure of their frame of reference.

Summary of the evaluations

Team 1 conducted the user test with their prototype with the same users as in the observation of the use of the current Airfryer. The aim of the user test with the prototype was to verify issues with regard to handling of the appliance, for example if the lid was not too heavy. The research questions are made explicit in their last frame of reference (see figure 9.23), so the frame of reference based on their second Envisioning Use workshop clearly supported the generation of the evaluation questions. The connected use situation in their frame of reference is 'half-time shaking'. Although participants were asked to show how they thought a

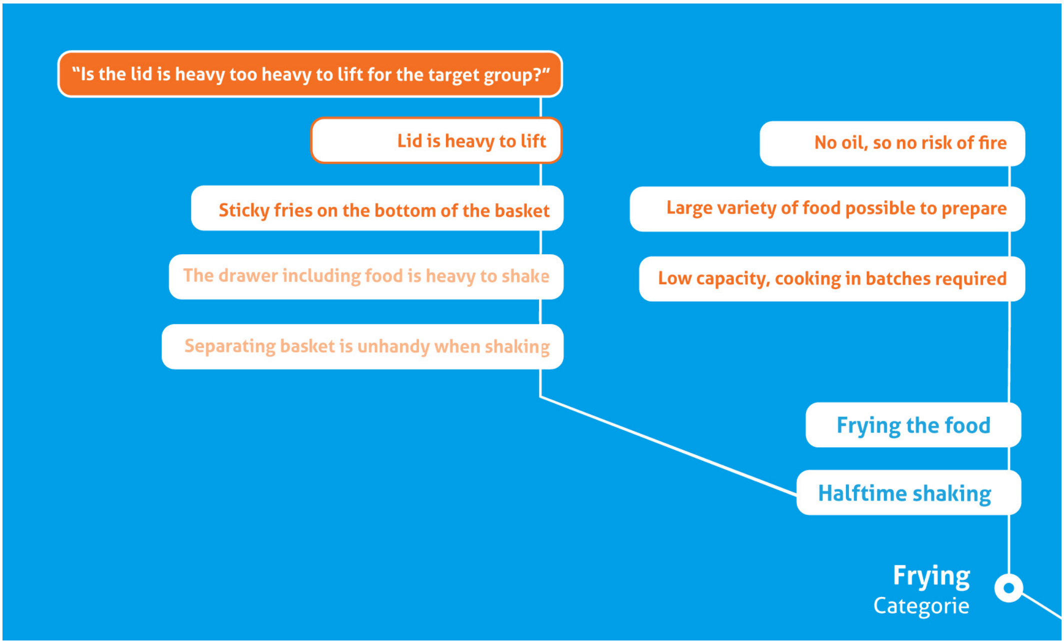


Figure 9.23: the structure of connections in the frame of reference of team 1 including the research questions

complete use cycle would go (presumably including shaking), other use situation aspects that could influence this use issue were not simulated. For example, although people from the target group were asked as respondents, none of the evaluations took place in a kitchen environment (see figure 9.25). This kitchen environment was not part of their frame of reference. If there is a causal relation between these two observations is discussed in the following section.

Team 2 conducted a user test with a paper prototype of the App and graphical user interface of the appliance and 2D representations of the complete appliance. Their research questions concerned appeal, preference and usability in general. So less focused questions were asked than team 1 did. The test conditions were simulated by using card board food that users could place in the 2D visualisation of their design. The test was not conducted in a kitchen environment. The test conditions concerned the respondents which were part of the target user group and the different types of food. However, different types of food are not part of their frame of reference (see figure 9.20), so they probably did not use the frame of reference to set up the test conditions.

Team 3 conducted a user test with the two families who also participated in the initial observation of the use of the current Airfryer. Most research questions are focussed and connected to the issues presented in the target storyboard format, for example if the raised edges on top of their solution were perceived as a safe option to place the basket. The storyboard format is not very structured by itself, because it connects assumed issues for their solution to actual issues with the current Airfryer, but it does not connect those issues to use situation aspects. The relevant use situation

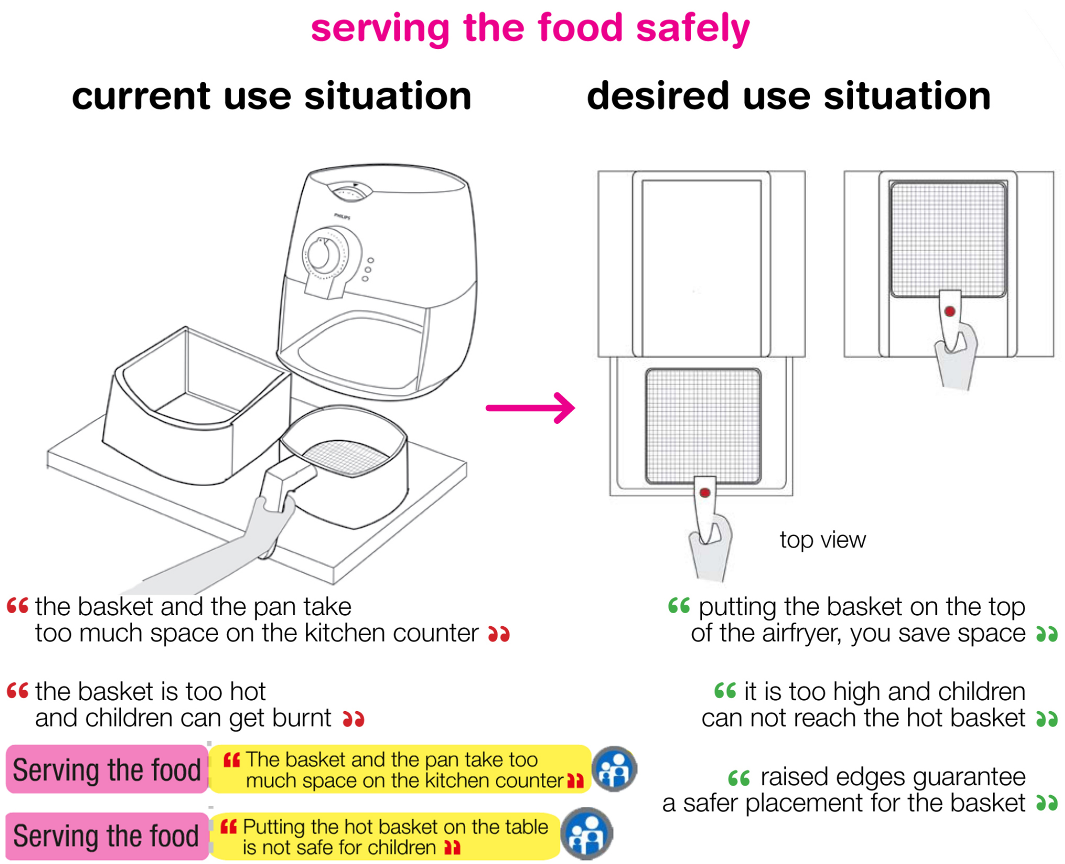


Figure 9.24: The target frame of reference of team 3 of the solution with the related use situation – use issue connection of the current Airfryer in the Prezi format.

aspects can be derived from analysing the related use issue- use situation connection presented in the complete Prezi format (see figure 9.24). The only use situation aspects that are mentioned in the target are 'serving the food safely' and 'cooking safely with children around'. Those aspects clearly come back in the test conditions. However, when studying for example in more detail the aspect: 'device takes too much space on the kitchen counter', the connected use situation aspect in the Prezi format is 'serving' and not 'size of the kitchen counter'. Like the other teams, this team also did not execute their test in a kitchen environment, although the issues mentioned can easily be imagined as being influenced by this environment. It therefore seems that a lack of completeness in the frame of reference negatively influenced the external validity of the evaluation.

Influence of structure of connections in the frame of reference on the evaluations

The results show that a structured frame of reference which connects use situations to use issues leads to more focus in the test objectives. Team 2, who did not create a structured frame of reference for their solution, as discussed in section 9.3.2., set higher level evaluation questions than the other two teams who did have a frame of reference that connected use issues to use situations.

There is no clear correlation between structurally connecting use situations to use issues and setting externally valid test conditions. The first study did show that the frame of reference can successfully be applied to set test conditions (team 1 and 4, section 6.4.5). In the case of the Airfryer both structured and unstructured frames of reference led to the selection of relevant respondents and tasks, but not to relevant test environments. None of the tests was executed in a kitchen environment, but it is not clear why. It could be caused by the fact that the kitchen environment was not part of the frame of reference (a lack of completeness, as suggested for team 1 and 3) or a lack of structure (as for team 2). Or it might have happened because the frame of reference was not used to set test conditions or because it was not feasible to conduct the test in the kitchen. In this case the latter reason is not probable since most tests were executed at respondent's homes. Some indications were found that the frame of reference was not optimally applied to set test conditions. The teams that used a structured frame of reference did not explain if and how they used it to select a test environment. One student even indicated that this purpose of the frame of reference was unknown to them: student (team 1):

> *"we mainly used the frame of reference to create the target and make the first choices. Initially we did not think it would be an evaluation tool."*

Apparently the workbook did not stimulate applying the frame of reference for setting test conditions, even though it is an explicit guideline. Again, this might have been caused by the flexibility of the guidelines and the usability of the workbook (see chapter 10). The possible influence of a lack of completeness of the frame of reference is further discussed in the following section.

Influence completeness of the frame of reference on evaluations

The influence of the completeness of the frame of reference on external validity of the evaluations turned out to be difficult to measure. The indicator for the completeness of the frame of reference was taken from the study in chapter 6 on the influence of different design activities on the completeness of the frame of reference (section 6.3.2). Since absolute completeness of the frame of reference cannot be measured during the design process, it was there chosen to measure the relative completeness: the extent to which activities led to new insights in use situation – use issue connections. When this relative completeness is applied in this study, it seems that the frames of reference of team 1 and 3 are more complete than the frame of reference of team 2, since their evaluations led to relatively little new issues in comparison to the evaluation of team 2, at least in relation to the tested use situations. However, the chosen test environments left little room to explore additional use situation – use issue connections, for use issues that could occur in more realistic test conditions, for example a test in the kitchen environment. The question is if their evaluations led to little additional issues because their frame of reference was so complete, or if this was caused by a lack of applying

Figure 9.25: the test conditions of the three teams: elderly, social climbers and families with children. The tests include relevant respondents and tasks, but none of the tests is conducted in a kitchen environment.

the test in a realistic environment, which in turn might have been caused by an *incomplete* frame of reference. Measuring the relative completeness does not give an answer to this question. The measurement of the relative completeness of the frame of reference was therefore not successful in measuring the influence of the completeness of the frame of reference. Therefore no reliable conclusions can be drawn with regard to this issue.

Conclusions question 3

From the results can be concluded that structured use situation – use issue connections in the frame of reference support generating more focused research questions. The frame of reference was not employed to its full potential to set test conditions for usability evaluations, so it cannot be concluded that more structure and completeness lead to more externally valid test conditions. Like the limited application of the guideline discussed in the previous section, the flexibility of the guidelines and the usability of the workbook might have contributed to this problem (chapter 10). The lack of a representation of realistic test conditions in the frames of reference is further discussed in section 9.4.3.

9.3.8 Question 4: creation and application of the shared vision

Chapter 8 already discussed the influence of the workshop on the shared vision on product use. In this study, the lasting effects of the shared vision were shortly investigated.

Creation of the shared vision on product use

The first sub question was how the shared vision was created. The results confirmed again that the Envisioning Use workshop was successful in generating a mindset of DDUS. This can be illustrated by a quote that was taken from the article of team 3:

> *"The Envisioning Use workshop makes members of the design team aware of dynamic use situations, which is a proper start for a design project. Thinking about different target groups, contexts of use and goals of the product is useful to open designer's minds in terms of usability."*

The teams also all commented on the added value of the Envisioning Use workshop in aligning those individual mind sets and creating a shared vision. As a student from team 1 stated:

"I think the Envisioning Use is a really good tool. […] I would apply it again in a future project to create a uniform mind set within the team."

In addition to the role of the Envisioning Use workshop, all teams discussed the added value of the explicit frame of reference for creating the shared mindset. Team 2 mentioned in their process evaluation that the explicit frame of reference simplifies communication, because everyone has the same ideas about the context of use. However, a student of team 1 indicated that it only works for this purpose when the frame of reference is created *together*. He mentions:

"If I would not have joined the Envisioning Use technique, I would not have understood the explicit frame of reference."

Team 3 also emphasised that creating the frame of reference together resulted in an alignment of implicit frames of reference.

Role of the shared vision in team communication

The assumed effect of the shared vision for communication was confirmed in the written process evaluation of team 2:

"The Envisioning Use workshop seemed to be not only a tool to create a shared frame of reference, but it also stimulated the communication about the ideas and issues during later sessions. This could be the result of the shared starting point."

A student in team 3 furthermore explained:

"We started with the envisioning use workshop and that particularly helped, because together you look at product use and then in the course of the project it is mainly in your head. We did put it on paper, but it was not brought into the discussions by means of really looking at that paper."

These quotes suggest that the shared vision indeed supports communication and that that influence is larger than the influence of the explicit frame of reference itself. The added value of the explicit frame of reference for communication is therefore rooted in its joint creation.

Conclusion question 4

From this can be concluded that the Envisioning Use technique and in general creating an explicit frame of reference of use situations together, leads to a shared vision of use situations and issues. This mindset was experienced as having an added value in communication within the team.

9.3.9 Question 5: application domain of the guidelines

The last question concerns the application domain of the guidelines with regard to the types of products that are appropriate to design by means of the guidelines. Compared to the carrier bike in the first study, the Airfryer was expected to have a less dynamic and diverse character. Expected dynamic aspects of the product concern the different kinds of food that can be prepared using the fryer and the different needs of users. The validations of the Envisioning Use technique in practice had shown that applying the technique to similar cases also led to a lot of use situation – use issue connections. Therefore the Airfryer was expected to be an appropriate case to evaluate the guidelines.

However, team 3 indicated some limitations of the Airfryer case. They described that this was mainly due to the target they chose, the families. Initially they thought it would be a target group which contained quite some diverse aspects such as different levels of interest of parents for cooking, available time for cooking and different ages and characteristics of children. They focused at issues surrounding child safety of the Airfryer. However, later in their design process, they found out that little dynamic and diverse aspects of the use situation influenced these issues. This can be illustrated by the following example that was described in their written process evaluation:

> *"Two families were observed, where one family was more child protective than the other. With the first family, the children were not allowed in the kitchen and with the second family the children could even touch kitchen appliances. This looks dynamic, but the problem is that these different situations did not result in different issues. In both cases child safety is important. With the first family the children are not allowed in the kitchen but children don't always listen to their parents, so this family appreciates a child lock. The second family is not that strict, but they don't want their children to burn their hands when they are in the kitchen, so this family also appreciates a child lock."*

The only dynamic aspect that was discussed with regard to the child lock was how the age of children would influence the extent to which they would be able to open the child lock (see also figure 9.21).

The question is if this limited amount of dynamics could have been anticipated and if it makes the guidelines less valuable. The answer to the first question can be derived from looking again at the example of the child lock. The team initially thought the level of protectiveness of the parents would influence their needs with regard to the child lock, but they found out this was not true after having presented the child lock concept to the parents. Furthermore the fact that the age, and more particularly the length of children would influence the visibility of the child lock was only discovered when they actually created and explored the solution with the button on top of the handle. As already discussed in the section on usability evaluations, this shows again that discriminating use situation aspects are often only discovered after exploring solutions and presenting solutions to users. This means also that the dynamic and diverse character will unfold in the course of the design process and cannot be completely defined at the start of a design project.

The second question concerns the added value of the guidelines to cases which turn out to have a less dynamic character. Team 3 indicated that even though the case was not so dynamic, they still found it very useful to explicitly take use situations into account in their design process. They mentioned that their approach led to surprising results with regard to this aspect if they compare it to working with just product specifications, because they were more stimulated to take the context and goal into account in their evaluations. The downside they experienced was the lesser added value of the imagining step in the Envisioning Use technique and the difficulty of setting scenarios for the role-play in the experiencing step. In the tutorial they executed the workshop with the fictive case of the compact camera. The imagining and experiencing step then led to a lot of new issues, while in the Airfryer case they were disappointed this step did not have this effect. The other teams indicated this downside of the Airfryer case as well in the progress meetings. This might also be the reason why less internal explorations were executed than in the previous study (see section 9.3.3). Therefore it can be concluded that the guidelines are also useful to apply to products with less dynamic and diverse use situations. However, when introducing the guidelines, such as was the goal of the course, a case with more DDUS could be chosen to gain experience with all the aspects of the guidelines.

9.3.10 Evaluation of the research method

The research method differed from the previous study with regard to the kind of documents that were asked. Firstly, the log was kept by the researcher based on the progress meeting instead of having the students log their own process because of the observed overload of documentation activities in the previous study. For similar reasons, students were not asked to give insight in their online file storage.

The logging process by the researcher proved to be an efficient means to keep track of the type of activities that were carried out each week. However, comparing the results of the portfolio, log, analysis reports and written process evaluation, showed several inconsistencies in what was decided when. None of the documents presented a complete view on the design process, but comparing them led to sufficient results. Many of the gaps that remained in the data could be covered in the group interview. However, the limited time for the interview (30 minutes) made it impossible to discuss all inconsistencies and gaps in detail. This particularly limited finding an answer to research question 3a (the influence of the frame of reference on the external validity of evaluations), since a complete description and motivation of the test conditions of all usability evaluations could not be gathered.

9.4 Discussion and recommendations

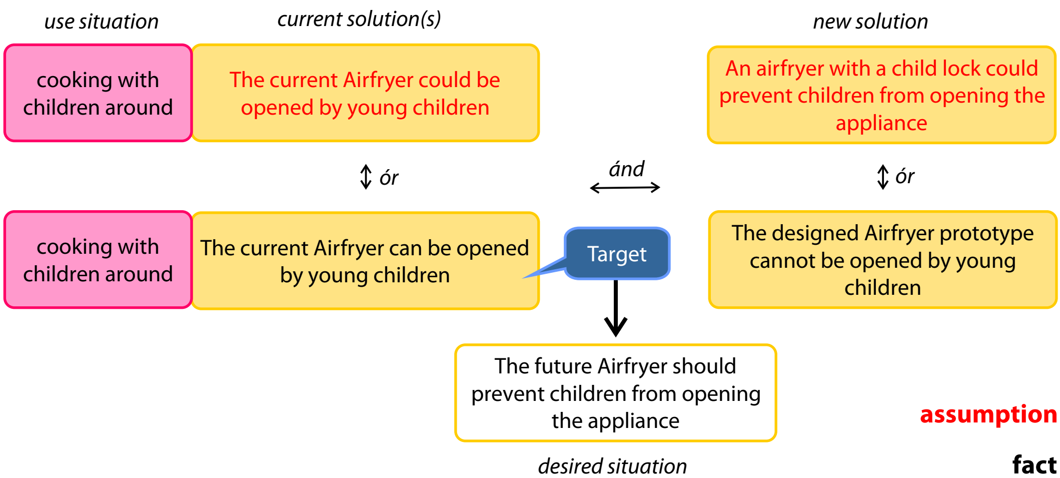
Based on the results presented in the previous section, recommendations can be formulated for a further improved support. Therefore this section discusses the most striking results and describes the consequences of this discussion for adjustments to the workbook. The thus created final workbook can be found in appendix 10, presented as adjustments to the previously revised workbook. Recommendations for the introduction of the workbook will be discussed and presented in chapter 10. The topics that are discussed here concern the structure of connections in the frame of reference, the relevancy of the frame of reference for anticipating future use, setting test conditions in evaluations, and means of representation of the frame of reference for communication and solution generation.

9.4.1 Structure of connections in the frame of reference

The results showed that the guidelines did not directly positively influence the structure of connecting use situations to use issues in the frame of reference. This could be caused by the fact that the guidelines do not clearly make a difference between issues, requirements and solution specific issues. This aspect therefore needs more explanation in the workbook. The workbook mentions that use issues are defined as *characteristics and qualities of the interaction between use situations and products*, but might not be that clear about the status of this interaction. A separate section of the workbook mentions that assumptions and facts can be distinguished in the frame of reference, but it does not connect that clearly to the definition of use issues. Therefore a new definition of use issues is proposed: *use issues are the characteristics and qualities of the interaction that can, could or should occur between use situations and a current or future product.* The differences between the three is illustrated by the example of issues connected to the use situation of cooking with children around presented in figure 9.26.

An assumption can lead to facts when an issue is verified. They are different formulations for different status of the same issue. It is not recommended to use the different formulations next to each other, but to formulate them according to the appropriate status. An issue can lead to a desired situation when it is indicated as relevant for the target. The formulation for a desired situation was not included in the explanation of the frame of reference in the workbook. Instead it was advised to indicate a target by means of a separate 'tag'. In the application of the

Figure 9.26: different ways to present use issues: assumptions or facts for current and new solutions



Envisioning Use technique in practice (chapter 8) a separate overview of the target use situation and issues was created to formulate the desired situation. However, participants there indicated that they preferred to keep the 'background' of the target issues in that representation. To keep the formulation of the target connected to the related use issue and use situation aspect), the final workbook proposes to integrate those formulations of the desired situation in the frame of reference, for example such as presented in figure 9.26.

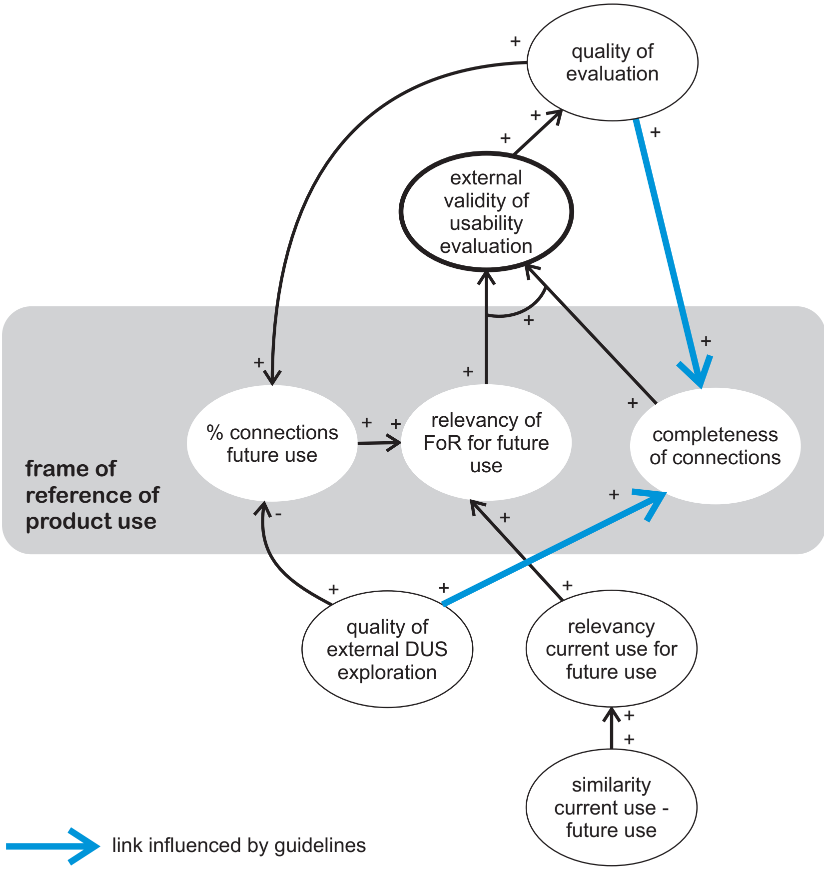
When introducing new solutions, such as the child lock, a new issue could be formulated next to the related issue which represents the desired future situation, because a new product essentially introduces a new interaction. Introducing solutions can also lead to new issues which are not related to preceding issues, such as 'the child lock is not visible for young children'.

9.4.2 Current use versus future use

In the impact models the completeness of the frame of reference was presented as the number of connections combined with the extent to which connections are verified. Until now no division was made in the impact model between use situation –use issue connections which considered future use and use situation – use issue connections which considered current use. However, the more detailed analysis of types of issues such as described above, and a further analysis of the different projects with regard to the extent to which their frames of reference represent current or future use led to an important new insight with regard to this issue, which will be motivated here.

The external validity of use evaluations was considered an important factor in achieving the ultimate goal: better usability of products in intended use situations. The external validity is the extent to which the test conditions are representative of the variety of real world situations. These real world situations consider the situations for the to be developed product. In other words, they consider future use. Because future use cannot be predicted, it needs to be anticipated indirectly by either extrapolating knowledge about use of comparable products and situations or by evaluating solution proposals in intended use situations. However, when there is a large difference between the to be developed product and/ or its intended use situations and the current product and use situations, it is not likely that insight in current use will lead to relevant knowledge with regard to future use. This was for example the case in the workshops presented in the study in chapter 6 in which students chose a completely different target use situation domain (use by employees of holiday parks to transport tools) than the current domain (use by parents in the city to transport children). When they executed the envisioning use technique with regard to transporting children, it gave very little insight in relevant issues for holiday park employees. In the study presented in this chapter, the team that chose to focus on the new target group 'social climbers' also had problems with an incomplete frame of reference

Figure 9.27: new impact model which shows the influence of the similarity between current use and future use on the success of the frame of reference in influencing the external validity of use evaluations.



because of their lack of insight in how the product would be used by their target users. Therefore it is proposed to also add the factor 'relevancy of the frame of reference for future use' to the impact model. This is shown in figure 9.27.

The completeness of the frame of reference positively influences the external validity of evaluations when the frame of reference is relevant for future use, in other words when it can be used to anticipate future use. This relevancy can be influenced by either a large percentage of use situation – use issue connections that are related to future use or a high relevance of current use for future use. The latter is the case when there is a large similarity between future use and current use. The former is the case when evaluations of solution proposals are used to update the frame of reference. External explorations of current use negatively influence the percentage of use situation – use issue connections for future use. However, they are still useful to set a relevant frame of reference when current use is similar to future use. Similarity between current and future use is high when both the solution and the intended use situations are similar. This means that in case of novel use situation – product combinations, the guidelines should stimulate to mostly verify issues with regard to future solutions in use evaluations, while when considering familiar use situation – product combinations, one can make more use of available knowledge about current use in external explorations of current use.

9.4.3 Setting test conditions and questions for evaluations

The results showed that the frame of reference was not employed to its full potential to set test conditions for usability evaluations. The fact that none of the teams executed the tests in a kitchen environment and the fact that this kitchen environment was not part of their frames of reference suggests that unknown gaps in the frame of reference can lead to incomplete test conditions. The question in this case is if the kitchen environment is a 'discriminating use situation aspect': a use situation aspect that influences use issues. To find out what discriminating use situation aspects are, it needs to be known how certain use situations are connected to use issues. These connections cannot be fully anticipated when a new solution is introduced to a certain use situation. Therefore, evaluations should always have a partly explorative character. Depending on the stage of the development process and the novelty of the generated solution in comparison to earlier solutions, the character of the evaluation should be somewhere on a sliding scale between completely explorative (what Carroll (2000) calls discovery oriented evaluations, see section 4.1.1) and mostly verifying (a theory based evaluation). The explorative part is not only useful for finding unexpected usability issues, but for finding new related use situation aspects as well. However, these unexpected use situation aspects will most likely not be found in simulated use situations, such as in a lab. It is therefore recommended to conduct evaluations in the field.

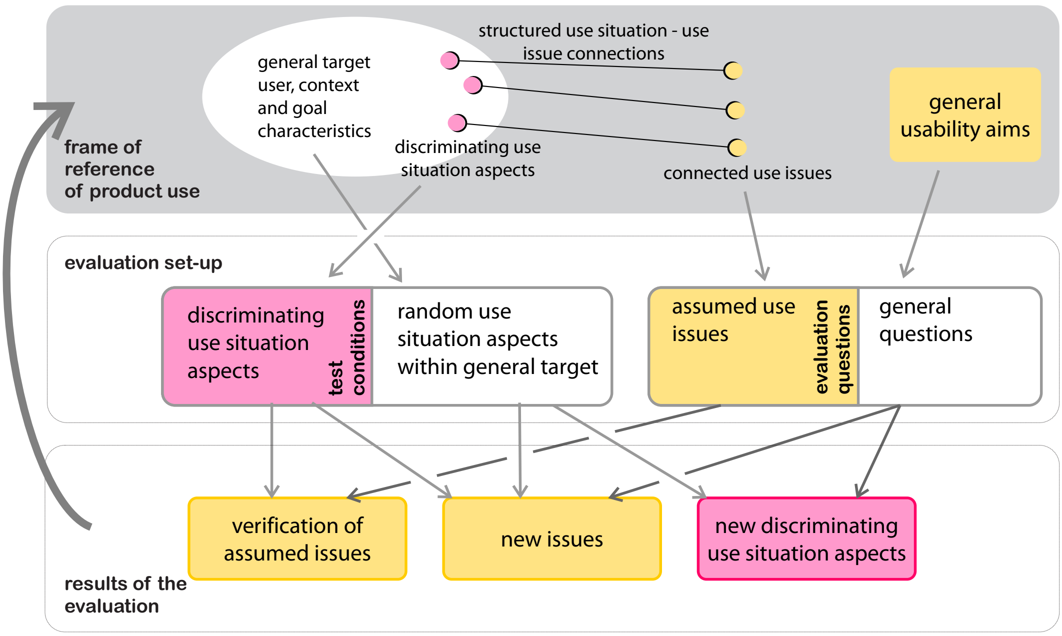
The question is which characteristics this 'test field' should have to allow both verification of assumed use situation – use issue connections as well as exploration of unexpected connections. The revised workbook describes to choose random test participants and environments when it is not clear what discriminating use situation aspects are. However, when the frame of reference *appears* to be complete with regard to this issue, other use situation aspects might be left unconsidered, such as the kitchen environment in this study. This apparent completeness can also be illustrated by the written process evaluation of team 2 which states:

> *"During the AirFryer project there was no awareness of missing important use situations, because it looked like all the issues were covered. Missing situations might become clear during use tests and should be addressed at that moment"*

So the students were aware of the fact that usability evaluations could lead to more insight in discriminating use situation aspects, but did not set up their test in such a way that it could lead to these kinds of insights. Therefore the support should more clearly emphasise that even though an evaluation might have a more evaluative than explorative character, more aspects of the use situation should be considered in the test conditions than just the ones that are part of the frame of reference. At least the user (respondent), goal (tasks) and context of use (test environment) of the expected or target use situation should be included in a test plan. This corresponds with the general notion in the user-centred design field that usability testing should be conducted with representative users and tasks in a representative environment (see for example, Rosson and Carroll (2002)). If it is not clear how these use situation aspects relate to use issues, such as with the kitchen environment and the Airfryer, a random use situation within the target or expected category of use situations can be chosen as test condition. For example choosing a random test environment within the category 'kitchens'. To verify assumed issues, the related discriminating use situation aspects should be part of the test conditions, in the case of team 2 for example different kinds of food. To explore new issues, the use situations need to be completed with random use situation aspects within a general realistic category of use situation aspects (a random kitchen), which in turn can lead to the discovery of new discriminating use issues (for example the size of the kitchen counter), as illustrated in figure 9.28.

The proposed structure of the frame of reference in the current workbook does not allow the inclusion of general use situation categories which are not (yet) connected to specific use issues. Therefore it is recommended in the final workbook to add a representation of these general use situation characteristics to the frame of reference, for example by means of a scenario description. Further research is necessary to investigate what the most appropriate means of representation is for this part of the frame of reference.

Figure 9.28: relationship between the content of the frame of reference, the test conditions and possible results. Evaluation results can be used to update the frame of reference.



The explorative character of the evaluation furthermore requires that higher level evaluation questions are formulated, in addition to the questions focussed on verifying use situation – use issue connections. Therefore it is recommended in the final workbook to include these type of questions as well. For example: what is the ease of use of the device in different types of kitchens?

9.4.4 Means of representation of the target frame of reference

With regard to the means of representation of the frame of reference, better guidance should be given on the means of representation of the target frame of reference and the importance of this overview for proceeding in the design process. One team used a one page A3 overview for this purpose. This is comparable to the A3 Architecture Overview developed by Borches and Bonnema (2010) which was applied successfully in industrial projects as a powerful communication tool to share architecture knowledge in complex system design. Like the simplified version of the complete DDUS frame of reference, the A3 architecture overview contains only the essentials and may serve as a baseline for a more comprehensive description with more detailed information.

However, the target representations of two of the three teams still contained a lot of issues (21 for both team 1 and 2). The revised workbook mentions that, apart from serving as a communication tool, the target view can be used in guiding solution generation as well. In the workshop iterations described in chapter 5 participants indicated they would like to take the five to seven most important issues for this purpose. This is a well-known characteristic of design, called 'problem framing' (Schön 1988; Cross 2007) or choosing a guiding concept (Visser 2009) or a 'primary generator' (Darke 1979). A representation of 21 use situation – use issue connections does not seem appropriate as such a guiding concept. What might have been a cause for this is the fact that 'target view' can be understood as a view of the selected intended use situations (e.g. 'elderly' or 'families with children) with all connected use issues, instead of as a selection of the (e.g. five to seven) most important use situation – use issue connections within that higher level target, which can be used as a guiding concept in solution generation. Therefore new terms are introduced for the different views on the frame of reference, as presented in figure 9.29. The level of detail of the 'priority view' which can be used to inspire solution generation, can vary and can be adjusted to the preferences of the development team.

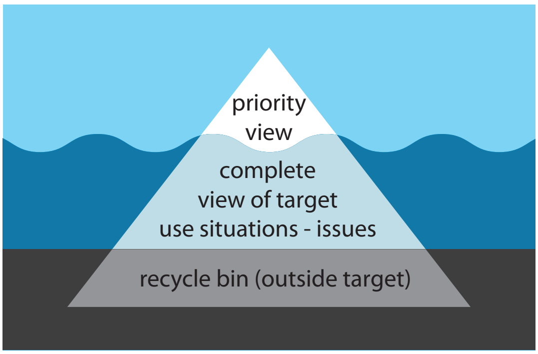


Figure 9:29: new definitions of the different views on the frame of reference

9.5 Conclusions

This chapter described a comprehensive descriptive study of the application of the revised workbook with guidelines to create a design approach aimed at dealing with knowledge of DDUS in the design process. Based on this study, adjustments were made to the workbook which resulted in a final workbook. Summarising, this study led to the following conclusions:

The guidelines positively support making relevant frames of reference explicit and they positively influence creating overview in the target frame of reference. The guidelines did not directly positively influence the structure of connections in the frame of reference. Therefore, a more detailed explanation of different formulations of use issues with regard to current and future use was added to the workbook as well as a recommendation for the integration of formulations of the desired situation in the frame of reference.

The target view of the frame of reference can be represented at different levels. For communication purposes a one page overview of selected intended use situations with connected use issues is appropriate. The study showed this overview was important to prevent blocks in the progress of the design process. For solution generation a more detailed 'priority' representation of about five use situation –issue connections seems more useful as a guiding concept, although this could not be confirmed by the applications in this study.

A further comparison of the studies presented in this chapter and in chapter 6 led to the conclusions that similarities between current use and future use define the extent to which a relevant frame of reference can be built of knowledge from either external explorations of current use, or from evaluations of solution proposals in intended use situations. In case of novel use situation – product combinations, the adjusted guidelines stimulate to mostly verify issues with regard to future solutions in use evaluations. When considering familiar use situation – product combinations, one can make more use of available knowledge about current use in external explorations of current use.

The study confirmed that a combination of exploring and verifying activities leads to a more complete frame of reference. However, the revised workbook did not lead to more explorations and verification in comparison to the initial workbook. The results also again confirm the importance of early verification of use issues. Although the added value of combining explorative and verifying activities was a new guideline in the workbook and although early verification was explicitly recommended, the guidelines were not applied by all teams. This might be due to the flexibility of the guidelines and the usability of the workbook, which is further discussed in chapter 10.

A structured frame of reference supports generating more focused research questions, but it cannot be concluded whether the completeness of the frame of reference contributes to this focus as well. The frame of reference was not employed to its full potential to set test conditions for usability evaluations, so it cannot be concluded if more structure and completeness lead to more externally valid test conditions.

To further support the use of the frame of reference for evaluations, it was advised that in case of verification of assumed issues, the related discriminating use situation aspects should be part of the test conditions. To explore new issues, the test conditions need to be completed with random use situation aspects within categories of general use situation characteristics. This can in turn lead to the discovery of new discriminating use situation aspects. Further research is necessary to investigate what the most appropriate means is to represent these general use situation characteristics in the frame of reference.

Apart from applying the Envisioning Use workshop in later design stages again to share newly acquired information and link it to case specific issues or to imagine issues for a newly defined target, this study shows that the workshop can also successfully be used to explore issues for developed solutions.

The heterogeneity of how the target use situation is connected to use issues does not become clear in the frames of reference presented in this study. More research is needed to identify what the best format is to present this heterogeneity.

This study again confirmed that the Envisioning Use technique and in general creating an explicit frame of reference of use situations together, leads to a shared vision or mindset of use situations and issues. This mind set was experienced as having an added value in communication within the team.

Although it is impossible to define the dynamic character of a product-target combination in advance, it seems that some guidelines are less applicable for product-target combinations with a low dynamic character. However, the guidelines are also useful to apply to products with less DDUS. When introducing the guidelines, a case with more DDUS should be chosen to gain experience with all aspects of the guidelines.

The next chapter will further discuss the conclusions of the complete research described in this thesis and compare the final support to the requirements introduced in chapter 4.

10 Reflection

10 Reflection

In this research I explored the relationship between usability and the dynamics and diversity of use situations, and how it can be taken into account in product design. Chapters 2 to 4 described research aimed at understanding this topic by means of a literature review and empirical studies. This led to the formulation of objectives for a design support. Chapter 5 to 9 described the iterative development of this design support, consisting of a set of guidelines aimed at designing for DDUS and the Envisioning Use technique. In this chapter I will reflect on the insights that were gained in these studies. In section 10.1 I reflect on and discuss the evaluation of the complete support, including both the developed guidelines and the Envisioning Use technique with regard to the formulated objectives. Section 10.2 describes a reflection on the research process. In section 10.3 recommendations are given for further development of the support and future research.

10.1 Evaluation of the complete support with regard to the formulated objectives

10.1.1 Summary of support objectives

This thesis investigated the relationship between usability and design for DDUS and how this relationship can be taken into account in the design process. The literature review described in chapter 2 showed that the dynamics and diversity of use situations in which products are used influences their level of usability. To design products with a certain level of usability in intended use situations, it is therefore necessary to evaluate solutions with regard to these intended use situations. Which aspects of intended use situations are important to consider in design, depends on the generated solution. This interdependency of use situations, usability and solutions, makes it difficult to analyse and define use situations and to apply them as a frame of reference in evaluations. It is generally acknowledged in user-centred design that it is important to describe and specify the intended use situations. It is also often mentioned that the test conditions of usability evaluations should represent the actual user, goal and environment. However, in spite of these acknowledgements, little guidance could be found on *how* a specification of intended use situations can lead to a frame of reference for those usability evaluations. This can particularly lead to difficulties for projects for which no suitable frames of reference are available from previous, comparable projects within the company or from generally available research on the use of the concerned type of product.

This research therefore included the development of a support aimed at filling this gap by guiding the creation of a flexible frame of reference which reflects the variety of intended use situations and the consequences for usability, and by guiding the application of the frame of reference in usability evaluations.

A study of the awareness of designers with regard to DDUS and a retrospective study of three usability oriented design projects in practice (chapter 3) showed the difficulty of defining relevant use situation aspects at the start of a design project. Both studies showed that use situation aspects that are not 'boundary conditions', can only become clear in evaluations of prototypes or of comparable products. Since these use situation aspects should at the same time serve as a frame of reference for these usability evaluations, building such a frame of reference can only be done iteratively.

However, the retrospective study showed that for unfamiliar products, relevant use situation aspects and connected usability issues were often only made explicit at the start of the design project. In chapter 4 it was argued that the lack of an up to date explicit frame of reference of most use situation aspects can negatively influence the external validity of the test conditions and focus of questions for formative usability evaluations. This can in turn can lead to a lower level of quality of recommendations for adjustment of the solution and consequently decrease the chance that usable solutions are created.

The retrospective study furthermore showed that knowledge of use situation aspects as well as of usability issues often remained implicit in the heads of design team members. A literature review described in chapter 4 showed that the lack of sharing of this knowledge can influence the 'team mental model' with regard to product use. It is assumed that this lack of sharedness in the 'vision on product use' can negatively influence the quality of design decisions with regard to choosing the most appropriate solution alternative and the intended use situations.

The analysis of the problem with regard to the design process of designing for DDUS led to the formulation of a list of requirements for a support in chapter 4:

1. The support should be able to support the design of products for which usability is considered an important issue and the use situations are diverse and dynamic
2. The support should improve the extent to which knowledge of product use is shared
3. The support should improve the external validity and focus of usability evaluations
4. The support should be easy to integrate in existing design processes
5. The support should be easy to learn

Based on these requirements, it was decided to develop a support which was aimed at generating a flexible frame of reference which reflects the variety of intended use situations and the consequences for usability of products for which the use situations are unfamiliar to the design team. Furthermore it was aimed at stimulating the application of this frame of reference in usability evaluations and in sharing knowledge of product use. A set of guidelines was developed to stimulate design teams to integrate the creation and application of this frame of reference in their design process. Furthermore a workshop technique was developed in collaboration with researchers Stella Boess and Christelle Harkema, to stimulate the sharing of implicit and explicit knowledge of product use by means of creating a first frame of reference. The support was evaluated in several iterations with both practicing designers and senior design students in both simulated and real design contexts.

Since the support is aimed at improving usability for products in intended use situations in design, it is also interesting to consider the usability of the support itself. Abovementioned requirements can be compared to the measures of usability: effectiveness, efficiency and satisfaction for specified users, goals and contexts of use (ISO 1998). The use situation of the support is reflected in requirement 1 which specifies the application domain of the support. This topic is discussed in section 10.1.5. Requirement 2 and 3 relate to the effectiveness of the support: the extent to which its users achieve the specified goals. The conformance of the developed support with regard to these requirements is discussed in respectively section 10.1.2 and 10.1.3. The creation of a frame of reference which was necessary to meet requirement 2 and 3 is discussed in section 10.1.4, exploring usability. The efficiency and satisfaction of the created support, which is reflected in requirement 4 and 5, is discussed in section 10.1.6.

10.1.2 Sharing knowledge of product use

In the original formulation of the objectives and the conceptualisation of the support in chapter 4, the idea was that the creation of an explicit frame of reference of product use would support the sharing of information and thus the creation of a shared vision on product use. The shared vision on product use could positively influence decision making with regard to choosing solutions and intended use situations. This could in turn lead to the design of products that are better usable in intended use situations. The activities ‘use situation analysis’ and ‘usability evaluations’ were expected to provide the content for this explicit frame of reference, while the developed Envisioning Use workshop technique was expected to be useful to bring implicit knowledge and otherwise available explicit knowledge together in a first explicit frame of reference (see the impact models in figure 4.3 and 4.4). The studies described in chapter 6 and 9 showed that these activities indeed led to such an explicit frame of reference. Moreover, the study in chapter 6 revealed that the Envisioning Use technique not only resulted in an explicit frame of reference of product use, but also in a 'mindset' on DDUS or an updated implicit frame of reference. By doing the workshop together, it could assumingly directly lead to a shared mindset or a shared vision on product use. Therefore in chapter 7 the hypothesis was formulated that the Envisioning Use technique can directly result in a shared vision on product use (see the revised impact model in figure 7.8). In chapter 8 this hypothesis was tested by executing the workshop in three different product development projects at different companies. These evaluations confirmed this hypothesis with regard to the direct effects of the technique. It showed that the shared vision includes sharing of available knowledge of product use, creating and sharing a vision on desired future use, and creating and sharing a vision on which knowledge lacks and which are the most important questions to investigate further. Although the lasting effects of the shared vision in design practice could not be evaluated fully, some comments of the participating design practitioners suggest that it supported team decision making with regard to choosing solutions and intended use situations later on. The results of the application of the guidelines in the student project described in chapter 9, which showed that the shared implicit frame of reference indeed supported communication, furthermore strengthens the assumption that the shared vision on product use supports decision making. The initial assumed influences on and of the shared vision on product use and the found influences are summarised in the combined impact model shown in figure 10.1. This model summarises the found influences with regard to the shared vision on product use described in the different chapters.

Influence of the explicit frame of reference on decision making

Based on the results of the first student project described in chapter 6, the revised guidelines advised to create a simplified version of the explicit frame of reference with a sufficient level of overview to support communication, for example by means of a one page (A3) overview. Although the actual developed workbook did not contain guidelines on the *application* of the explicit frame of reference in decision making, the application of the revised guidelines described in chapter 9 showed that such an overview for DDUS indeed supported communication within the student design teams, assumingly to make decisions on solutions and target use situations, and particularly with regard to preventing blocks in the design process. The latter goal was assumingly achieved by supporting decision making with regard to choosing which next steps to take in the product development process. *How* this explicit frame of reference influences decision making was not investigated. It is not clear if the explicit frame of reference influences this activity by contributing to a shared vision of product use, or if there is another mechanism which underlies this influence. Therefore the influence is indicated in dashed lines in the impact model in figure 10.1.

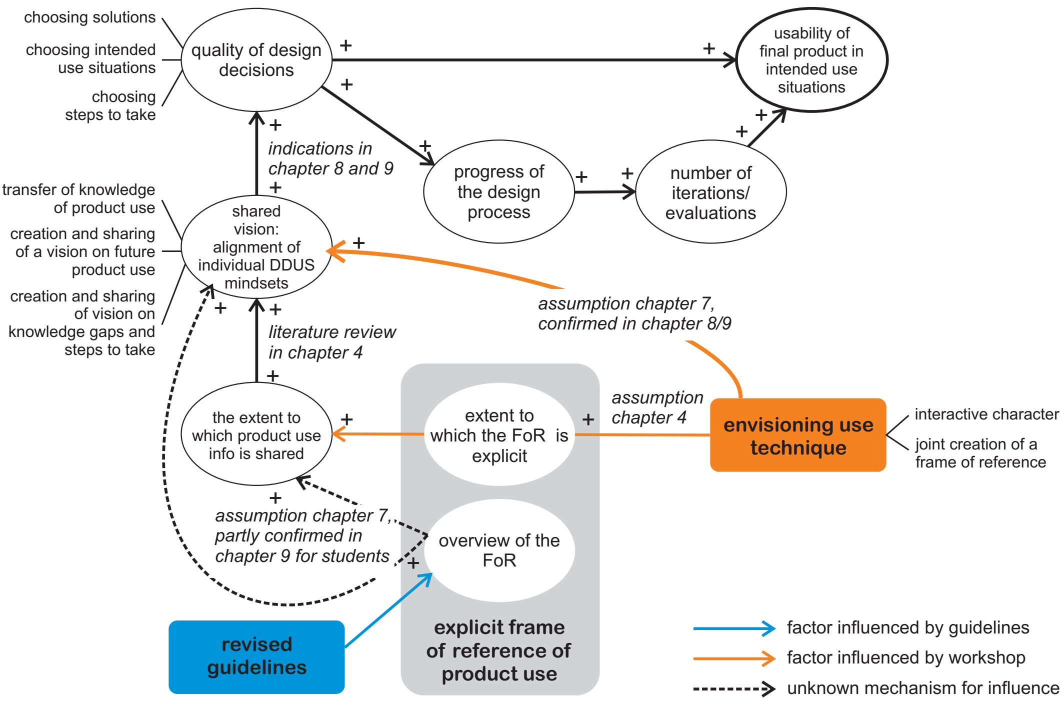


Figure 10.1: combined impact model which shows the assumed and found influences of the support with regard to the shared vision on product use

Stimulating knowledge transfer/ team mental model

In the study described in chapter 8, some participants indicated that the knowledge transfer seems to be stimulated by the active character of the workshop. In chapter 9 it was further concluded that generally the *joint creation* of the explicit frame of reference leads to a shared implicit frame of reference or shared vision on product use. Some students in that study argued that it would even not be possible to create this shared vision by means of just sharing the explicit representation. This raises the question to what extent a shared vision on product use can be generated by means of sharing information in an explicit frame of reference and to what extent other, joint and active activities are needed to create this shared vision. As Mohammed and Dumville (2001) argued information should not only be *mentioned*, but also be *actively considered*. The influence of 'activities' in knowledge transfer are also discussed in studies of educational research about active learning (for example, Prince (2004)).These studies showed for example that students remember more content when brief activities are introduced to a lecture. This suggests that other kinds of knowledge transfer, such as from team member to team member, might also benefit from an active approach. However, if and which activities are needed to increase the level of knowledge transfer, in particular with regard to the level of sharedness of the vision on product use, needs more dedicated research on a social and cognitive level.

Conclusions and recommendations shared vision on product use

The first requirement with regard to the formulated support objectives was that the support should improve the extent to which knowledge of product use is shared. This requirement is based on the assumption that sharing knowledge of product use would positively influence team decision making with regard to usability related issues. It can be concluded that the Envisioning Use technique indeed is successful in generating such a shared vision on product use and thus meets the concerning requirement. Additional research is needed to investigate the lasting effects of the Envisioning Use technique on the shared vision on product use and decision making, the influence of the overview of the frame of reference on decision making and the need for an active approach in creating the shared vision of product use.

10.1.3 External validity and focus of usability evaluations

The initial guidelines, described in chapter 6, were aimed at the expected core contribution of the support, namely the creation of the explicit frame of reference and its application in usability evaluations. The support was aimed at generating high quality recommendations as input to solution generation based on externally valid and focussed evaluations (see figure 10.2). This could ultimately lead to better usable products in intended use situations. The external validity refers to the generalisability of the results, while the focus of the evaluation refers to the aggregation level of evaluation questions, which can make the evaluations more effective (see section 10.1.4). External validity can be achieved by reflecting realistic test conditions in the evaluations, while focus can be achieved by aligning the evaluation questions to predefined assumed usability issues. Since in this study, the main objective was to take the dynamics and diversity of (real world) use situations into account in usability evaluations, particularly the external validity is crucial for the evaluation to lead to relevant recommendations for solution generation. Furthermore, the focus is necessary to take advantage of the externally valid test conditions, by measuring use issues that are considered relevant in these use situations.

In chapter 4 it was assumed that more appropriate use situations can be chosen to set test conditions, when enough insight is gathered in what these situations are and when these situations are made explicit in a frame of reference. Likewise, it was assumed that the focus of evaluations would be better, when enough insight would be gathered in what use situations are and which usability issues would be relevant in these situations. These factors are indicated in the combined impact model in figure 10.2 as 'the completeness of use situation-use issue connections' and 'the extent to which the frame of reference is explicit'.

Explicit frame of reference

The application of the guidelines in the carrier bike project described in chapter 6 showed that the explicit frame of reference indeed supported

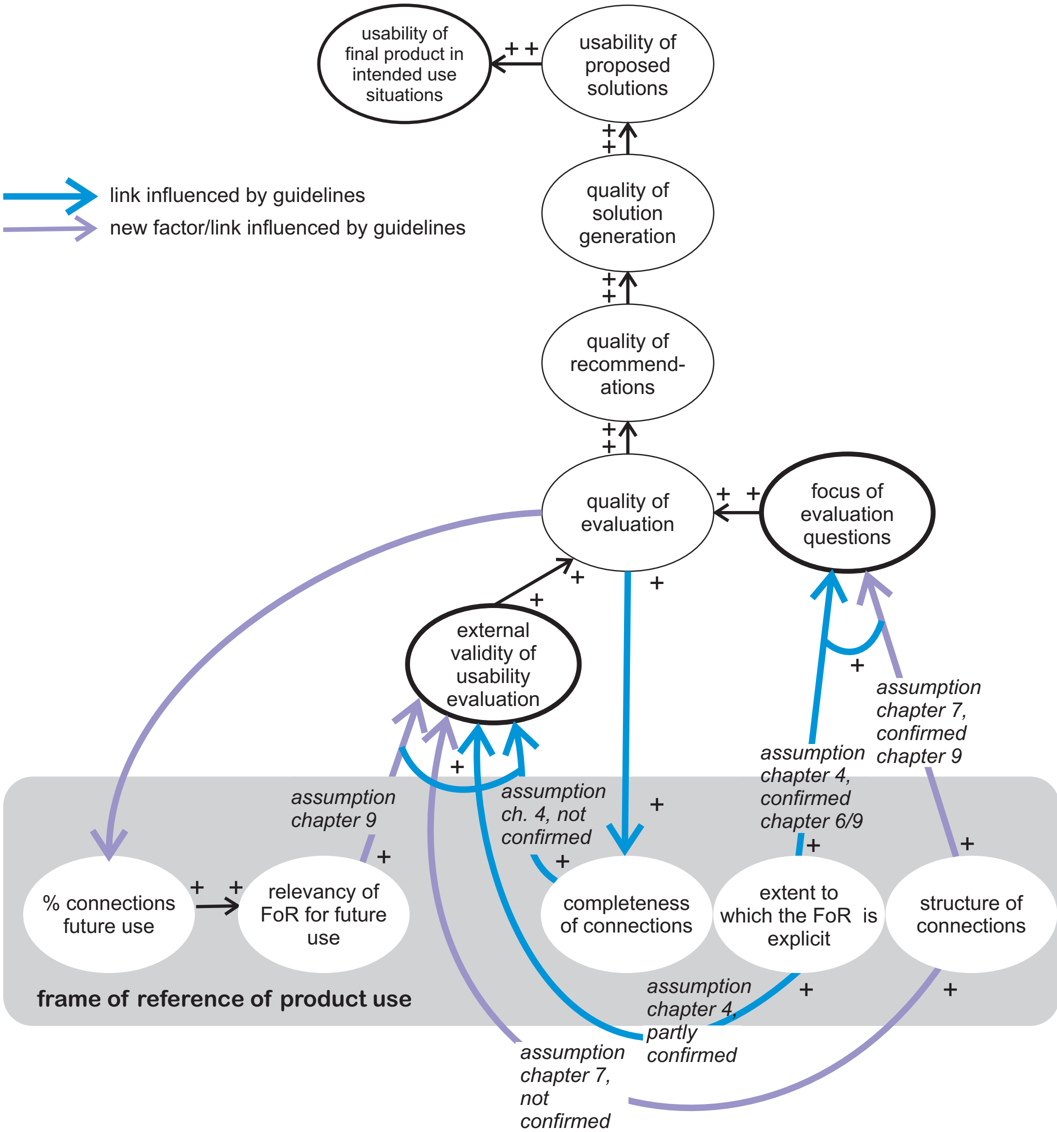


Figure 10.2: combined impact model which shows the assumed and found influences of the support with regard to the external validity of usability evaluation and connected focus of evaluation questions.

setting up test conditions. Conversely it could not be concluded that the test conditions cannot be set without the explicit frame of reference, since some teams managed to formulate realistic test conditions without the explicit frame of reference. The revised guidelines therefore described more extensively how to create an up to date explicit frame of reference and how to apply it in usability evaluations (section 7.1.5). Surprisingly, the explicit frame of reference was not used to its full potential to set externally valid test conditions in the Airfryer project described in chapter 9. All teams made explicit frames of reference and selected relevant respondents and tasks, but did not select relevant test environments. The teams did not explain if and how they used the frame of reference to select test conditions. It can therefore be concluded that an explicit frame of reference is no guarantee for an externally valid evaluation, since it is not useful when it is not *applied* for that purpose. This could be caused by a lack of support with regard to the application of the frame of reference. This issue is further discussed in section 10.1.6.

Although the frame of reference was not used to its full potential to set test conditions, both the carrier bike study and the Airfryer study showed that applying the explicit frame of reference did lead to more focus in the usability evaluations. The teams that did not use the frame of reference, defined research questions that were less focussed than the research questions of the teams that did use the frame of reference in doing so.

Structure of connections in the frame of reference

The results of the carrier bike study furthermore showed that it is important to connect use issues to use situations to be able to use the frame of reference to set relevant test conditions and focussed research questions (section 6.5.7) . The representations that did not connect use issues to use situations, such as collages, were not appropriate to set up usability evaluations. Since these representations do not clearly link use situations to use issues, they do not make clear which use situations are relevant to get answers to evaluation questions regarding specific issues. The extent to which these connections are made is defined as the structure of connections in the frame of reference (section 7.2.1). This need for a structure of connecting use situations to use issues was included in the revised guidelines presented in chapter 7. The application of the guidelines in the Airfryer project in chapter 9 showed that this structure indeed positively influenced the focus of evaluation questions. Since the frame of reference was not used to its full potential to set test conditions, it could not be concluded to what extent the structure could contribute to the external validity of the usability evaluations.

Completeness of the frame of reference

When the explicit, structured frame of reference is applied in usability evaluations, the next question is to what extent the completeness of the frame of reference contributes to the external validity and focus of evaluation questions. This turned out to be a difficult question to answer, since both absolute completeness of the frame of reference and absolute external validity cannot be measured during the design process. Therefore the completeness of the frame of reference was estimated based on the relative completeness (increase with regard to previous frame of reference) and the external validity was estimated, based on an analysis of other documents that gave insight in relevant use situations (see 9.2.4). Since the relative completeness of the frame of reference turned out to be a dissatisfying indicator (see section 9.3.4), no conclusions could be drawn with regard to this factor. The indirect measurement of the external validity of the evaluation based on other documents furthermore did not lead to optimal reliability of the results.

The absolute completeness of the frame of reference can practically never be proved, since you would need insight in all use situations that a product will actually encounter and all relevant issues in those situations. Therefore, a different approach is necessary to test related hypotheses. To make statements on the influence of the completeness of the frame of reference, it would be possible to measure the opposite: if the incompleteness of the frame of reference leads to lower valid usability evaluations. This could be measured retrospectively by measuring if use situation – use issue connections found after introduction of a certain product to the market, for example by means of after sales feedback, are present in the frame of reference of product use applied in usability evaluations in the design process of that product. The external validity of the evaluation could then be measured likewise by retrospectively analysing test conditions of usability evaluations and comparing them to use situations that are actually relevant. This would require the availability of cases in which such an explicit frame of reference was applied and for which after sales feedback on use situation – use issue connections is available. Since it is expected that these kind of cases are currently not available for the type of products considered in this thesis, this research question cannot be answered on short term.

Relevancy of the frame of reference for future use

The results of the Airfryer study described in chapter 9 further gave rise to considering the content of the frame of reference and the extent to which it describes either future use or current use. As argued in the first section of this chapter, the external validity of usability evaluations can be improved by reflecting real world situations in the test conditions. These real world situations consider the situations for the to be developed product. In other words, they consider future use. The relevancy of the frame of reference for future use can vary, depending on the extent to which its content is generated based on exploring either current solutions or new (future) solutions (see next section). The relevancy of the resulting frame of reference for future use was therefore added as an additional influencing factor for the external validity of usability evaluations in chapter 9 (see figure 10.2). How to increase this relevancy is described in the next section on exploring usability.

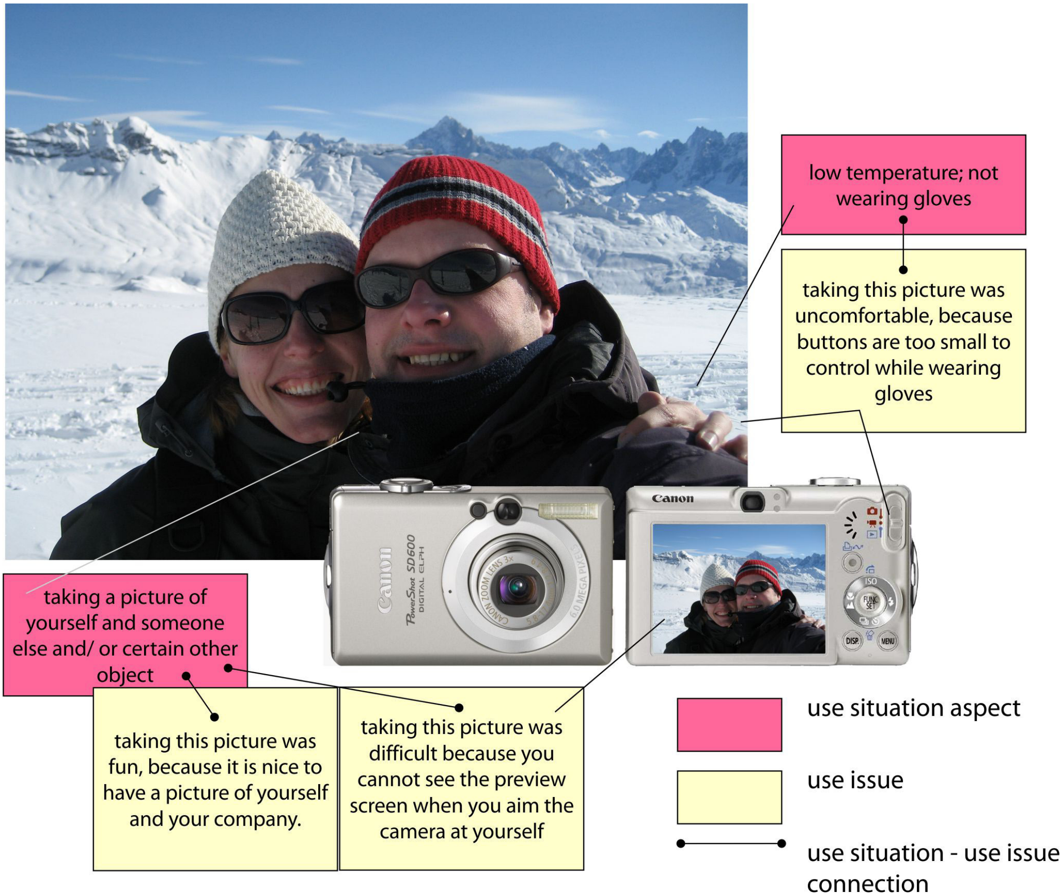
Conclusion and recommendations external validity and focus of usability evaluations

The second objective of the support was reflected in the requirement that the support should improve the external validity and focus of usability evaluations (requirement 3). To meet this objective, the support includes guidance in the creation and application of an explicit frame of reference of product use. The results showed that an explicit and structured frame of reference indeed supports the focus of evaluation questions in usability evaluations. Furthermore it has the potential of positively influencing the external validity of usability evaluations when it is appropriately applied. Although the completeness of the frame of reference is logically connected to the external validity of evaluations, no conclusions could be drawn with regard to this completeness because it could not appropriately be measured. Finally it was concluded that the external validity of usability evaluations is influenced by the extent to which the frame of reference is relevant for future use. Since this objective was evaluated with student teams, it is recommended to evaluate the added value of the frame of reference in usability evaluations in design practice. This is further discussed in section 10.2.3.

10.1.4 Exploring usability

This research was aimed at filling the gap between the analysis of dynamic and diverse use situations and the evaluation of solutions with regard to these use situations (see chapter 2). The creation and application of a flexible frame of reference of product use was proposed to fill this gap. The research furthermore showed that the *creation* of the frame of reference supports the generation of a shared vision of product use. In chapter 3 it already became clear that such a frame of reference both depends on, as well as is input to usability evaluations. It therefore has an

Figure 10.3: an example of explicit use situation – use issue connections, based on an exploration of the story in which my husband made a picture of ourselves and the Mont Blanc in the Haute-Savoie.



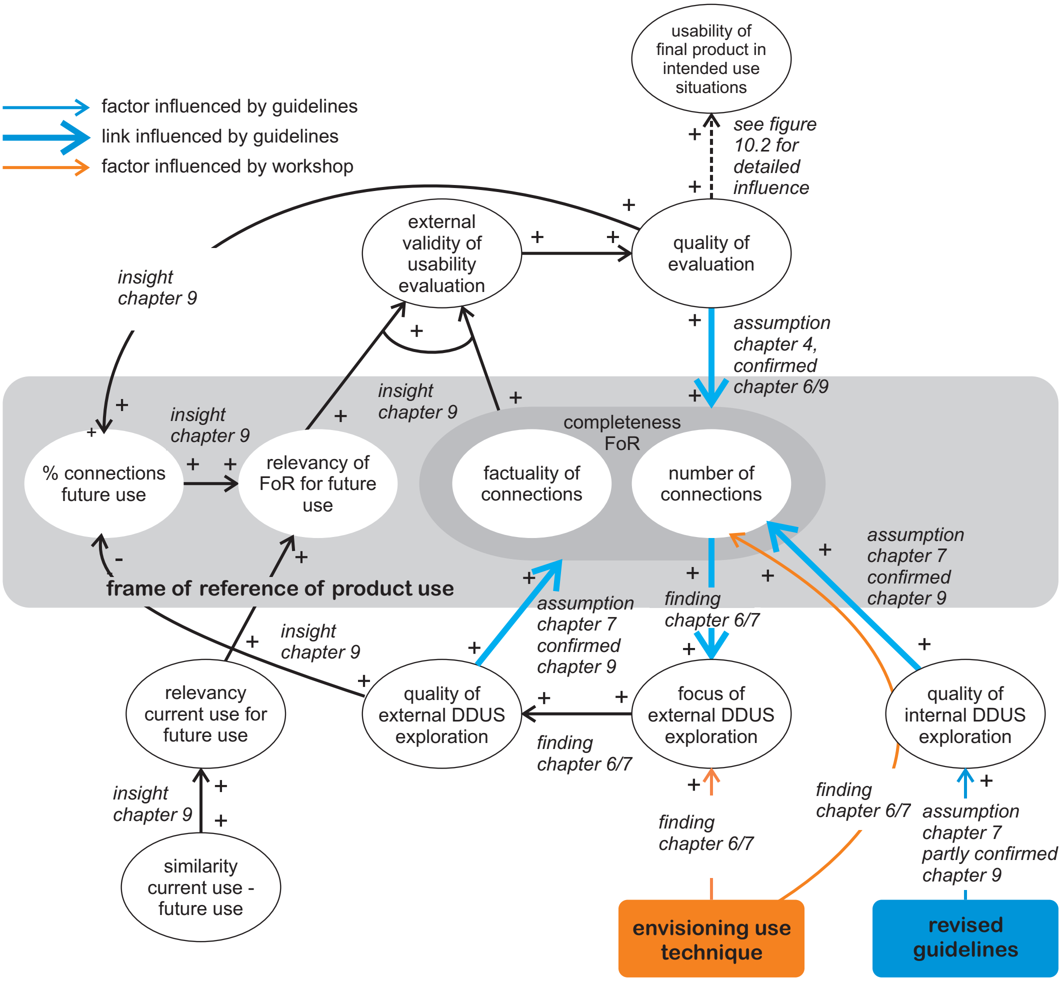
evolving character. This section describes the conclusions with regard to the creation and evolution of this frame of reference.

The initial guidelines presented in chapter 6 were aimed at generating the frame of reference by means of 'use situation analysis' and 'usability evaluations'. In the carrier bike study presented in the same chapter, it became clear that use situation analysis alone cannot be used to update the frame of reference when it does not connect use situations to usability issues. Just analysing who users are, where they will use the product for which purpose, does not give useful input to design when it is not clear how particular user, goal or environment *characteristics* or *aspects* are related to particular usability issues. Therefore, in the revised guidelines, presented in chapter 7, it was strongly advised to employ activities aimed at *exploring usability*. Explorative activities are those that are aimed at discovering new connections between use situation aspects and usability issues. Figure 10.3 shows some of those use situation – use issue connections for the introductory story in chapter 1 about my husband who took a picture in the Haute-Savoie of ourselves and the Mont Blanc.

Exploring usability is necessary to build a frame of reference of product use. This research has shown that for products that are new to the design team, it is not possible to define these frames of reference completely at the start of a design project because of their dependence on the solution. Relevant important use situation – usability connections become apparent while exploring solutions with regard to these connections during the design process. Although this difficulty is acknowledged in existing research, little guidance could be found on how to deal with this issue in practice. In this research I attempted to provide this guidance by means of the guidelines presented in the final workbook. In this section I further discuss the most important elements of exploring usability which were investigated in this research and presented in the final workbook. These elements include working with assumptions, exploring current use versus future use, exploring usability in evaluations and integrated types of usability exploration.

Working with assumptions

In chapter 7 it was concluded that the completeness of the frame of reference can be divided in the number of use situation – use issue connections and the factuality of these connections. This means that connections can be based on either facts or assumptions. As mentioned previously, explorative activities are aimed at finding new connections, thus increasing the number of use situation – use issue connections. Activities aimed at gathering assumed connections, such as scenario analysis or the Envisioning Use technique, were called 'internal DDUS exploration' in chapter 7, while activities aimed at gathering facts were called 'external DDUS exploration and verification' for current solutions and 'external evaluation' for new solutions. The latter activities could be aimed at finding (exploring) new facts or at verifying assumed connections in the



frame of reference. Figure 10.4 shows the influences of those activities in a combined impact model.

Figure 10.4: combined impact model which shows the assumed and found influences of the support with regard to the creation of the frame of reference.

In chapter 7 the hypothesis was posed that a combination of exploring and verifying activities leads to a more complete frame of reference of use situations. Although the absolute completeness of the frames of reference could not be measured, the study in chapter 9 showed that combining explorative and verifying activities was indeed successful in the generation of a broad frame of reference. The indication of assumptions and connected questions stimulated the execution of more activities to increase the verification of the frame of reference. Moreover, the explorative activities could be used to set a first frame of reference and thus provide focus for the verifying activities. This focus within the activities made their results more useful and thus made the activities more effective. From the emergence of this issue in both studied cases can be concluded that combining explorative and verifying activities indeed positively influences the generation of a frame of reference. The concerning guideline in the workbook is therefore valid.

A possible downside of generating a frame of reference based on assumptions is the false certainty such a frame of reference might give when design teams are not fully aware of the fact that they are working with an assumed frame of reference. In both the carrier bike study and the Airfryer study there were teams who neglected to verify their frame of reference early in the design process. The team in the last study even indicated that they were not aware of missing important information, because it looked like all the issues were covered. The support therefore did not have the intended effect for these teams, even though it was mentioned in both versions of the guidelines that verification is important and even though the first study showed that the questioning step in the Envisioning Use workshop could stimulate teams to have their assumptions verified. A possible explanation for the lack of verification in the second study is that it is sometimes difficult to assess if information on use situation – usability connections is factual or not. In that particular study the simulation level of both external explorations and evaluations was rather high, which influenced the validity of those analyses. For example, respondents were asked in a survey if they would mind 'shaking the basket' of the Airfryer, even though these respondents had never used an Airfryer before. Therefore better support is needed to make designers aware of the level of factuality of collected information.

Exploring current use and future use

As mentioned in the previous section, the relevancy of the frame of reference with regard to future use influences the extent to which it can be applied to improve the external validity of usability evaluations. Because future use cannot be predicted, it needs to be anticipated indirectly by either extrapolating knowledge about use of comparable products and situations or by evaluating solution proposals in intended use situations. However, when there is a large difference between the to be developed product and/ or its intended use situations and the current product and use situations, it is not likely that insight in current use will lead to relevant knowledge with regard to future use. Therefore in the final workbook introduced in chapter 9, it is advised to accommodate the choice for external exploration of either current solutions or newly generated solutions to the similarity between current use and future use. Similarity between current and future use is high when both the solution and the intended use situations are similar. In case of novel use situation – product combinations, the guidelines stimulate to mostly verify issues with regard to future solutions in use evaluations, while when considering familiar use situation – product combinations, one can make more use of the information that can be gathered by means of external explorations of current use. These influences are shown in figure 10.4.

It is sometimes debated how successful designs can be created based on knowledge of current solutions or current use. Moggridge (2007, page

726) discusses this issue when he compares 'designing something new' to 'designing a new version'. When you 'design something new' each team member will firstly need to listen and learn from all other experts to find out as much as they can about the context of the design problem. Then he recommends to start prototyping and evaluating early and often, making each iterative step a little more realistic. If you are designing a new version of something that already exists (such as a successor product), Moggridge advises to follow the same approach, with the difference that more time and effort is spend on understanding what has already been done in the first place, so that you are building on the state of the art rather than trying to reinvent solutions that others have developed before. This corresponds to above mentioned guidelines to make use of information of current use when there is a large similarity between current and future use situation – product combinations. More guidance on how this state of the art can be employed to create successful designs is given in the ViP approach (Hekkert and van Dijk 2011). This approach is aimed at 'exploring what is possible tomorrow instead of solving the problems of today'. Here designers are advised to 'deconstruct' existing designs by exploring their interactions and 'context level' and start (re-) defining the problem domain for which they are designing. Although this approach clearly starts from current interactions – here not just referring to usability, but to any quality of product-user interactions – it has the goal of 'helping you to free your mind from any preconceptions that might involuntarily or unconsciously affect the design steps taken later in the design process. […] When you start to look at products in terms of the factors underlying their existence, you will also start to feel, and eventually see, new possibilities.'(Hekkert and van Dijk 2011, page 136) This is exactly how an exploration of the relationship between DDUS and usability in current use could lead to successful solutions in the future.

Exploring usability in usability evaluations

As discussed in the previous sections, one of the means to explore usability is within the usability evaluations. They can be aimed at verifying assumed use situation – use issue connections and/ or exploring new use situation – use issue connections. This counts for both evaluating current solutions as well as evaluating prototypes. For verifying assumptions, the frame of reference is input to the evaluations by means of setting test conditions and evaluation questions.

As argued in chapter 9, when novel solutions need to be evaluated, such as in early design stages, the evaluation should be explorative, while in later design phases they should be more aimed at verification. The character of the evaluation should therefore be somewhere on a sliding scale between completely explorative and completely verifying. Chapter 9 concluded with additional guidelines on how to set test conditions and formulate questions for evaluations that are both explorative and verifying. To verify use situation – use issue connections, the evaluation questions should be focussed on the concerning use issues - for example: 'can the child reach the top of the device?' -, while to explore issues, more general evaluation questions need to be added, such as ‘in which ways is the device used by different children?’ Furthermore for the verifying part of usability evaluations it is recommended to make the related discriminating use situation aspects part of the test conditions. To explore new issues, test conditions need to be completed with random use situation aspects within the general target, which in turn can lead to the discovery of new discriminating use situation aspects. Since these random use situation aspects will not be found in a laboratory, it is recommended to conduct the evaluations in the field. Studies which show the advantage of field-evaluations over lab-evaluations usually mention its advantage with regard to the discovery of novel usability problems or issues (for example, Nielsen, Overgaard et al. (2006)). The results of this research lead to the conclusion that an additional advantage of field-evaluations is the discovery of discriminating use situation aspects for future evaluations.

In chapter 9 it was furthermore discussed how to determine random use situation aspects within the general target for the test conditions that are not addressed by the structured frame of reference. It was concluded that to be able to select appropriate test conditions, the frame of reference should contain general information about use situations, in for example (unstructured) scenario descriptions, in addition to the structured use situation aspect – use issue connections. More research is needed into both the format and effect of this additional content, before it can be added to the guidelines.

Integrated types of exploration

The different versions of the workbook each contained a process model of design activities surrounding the frame of reference. This model visualised how different design activities can be employed to create the frame of reference and how the frame of reference in turn can be employed to steer those activities. In the final workbook presented in chapter 9 (see figure 9.23), different types of activities are indicated to create the frame of reference. This division is based on the extent to which they result in assumptions (internal explorations) or facts (external explorations/ verification) and the extent to which they relate to existing, current solutions or to newly developed solutions. However, in reality the activities might overlap. In chapter 9 it was already argued that internal explorations might be aimed at both current solutions and developed solutions at the same time, such as in the envisioning use technique. Internal and external explorations can also be integrated, for example when an expert is involved in the Envisioning Use technique it will not only lead to assumptions, but also to facts. A specific type of integrated activities is participatory design, in which end-users are actively involved in the design process (Ehn 1993; Muller and Kuhn 1993). In participatory design sessions, designers and users can together explore both current use as well as future use. It is therefore an interesting means to efficiently create a frame of reference. In a separate study we have called this ‘participatory scenario generation’ (van der Bijl - Brouwer and van der Voort 2009). The sessions in that study involved only one or two end-users. When designing for DDUS these sessions would need to be adapted to cover a more broad spectrum of use situations, for example by involving experts with broad knowledge of user needs. How to employ participatory design for DDUS could be an interesting topic for future research.

Conclusion exploring usability

This research has shown that to create an explicit frame of reference, it is necessary to employ activities aimed at exploring usability, combined with activities aimed at verifying the created frame of reference. The developed support was successful in stimulating the exploration of usability. However, better support is needed to make designers aware of the factuality of collected information. In case of novel use situation – product combinations, the final guidelines recommend to mostly verify issues with regard to future solutions in use evaluations, while when considering familiar use situation – product combinations, one can make more use of information which can be gathered in external explorations of current use. It was furthermore concluded that usability evaluations should combine verification with explorations of new use situation – usability connections. To be able to explore new issues, more general evaluation questions should be formulated, in addition to focussed evaluation questions based on the frame of reference. Furthermore, evaluations need to be conducted in the field, in which test conditions need to be sought which include both the related discriminating use situation aspects as well as other realistic use situation aspects that are not explicitly connected to assumed use issues. More research is needed on how to integrate those general use situation descriptions in the frame of reference. Finally, future research could include the exploration of how participatory design techniques could be employed in the creation of the frame of reference.

10.1.5 Application domain of the support

The evaluations of both the guidelines and the envisioning use workshop have shown that the support is useful in the design of many different types of products, from carrier bike to presentation microphone and from software products to kitchen appliances. The products include both professional and consumer products as well as hardware and software products. The objectives stated in chapter 4 included that the developed support should be applicable to 'products for which usability is considered an important issue and the use situations are diverse and dynamic'. This section summarises the conclusions with regard to the necessary dynamics and diversity of cases to which the support is applicable, as well as the familiarity of the design team to the product's use situations and the design phase to apply the workshop.

The dynamics and diversity of use situations

In chapter 9, the applicability of the guidelines to products with less dynamic and diverse use situations was discussed. It was concluded that the guidelines are also useful to apply to products which turn out to have only limited dynamics and diversity in their use situations, since it stimulated the design teams to explicitly take the user, goal and context into account in their design process. However, some elements of the support that are explicitly aimed at exploring the broadness of use situations are less useful in that case, such as the imagining step of the Envisioning Use technique. It was furthermore concluded that to introduce the support (see section 10.1.6), a more dynamic and diverse case should be chosen which does allow gaining experience with all the elements of the support.

The familiarity of the design team with the product's use situations

The target design domain furthermore included projects with unfamiliar use situations for the development team. This target was chosen because for these teams it is most difficult to create a frame of reference, since they start with a 'blank page'. This was the case in both the carrier bike study and the Airfryer study. However, two of the three cases in which the Envisioning Use workshop was evaluated (chapter 8) concerned projects which were aimed at developing a successor product of a product that was already on the market. In these cases design teams could rely more on knowledge that was already available in the team with regard to product use, as opposed to the third case which concerned a completely new product. The workshop proved to be very well applicable to both types of cases. Although the guidelines in the workbook were not evaluated with regard to products with more familiar use situations, it is expected that they will be applicable to these kinds of cases as well. In that case design teams will not start with a blank page, but with the frame of reference of preceding products. Thus the aim becomes to let the frame of reference evolve over projects. A comparable approach was found in the retrospective study of the printer described in chapter 3. In that case the team could make use of knowledge of product use of preceding printers, available in both explicit representations as well as in the minds of the designers. For 'cross-case' use of the frame of reference and the shared vision, additional guidelines might be necessary, such as the general usability guideline stated by van Kuijk (2010, page 292): 'get and keep experienced people' and 'keep project teams intact' to manage implicit knowledge of DDUS. This guideline seems to undermine the objective of the Envisioning Use technique to make implicit knowledge explicit. However, it is not likely and also not desirable that the technique will make *all* knowledge explicit to be able to transfer the knowledge to other team members of a following project (see Badke-Schaub, Neumann et al. (2007) for a discussion of the necessary level of sharedness in creative problem-solving processes). Further research is therefore necessary to investigate these guidelines for cross-case use of the frame of reference.

Apart from an evolution of a frame of reference from project to project within a firm, a frame of reference can also be based on 'templates' of frames of reference which are generally available from research on the use of a specific category of products. In chapter 2 it already became clear that for some categories of products, such as software products, computer-supported cooperative work systems and mobile products, multiple studies in both research and practice have led to the generation of such general models or templates of frames of reference of product use. These templates, such as the contextual models of Beyer and Holtzblatt (1998) for computer-supported cooperative work systems contain the types of use situation aspects that should be considered, while connected approaches give suggestions on how to analyse those aspects. The difference from the guidelines described in this thesis is that the templates prescribe what the most important use situation aspects and connected usability issues are to consider, while the guidelines allow design teams to explore these connections themselves in the course of the design project. In other words, these researches offer 'ready-to-use' templates, while this research guides product developers in the *process* of generating these templates themselves. For categories of products for which these ready-to-use templates are available, the proposed approach has a lower added value than for types of products which require the generation of a completely new frame of reference. In the former case it is better to make use of those general models and the existing usability knowledge, than to reinvent the wheel by generating a completely new frame of reference. The design of some products might beneficially use the ready-to-use 'templates' of remotely related products as a starting point, but would still require the generation of dedicated frame of reference. Additional guidelines are needed regarding such a combined approach that leads to this adaptation of available templates.

The appropriate design phase to execute the Envisioning Use workshop

A final aspect of the application domain of the support is the appropriate design phase to conduct the Envisioning Use workshop. In chapter 5 it was concluded that the workshop is appropriate to apply in early design phases. In the carrier bike study and Airfryer study it became clear that the workshop is also very valuable to apply at later design stages to explore use situation – use issue connections when a new target use situation is chosen, to connect use situations to usability issues when new information about those use situation is gathered and to explore the usability consequences of newly generated solutions. The application of the workshop in chapter 8 led to the final conclusion that the workshop is useful at *any* stage of the development process in which the results of the workshop can still be used to improve the design or to steer research activities with regard to design.

Conclusion and recommendations application domain of the support

The first formulated requirement for the support was that it should support the design of products for which usability is considered an important issue and the use situations are diverse and dynamic. It can be concluded that the support is indeed successful for this application domain. However, the guidelines are also useful to apply to products which turn out to have only limited dynamics and diversity in their use situations. Furthermore, with regard to the application domain it could be concluded that the Envisioning Use workshop is useful at any stage of the development process in which the results of the workshop can still be used to improve the design or to steer research activities with regard to design. The workshop is applicable to both projects aimed at developing a successor product as well as at developing products with unfamiliar use situations, while the guidelines have so far only proved to be valuable for the latter type of projects. Additional guidelines need to be defined and investigated for the application of the support in the design of successor projects and of products for which ready-to-use templates are available.

10.1.6 Usability of the support

Like product usability, the usability of the support is also dependent on its use situation. The applicability of the support for different types of projects was already discussed in the previous section. The usability of the support differed for different teams of designers, for both the workshop and the guidelines. The extent to which the guidelines could be used by the students showed large individual differences. Some students indicated that they found them very easy to use. However, the results clearly revealed that for other student teams, working with the guidelines did not have the intended effects, such as the limited use of the frame of reference in usability evaluations. In some cases the workshop technique also gave some usability problems. Some participants particularly experienced problems with regard to the required 'use situation – use issue thinking'.

The main 'usability issues' that were mentioned in the requirements as being important for the success of the support are its 'learnability' and the possibility to integrate it flexibly in design processes. The learnability of the support can be improved by providing an appropriate introduction. Blessing And Chakrabarti therefore suggest to develop an 'introduction plan' (Blessing and Chakrabarti 2009, page 160). This section further discusses the observed issues with regard to the learnability and flexibility of the guidelines and the Envisioning Use technique and gives recommendations for an introduction plan.

Introduction to the guidelines

As mentioned in section 4.3.3., guidelines were chosen as a support tool, because they allow a flexible integration in the design process (requirement 4). However, as Blessing and Chakrabarti (2009, p160) stated: "the higher the degree of freedom for the user as to how the support can be used and the more the support allows different interpretations, the more difficult it will be to ensure that the support will be effective and efficient." The research showed that the guidelines' flexibility indeed allowed an integration in the design process, but in some cases also led to an unsatisfying level of application. The results of the Airfryer study show that, as opposed to the implicit frame of reference created through the Envisioning Use workshop, the explicit frame of reference was not applied to its full potential. Particularly in setting test conditions for usability evaluations it did not lead to satisfying results. One of the participating teams indicated that the intended use of the explicit frame of reference was not clearly defined in the guidelines. They furthermore explained in their report that '*designers tend to stick to the familiar way of designing, since they are not very experienced with working with the new method.*' The problems were therefore caused by a combination of a lack of learnability and too much flexibility. To further investigate this learnability problem the concerned team was asked in the group interview how they used the workbook to plan their design approach. They read it at the beginning as a start-up, but it contained so much detail that they could not take it all into the design process at once. So, although the application of the frame of reference in later design phases is explained in the workbook, the workbook was not read in those design phases by this team. Thus, for this team it can obviously not be expected that the workbook supports applying the frame of reference in usability evaluations. The only input the team used to set up their usability evaluation was the feedback of the researcher in the progress meeting and their experience with those kinds of evaluations from previous projects. Thus, the learnability of the support was in this case negatively influenced by the workbook format and partly compensated by the better accessible personal guidance in the progress meetings. Although for other teams the workbook format did not lead to any observable learnability problems, the question is if the application of the workbook by practising product developers would lead to the same problems. The flexibility of the guidelines was chosen on purpose, to allow the flexible integration of the guidelines in existing design approaches. It was and is not expected that design teams would completely change their way of working, just for the sake of DDUS, so it is not desirable to change the guidelines' flexibility. However, most of the designers who participated in the study described in chapter 3, indicated that they 'learn most from doing, and less from for example reading a book'. The workbook clearly does not provide this active character by itself. In the course this was partly solved by introducing the workbook at the start of the course in lectures and providing the additional personal guidance in progress meetings. Based on the results of the student projects, even more active guidance would be needed later in the course, for example by means of workshops in which students are actively introduced to the application of the guidelines in later design stages. For practicing product developers such as designers, usability experts and project leaders, a similar series of workshops could introduce them to the guidelines. Of course the downside of this approach to introduction is that it requires a considerable investment of time and effort. To persuade companies to make these investments, the success of the guidelines should be demonstrated, for example by means of showing best practices. Since the research at this stage does not provide this kind of evidence, a more customised type of introduction should be developed to gradually introduce the guidelines. This could be achieved by for example personal guidance on the application of the guidelines in a specific project, comparable to the progress meetings in the student cases. In this type of 'design-consultancy' a development team could be guided step-by-step in the creation and application of the frame of reference.

Introduction to the Envisioning Use technique

The usability of the workshop was evaluated and discussed in section 8.2.4. The problems that were experienced in the workshop referred firstly to the required thinking in use situations and use issues. It was concluded that the motivations for learning that way of thinking should be explained clearly at the start of the workshop. Another conclusion that was made with regard to the usability of the workshop is that the starting point of the workshop should be made clear by means of alignment of workshop expectations and the wrap up of the workshop should always be included to make a connection between the workshop results and subsequent activities.

Although the workshop also gave some usability problems, its introduction is a lot easier than the introduction of the guidelines since it already has an active character in itself. A tutorial of the workshop therefore proved successful in the student projects to introduce the workshop. A manual was developed for the workshop to allow design teams to organise their own workshop (van der Bijl - Brouwer, Boess et al. 2012). To further introduce the workshop and disseminate these research results, several additional tutorials were already given by the researchers at for example the Design for Usability symposium in Delft in November 2011.

Conclusion usability of the support

It can be concluded that the Envisioning Use technique largely meets the requirement that it should be easy to learn. To further increase the learnability of the workshop it was recommended to particularly pay more attention to motivating the purpose of some of the workshop characteristics. Furthermore from the successful application of the workshop in design practice it can be concluded that it is also flexible enough to apply it in existing design processes and therefore meets the requirement that it should be easy to integrate in existing design processes. The guidelines also meet the latter requirement. However, the learnability of the guidelines is not optimal and should be improved by means of an adjustment of their introduction. This can probably be achieved by accompanying the workbook with a more active introduction of the guidelines. More research is needed with respect to the exact form of this active introduction of the guidelines in design practice.

10.1.7 Additional support functionalities

The expected core contribution of the support defined in chapter 4 was the guidance in creating an explicit frame of reference of product use and its application in usability evaluations. Therefore this was the main objective of the developed actual support, including the guidelines and

Envisioning Use technique. In chapter 7 and 8 it was concluded that the support also positively influences the generation of a shared vision of product use which assumingly influences decision making with regard to usability. However, the actual support does not include guidelines with regard to the application of the explicit frame of reference in decision making. Although the research gave some first indications that an overview of the frame of reference could support this process, additional research is needed to further investigate this issue to be able to include it in the guidelines.

The intended support defined in chapter 4 furthermore contained a third functionality which was supporting 'use situation analysis' by means of providing a catalogue of appropriate existing techniques which could be employed for this purpose. In the revised workbook 'use situation analysis' was replaced by 'external explorations of DDUS for current solutions'. Currently, the 'UCD-toolbox' is being developed by Weevers (2012) which attempts to give access to and support the selection of a large part of available user centred design methods. The proposed tool filters methods with regard to self-chosen criteria such as type of object, goals and available resources. For design for DDUS it could be interesting to develop a dedicated filter for such a tool to select methods that can be used to explore usability for DDUS.

10.1.8 Conclusion support evaluation

The developed support was aimed at the design of products for which usability is considered an important issue and the use situations are dynamic and diverse (requirement 1). The support proved to be successful in supporting the design of these kind of products. Moreover, it was also assessed as valuable for the design of products which have use situations that turn out to be less dynamic and diverse. The main objectives formulated for the support were that it should improve the extent to which knowledge of product use is shared (requirement 2) and that it should improve the external validity and focus of usability evaluations (requirement 3). The expected core contribution of the developed support was to provide guidance in the creation of an explicit frame of reference which reflects DDUS and its application in usability evaluations. This explicit frame of reference was also expected to be valuable in sharing knowledge of product use. The 'guidelines to design for DDUS' proved successful in giving the required focus to usability evaluations in the student projects and also proved that they can be used to set-up externally valid usability evaluations. In the course of the research it became clear that the added value of the support was not only the assumed core contribution of the explicit frame of reference, but even more or at least as important the added value of the support in generating an implicit, shared frame of reference of DDUS and related usability issues and its assumed influence on decision making. The developed support influenced the objective with regard to sharing knowledge of product use in a different way than expected. Instead of creating a shared 'vision of product use' through sharing an explicit frame of reference of product use, the shared vision was found to be created directly through the *joint creation* of such a frame of reference in the Envisioning Use technique. Exploring usability proved to be a valuable approach in creating both the explicit as well as the implicit frame of reference of DDUS and related usability issues. This approach includes a combination of explorative and verifying design activities. The guidelines and the Envisioning Use workshop were both easy to integrate in existing design processes (requirement 4). A downside of the support is the workbook-format for the guidelines, which in some cases lacked to stimulate the application of the frame of reference to a satisfying level. To meet requirement 5 which states that the support should be easy to learn it is therefore needed to adjust the means by which the guidelines are introduced.

10.2 Evaluation research method

In this research a support was developed for designing for dynamic and diverse use situations. The development of the support was preceded by an understanding of this topic based on both a literature review as well as an empirical study of the subject in design practice. Blessing and Chakrabarti's Design Research Methodology (Blessing and Chakrabarti 2009) was used as a framework for this approach. In this section I will shortly reflect on the use of the DRM framework, the explorative character of the research and the external validity of the gathered results.

10.2.1 Evaluation of the use of DRM

The framework proved to be a very valuable means to connect the insights gathered on the existing situation in design practice and design research, to the development and evaluation of the support. The reference model described in chapter 4 and the consecutive impact models made explicit what the existing influencing factors are in the formulated problem and how the support was desired to influence those factors. The creation of the models turned out to be an iterative process. In the course of the research process, both reference and impact models became more clear, although this thesis only shows their final representation. Just like the frame of reference of product use, the reference and impact models evolved based on new insights gained in the several studies. In that way the models proved to be very valuable for interpreting the results of the studies.

Furthermore these models make visible which of the links between factors are assumed and which are based on facts, either based on own investigations or existing research. In this research, this particularly supported the generation of a research plan and the formulation of research questions. Like the frame of reference of product use, the impact models thus were both input to the studies as well as a means to visualise their results. For example, the studies in chapter 6 gave rise to the formulation of an assumed link in the impact model between the

Envisioning Use technique and the 'shared vision on product use', while this link was later used to formulate the main research question of the study described in chapter 8 in which this link was verified. The flexibility of the models supported this iterative process.

A limitation of the models is that the links do not reflect the more subtle characteristics of the influences. For example, one of the influences in the reference model was the influence of the 'shared vision on product use' on the 'quality of decision making'. Firstly, only partial evidence could be found for the existence of this link, so it's not an assumption, but also far from a proved influence. Secondly, the influence seemed to have a certain optimum. A too low level of sharedness could negatively influence decision making, but a too high level as well. This non-linear influence could not be reflected in the concerning link. Therefore additional explanation was always needed when the models were used to communicate the research plan or results.

10.2.2 The explorative character of the study

The importance of considering different users, goals and contexts of use when designing for usability has been discussed in many studies on user-centred design. However, providing guidance in designing for DDUS is a new research subject. Therefore this research had a strong explorative character, which is reflected in the title of this thesis: 'exploring usability'. Exploratory studies are aimed at developing pertinent hypothesis and propositions for further inquiry (Yin 2009). In this case this meant that the research was aimed at investigating what the relevant factors and links between factors are when designing for DDUS, instead of an in-depth, rigorous study of the factors and links themselves. As a result of the focus on relevance instead of on rigor, some aspects of DDUS have only been considered superficially. It was already discussed that the influence of the explicit frame of reference on the shared vision on product use and decision making needs a more rigorous study. Furthermore, little attention was paid to the creative process of designing for DDUS. What is the influence of the mindset of DDUS on the creative process? What is the influence of internal explorations of DDUS within the creative process? And how can internal explorations of DDUS be stimulated within this creative process? Answering these questions needs a different research approach, as the data gathering methods used in this research – for example document analysis and post-project interviews – do not give sufficient insight in what goes on during the 'short term' creative process. This type of design processes is often studied by means of protocol analysis (Dorst 1995). Future research should include such a rigorous research method to be able to zoom in on the design process and answer aforementioned questions.

10.2.3 External validity of the gathered results

The broad character of the research also influenced the external validity of the research results. The fact that the guidelines support the majority of phases in the design process made it practically impossible to evaluate the guidelines in design practice, due to the general lead time of product development processes and the available research time. Therefore the guidelines were applied to student projects. The differences between students and practicing designers relate to their expertise level, the multidisciplinary composition of design teams in practice as opposed to the student teams consisting just of industrial designers and the lack of a real design context. To be able to generalise the found benefits and limitations of the guidelines to design practice, additional research is therefore needed. The Envisioning Use technique could be evaluated successfully in design practice. However, its lasting effects could not be measured. As suggested in chapter 8, additional research is therefore also recommended to measure these effects.

10.3 Recommendations

The exploration of DDUS as described in this thesis has led to the development of two supports, the Envisioning Use technique and the workbook with guidelines on design for DDUS and its accompanying introduction. The evaluation of the guidelines described in chapter 9 led to the creation of the final workbook with guidelines to design for DDUS. In this chapter, additional recommendations were formulated for the adjustment of the guidelines. These support recommendations include:

- The formulation of additional guidelines to extend its application domain
- The development of an adapted introduction to the guidelines
- Facilitating the application of the guidelines in combination with the use of other tools and techniques

Furthermore, additional research can lead to further improvement of both supports. For reasons of controllability and feasibility, the guidelines have only been evaluated with students within this research. The guidelines therefore need to be evaluated in design practice to conclude on the success of the guidelines for that design context. The Envisioning Use technique has already matured to a support that has proved to be successful in design practice. However, each application of the workshop has led to new insights with regard to its set-up and applicability. Therefore it is expected that in the future, the technique can become even better when it will be continuously evaluated and adjusted.

The studies described in this thesis could be used to answer most of the initially formulated research questions. However the explorative character of the complete study has led to the formulation of even more questions. For each of the conclusions discussed in this chapter, recommendations were made for future research. These recommendations include:

- A study of the existence of (higher level) assumed influences in the impact model that could not be investigated in this research
- A more rigorous study of the influences for which indications were found in this study
- An evaluation of the application of the guidelines in design practice
- An exploration of the recommended adjustments to the guidelines and its introduction

In this research I explored the concept of usability and what it means to design usable products for dynamic and diverse use situations. By solving a little piece of the puzzle, the thesis contributes to building a body of knowledge of design and usability. I hope that we as design researchers, design practitioners and design students can continue to better understand this topic in order to stimulate and support designers in designing products that fulfil the needs of users.

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List of abbreviations

CSCW	computer-supported cooperative work
DDUS	dynamic and diverse use situations
DIF	design information framework
DRM	design research methodology
FMEA	failure mode and effects analysis
FoR	frame of reference
HMS	health monitoring system

Appendices

Contents

Appendix 1 checklist of use situation aspects

User characteristics

Aspect	Description	Examples
General demographic data	Aspects that describe a certain segment	Examples: age, sex, nationality
Background information	General aspects about people's lives	Exampes: family members, home, occupation
Physical characteristics	Characteristics of the human body such as dimensions and biomechanical characteristics	Exampes: size, weight, power
Cognitive characteristics	Characteristics of the human mind that relate to knowledge acquisition	Exampes: IQ, memory, learning style
Sensory characteristics	Characteristics that relate to perceptive capabilities of the senses	Examples: sense of sight/ hearing/ touch, kinesthesia
Cultural characteristics	Values and believes that apply to a certain culture	Examples: meaning of colours, compatibility of movement
Personal traits and emotional characteristics	Behavioral and mental characteristics by which an individual is recognized as being unique	Examples: extravert/ introvert, seriousness, optimism

User characteristics

- **Knowledge and bodily skills**
  Mental and bodily skills that people can develop or acquire.
  - **Basic knowledge and bodily skills**
    Skills and knowledge that can be useful in everyday liefe or in multiple interactions with products
    Examples: language, walking, typing
  - **Knowledge and bodily skills related to use**
    Skills and knowledge that are related to the use of a specific product
    Examples: novice/ expert, training, experience comparable products
  - **Knowledge and bodily skills related to domain**
    Skills and knowledge that are related to a certain domain.
    Examples: knowledge of procedures
- **Personal state**
  The conditions of a user at a certain moment in time and that can be subject to change
  - **Physical state**
    Physical conditions
    Examples: illness, fatigue, intoxication
  - **Cognitive state**
    Cognitive conditions
    Examples: ability to react, attention, fatigue
  - **Emotional state**
    Emotional conditions
    Examples: tension, happiness
  - **Relation to context**
    The relation a user has to an environment at a certain moment in time.
    Examples: position, location, role

Goal

Main personal goal

Higher level goals people want to reach

Examples: acquiring status, driving safely

Product related goals

The goals that are directly related to the use of a product: what people want to reach on short term using the product.

Examples: get trainticket, write a letter

Preferences

Preferences people have with regard to behavior or appearance of a product

Examples: colour, form, sound preferences, information preferences

Context

Physical conditions

The physical circumstances of the environment in which a product is used

Examples: light, sound, weather conditions

Infrastructure

Structural elements that provide the framework supporting an entire structure such as civil and ICT infrastructure

Examples: roads, energ supply, internet access

Objects

Tangible and visible things in the environment that influence use

Examples: outfit, tools, accessories, manuals

Persons

Human beings in the environment that are not the users themselves.

Examples: client, audience, crowd

Substance

A homogeneous material of a definite composition such as water.

Examples: mud, dust, humidity

Information

External knowledge

Examples: procedures, pass word

Appendix 2 Interview questions retrospective study

This interview consists of four parts. Firstly I will ask you about your background. Then we will discuss the project in general and further discuss the use situation aspects that came forward in the group interview. Finally I will ask you some questions about the follow-up of my research. The complete interview will take about one hour. I record the interview on this memo recorder.

Part 1 background

1. What is your background in work and education?
2. How do you define usability?

Part 2 general information on the design project

3. What was your role in this project?
4. How important was usability in this project in comparison to costs, functionality, aesthetics, etc.?
5. Which usability issues were of importance in this project?
6. How are they related to the use phases of the product?
7. Are these usability issues documented?
8. Which techniques were used to improve usability?
9. What was your frame of reference for evaluation solutions on usability? Was this frame of reference adjusted during the design process? How is the frame of reference documented and communicated between team members?
10. To what extent was this an iterative design process? Did you have to make steps backward? How often was the design evaluated on usability?

Part 3 varying use situation aspects

These are the use situation aspects I analysed, based on the results of the group interview. For each aspect I indicated the extent to which they vary en how they were investigated. We will now go through these use situation aspect cards together.

11. What are the most important use situation aspects? Which are of most importance to usability? Put them in order from most important to least important.
12. Which aspects vary most?
13. Can you confirm my interpretation of the five most important use situation aspects? Can you tell me if and how these use situation aspects were documented and communicated? What kind of solutions were generated to accommodate these use situation aspects?
14. Which aspects were difficult to predict?
15. Which aspects led to conflicting requirements? How was that solved?
16. Which of these aspects were integrated in evaluating the solutions, such as in usability evaluations?
17. Which of these aspects result from previous projects and can be re-used? How does this project fit in the complete range of products developed by your team?

Part 4 learning a new support

18. Which methods or techniques did you learn the past years with regard to usability?
19. How do you prefer to learn a new technique?

Appendix 3 Techniques to analyse DDUS

Different techniques can be applied to conduct external (use situation) analyses, such as observations, interviews, online reviews, literature, expert interviews etc. The table below gives an overview of different techniques to explore and verify dynamic and diverse use situations.

Type	Benefits/ limitations	Reference
Expert interviews	Experts have a broad knowledge about users, contexts and issues. The expert is not always the end-user.	
Online: internet fora, reviews, YouTube	Broad variety of stories is available, in case of movies with visualizations. Reliability cannot be inspected. Very often only extreme cases and problems are shared.	
Probing	Gives deep insight in the use stories of one particular user. Not so efficient.	(Gaver, Dunne et al., 1999; Wensveen, 1999; Sleeswijk Visser, Stappers et al., 2005)
Observation of current use	Observations can give direct insight in context characteristics. One cannot observe what goes on in the user's head. Longer observations necessary to analyse dynamic use.	(Wilson, 2012)
End-user interviews	To get insight in user goals. To achieve breadth in results many users should be interviewed.	
After sales feedback	Depending on the way the after sales feedback is retrieved, a broad variety of issues can be analysed.	(van Kuijk, Kanis et al., 2007)
Use evaluations of current solutions	Explore the use of existing solutions in new use situations. Does not give insight in actual use, as opposed to above mentioned techniques.	
Analysing catalogues	Particularly anthropometric data are commonly available, but also other use situation aspects can be found in reports or catalogues. However, this data is mostly not connected to specific use issues.	(Daanen, Krul et al., 2004)
Standards and legal requirements	Norms often mention the test conditions (=use situations) that are used to evaluate products for a specific norm.	

Appendix 4 Course information 'Design for DDUS'

Introduction

As part of the research of Mieke van der Bijl-Brouwer on 'design for dynamic and diverse use situations (DDUS)' a set of guidelines is being developed to support designing products with DDUS. The support consists of a workbook with guidelines and a 'knowledge gathering workshop'. A first version of the workbook was created and the workshop has been evaluated multiple times in design practice. In this project, students will apply the guidelines for the first time to a complete design project. Students will partly follow the guidelines and partly explore aspects that have not been captured in the guidelines yet.

Assignment

Analyse the dynamics and diversity of the use, users, and context of use of a carrier bike. Based on these analyses, design a new version of (a part of) the Bongo carrier bike or an accessory that is suitable for a broad, specified part of the analysed use situations.

http://www.bongobakfiets.nl/

Process

Apply the guidelines to design for DDUS as much as possible, as described in the workbook. Develop a frame of reference for DDUS as described in the workbook. Keep a log of the development of the frame of reference and the created design. Make every step explicit in this log, including informal or implicit steps. You can use the template to create the log (see deliverables).

Within the assignment, three phases are distinguished which can partly be executed in parallel:

1. Research phase: analyse the current use of the carrier bike and related products for the transport of persons and luggage on short distances. Based on these analyses create an overview of use situations and issues. This is the basis of your frame of reference. Choose a target within this frame of reference: the use situations (users, goals, context) at which your design will be aimed and the issues that you want to take into account. Make a simplified representation and description of this target. This will be your vision for the design process.
2. Iteration 1: create solutions based on your vision. Evaluate representations of these solutions (such as low-fi prototypes or sketches) informally with regard to your complete target. If needed, adjust your frame of reference based on evaluations or additional analyses. Present your vision and at least two concept designs to the client.
3. Iteration 2: choose a concept design and improve the design based on the evaluations and the feedback of the client. Adjust the frame of reference where needed based on the feedback of the client and additional analyses. Create a functional prototype of your design and execute a user test which includes less simulations than your earlier evaluations (see workbook, anticipating use/ analysing use issues). Make sure your test conditions clearly relate to your frame of reference. Choose multiple use situations to evaluate the dynamics and diversity of

use. Draw conclusions with regard to the appropriateness of your design and recommendations for the client. Show your design and your conclusions in an oral presentation.

Assessment

The course will result in a final grade for the group assignment. The assignment will be assessed on the following criteria:

- The overview and completeness of the frame of reference
- The clarity of the chosen target/ vision. Is it clear at which users, goal and context the design is aimed? Is it clear which issue (of usability, user experience, …) should be achieved by the design?
- The application of the frame of reference in usability evaluations
- The suitability of the design for the chosen target
- The evolution of the frame of reference based on new information
- The integration of DDUS in the design process.

Planning

The table shows a proposal to go through each stage. You are allowed to deviate from this planning, but the intermediate presentation and scheduled days to build your mock-up and prototype are fixed. Phases can be executed in parallel.

week nr		Monday	Tuesday	Wednesday	Thursday	Friday
5	31-1-2011	**Lecture 1**			**Lecture 2 group 1**	
6	7-2-2011	**Lecture 2 group 2**		**Start project**	Literature/ competitor analysis	
7	14-2-2011	**workshop knowledge gathering**	use situation analysis			
8	21-2-2011	holiday				
9	28-2-2011	**present basis framework & vision**	Iteration 1		Possibility to build a first mock-up	
10	7-3-2011	**Progress meeting**	Possibility to build a first mock-up			
11	14-3-2011	**Intermediate presentation**	Iteration 2			
12	21-3-2011	**Progress meeting**				
13	28-3-2011	**Progress meeting**	Possibility to build prototype			Possibility to build prototype
14	4-4-2011	Use evaluation, create portfolio, prepare final presentation				
15	11-4-2011	**Final presentation**	Course evaluation			

Guidance

Every Monday afternoon a progress meeting is scheduled. Since your design process will be used for research purposes you are kindly requested to come to these meetings.

Deliverables

(see section on ‘documentation’ for a more detailed explanation of below mentioned deliverables)

- Log of the process
- Visualised log of the development of the frame of reference
- Portfolio of the development of the design (can be combined with the log of the frame of reference)
- Oral presentation of the intermediate results and final results
- Evaluation of the followed approach (group meeting and a written evaluation, not assessed for final grade)

Preparation workshop

You need to facilitate and prepare the knowledge gathering workshop by yourself. You will learn the procedure for this workshop in lecture 2. You can find more information on the workshop in the manual. Assign the facilitation task to one of the team members. The other team members should gather as much as possible information about the use of carrier bikes preceding to the workshop. Think of literature, online user fora, reviews etc. Mieke will observe your workshop for her research and is available for assistance. General workshop materials will be available. Furthermore a carrier bike is available for the experiencing step. Other materials such as 'associative materials' and props for experiencing need to be provided by yourself.

Research of the design process/ log

Since your design process will be evaluated for the research, it is important that we can gain insight in this process as much as possible. Therefore you are requested to fill in your log every week and bring it to the progress meeting. Furthermore we would like to ask you to share your digital documents through Blackboard or another online file storage provider.

Documentation

To document the design process you are requested to keep the following documents up to date:

Process log: fill out the process –template with the steps that are taken every week. For each step, fill in what you did, who was involved, how long this took and indicate what kind of activity it was (use situation analysis, use evaluation, solution generation, decision making, other). Make a short report for 'use situation analyses' and 'use evaluations' according to the analysis-template and refer to this in your log. Refer to the design portfolio or frame of reference for the other activities.

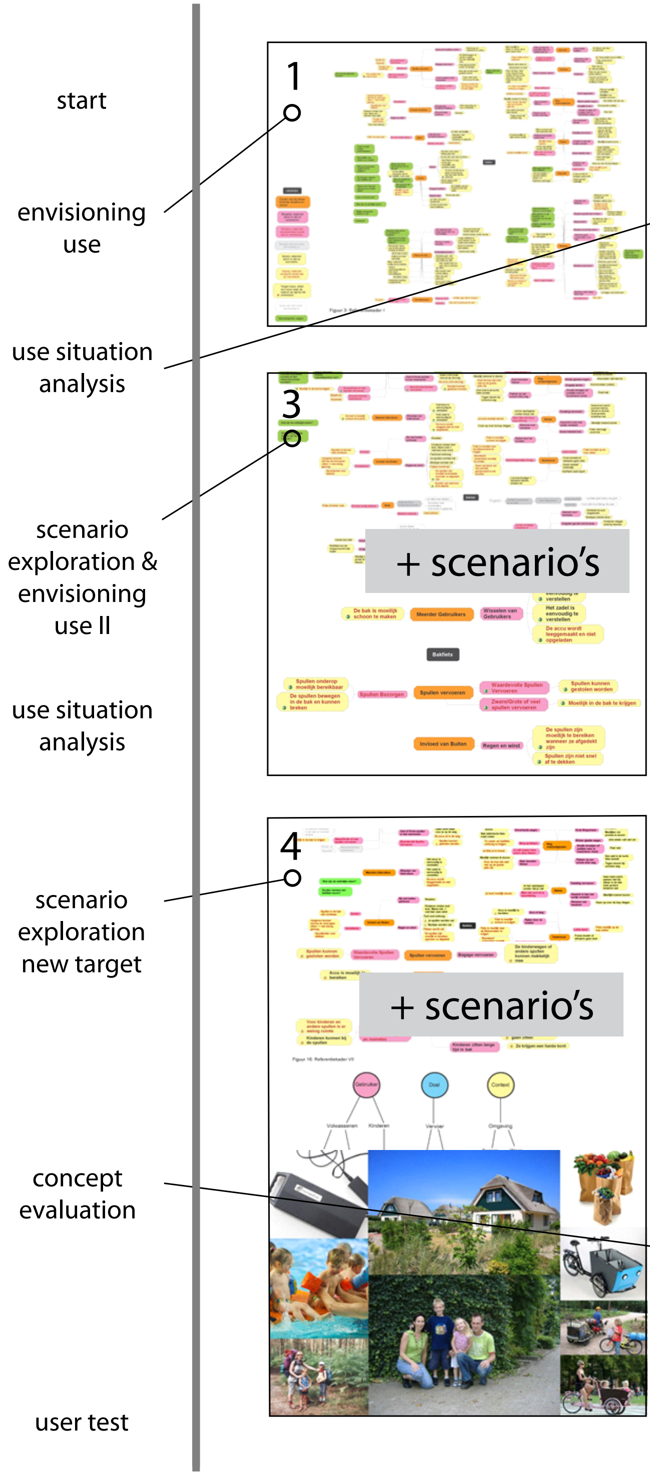
Evaluation/ analysis reports: make a short report for each analysis and evaluation that you executed and refer to this in your log. These are simple reports of the evaluations and use analyses. Do this for informal evaluations as well, for example when you quickly create a mock-up and imagine how people would use this or when you choose a solutions from some ideas.

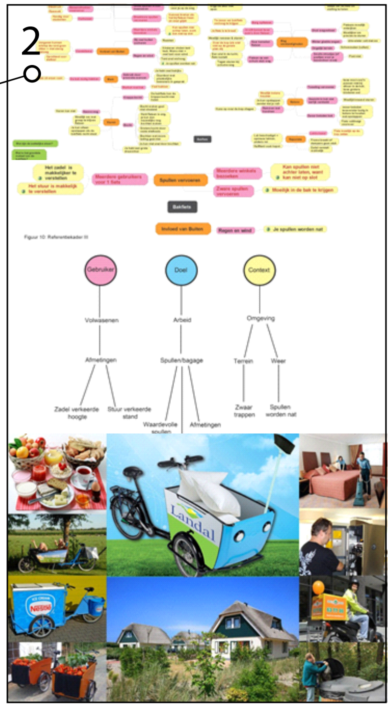
Visualisation frame of reference: show how your frame of reference evolved. For example, by taking a picture of your frame of reference each time you adjust it. Of course this depends on the format you choose for your frame of reference. What is important is that you indicate for each moment in time at which you change your frame of reference, what you changed compared to the previous frame of reference. Discuss the means to log the evolution of your frame of reference with the supervisors.

Development of the designed solution: portfolio with all representations of your design including sketches, computer models and pictures of mock-ups and prototypes.

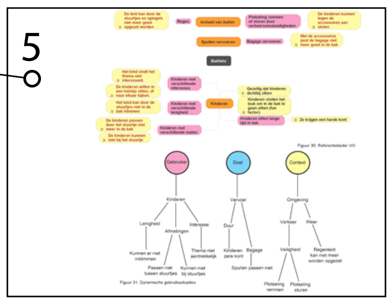
Appendix 5 Evolution frames of reference course 1

Evolution frame of reference team 1 (study 1)

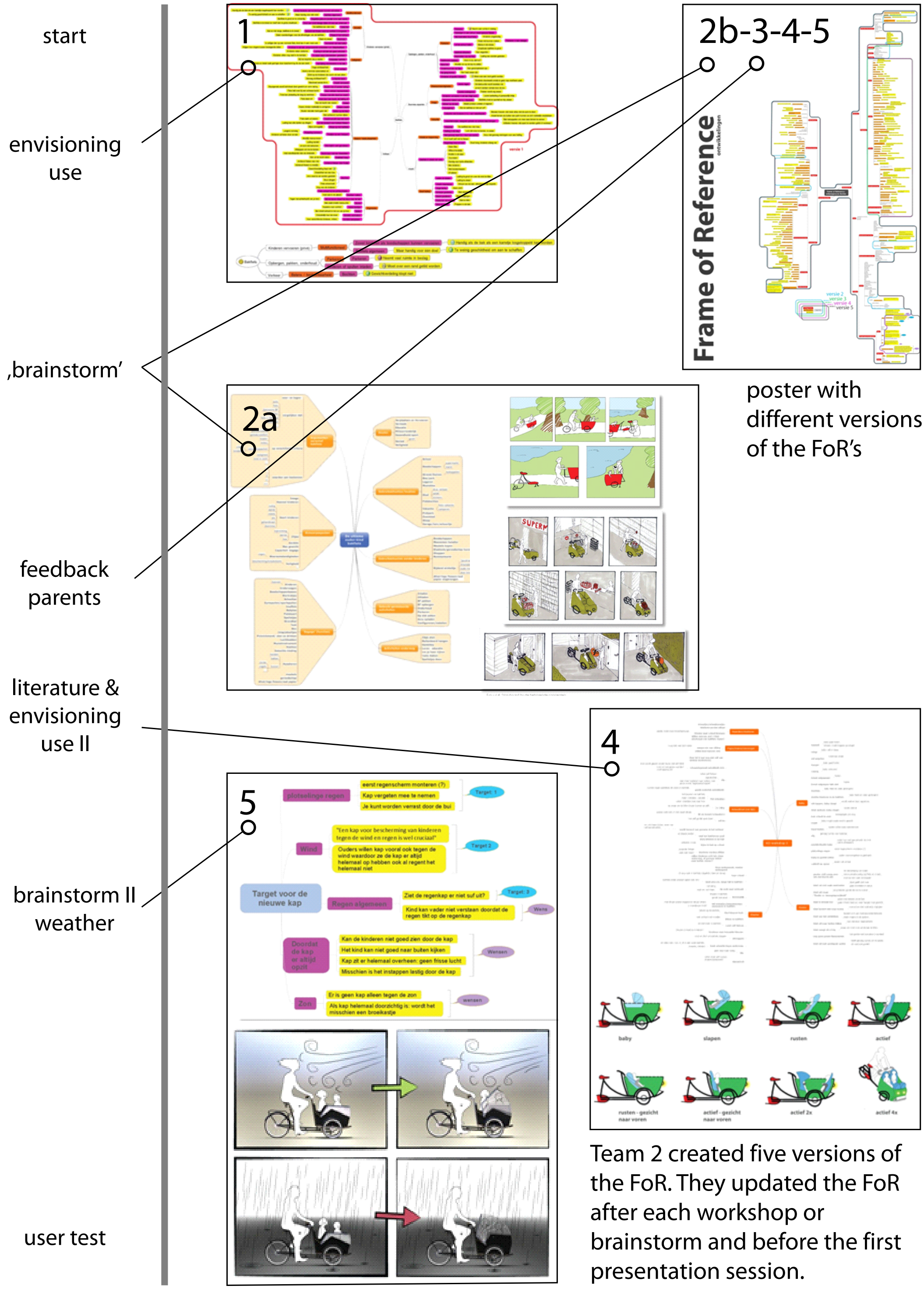




Team 1 created five versions of the frame of reference (FoR), updated after each analysis or evaluation study and after each workshop or change of target.

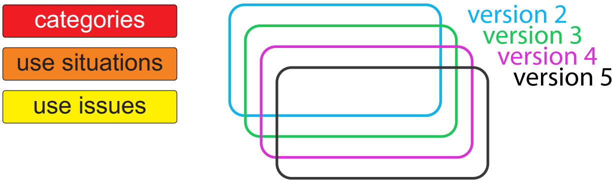


Evolution frame of reference team 2 (study 1)



Team 2 created five versions of the FoR. They updated the FoR after each workshop or brainstorm and before the first presentation session.

Evolution frame of reference team 2, poster (study 1)



Frame of Reference
ontwikkelingen

Evolution frame of reference team 3 (study 1)

start

envisioning use

define target/ brainstorm

envisioning use II/ imagining sub target

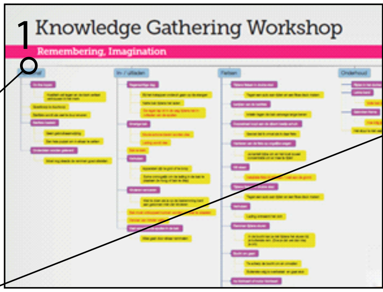
scenario exploration sub target

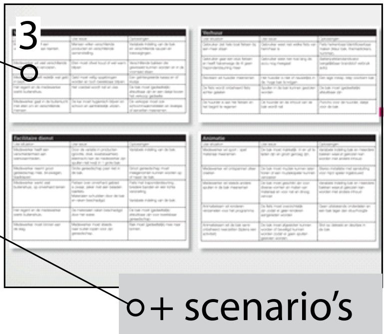
mock-up evaluation holiday park

redefine target

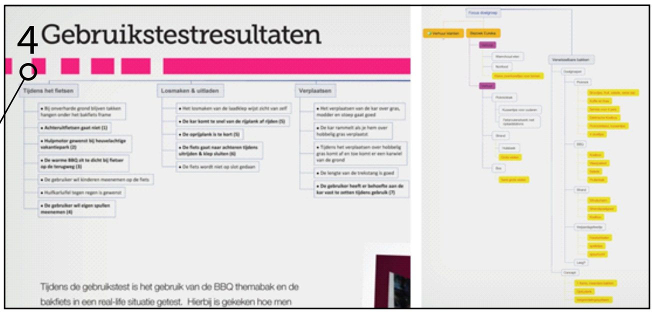
use situation analysis (survey)

user test





Team 3 created four versions of a FoR. The first three were created after an exploration of the initial targets in a brainstorm or workshop. The third FoR was based on different scenarios for holiday park employees. When a new target was chosen, no new FoR was created until after the final user test.



Evolution frame of reference team 4 (study 1)

start

envisioning use

define target

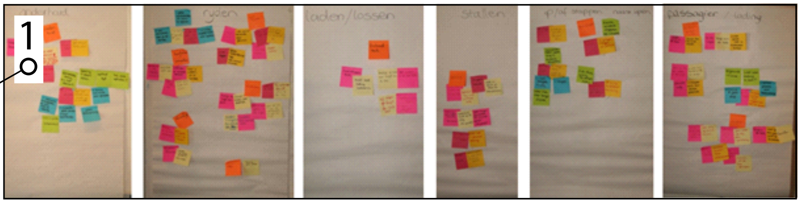
visit holidaypark

redefine target

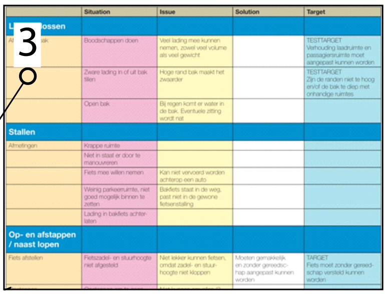
client presentation

scenario exploration

user test

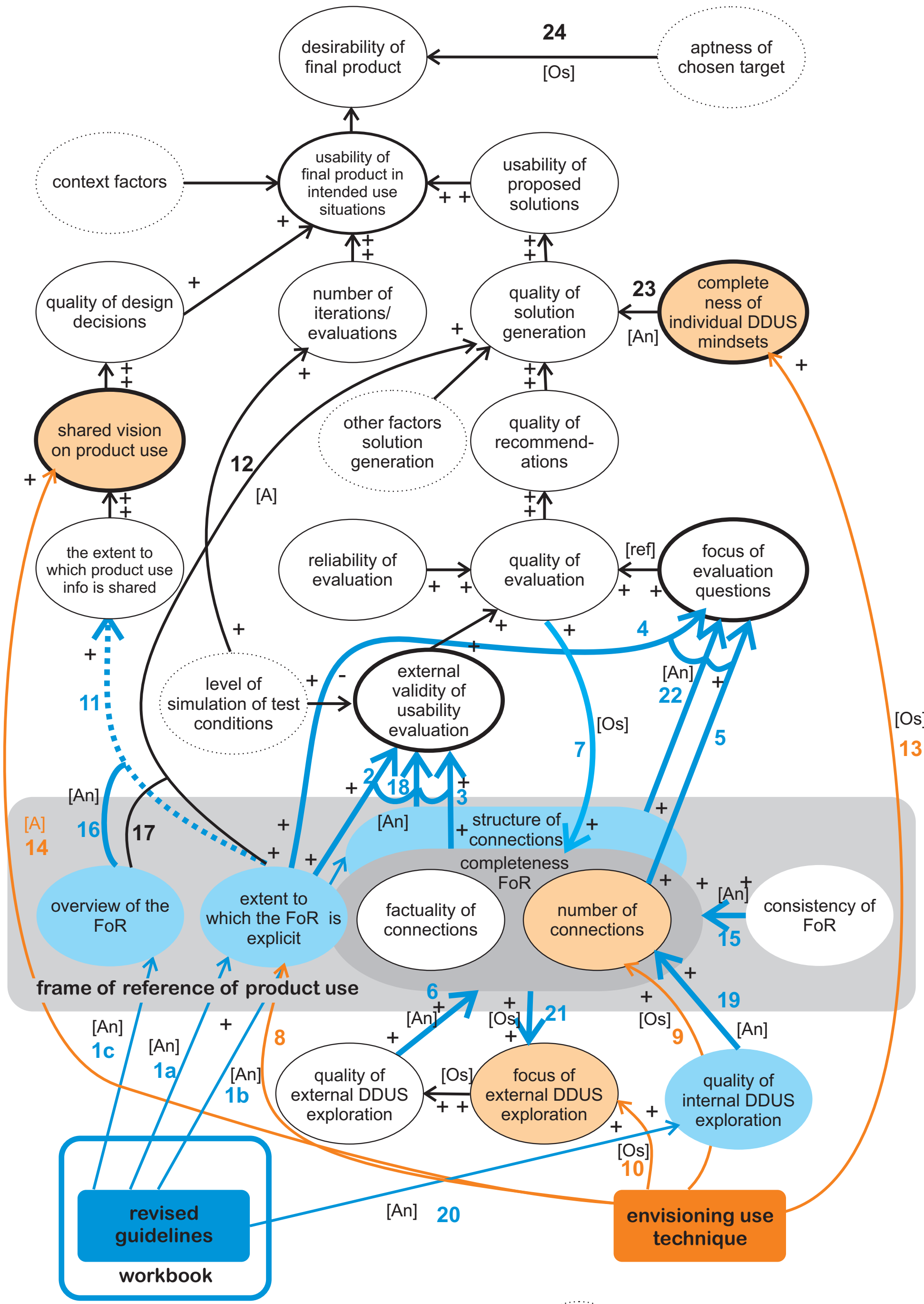


only product use mind map
no other FoR documented



Team 4 created three versions of a FoR of which only one was reported in the portfolio. The first one is the product use mind map created in the first workshop, concerning use at a holiday park. The second one was presented in the intermediate client presentation and considered the four target issues for the rental of the bike at Vlieland. The third one was a complete FoR for this use situation that was used to set test conditions for the user test.

Appendix 6 revised impact model



[An]: new assumption

[Os]: statement based on own investigations with students

Appendix 7: example workshop plan

This plan is anonymized for reasons of confidentiality. The plan was created after a meeting with the usability expert of the company

Set up usability workshop project X

This document describes the objectives and set up of the 'Envisioning Use Workshop' organized by researchers from the Design for Usability project for the development team of project X.

Goal of the workshop

- Company: create a shared view in the development team with regard to both current usability/ user experience and possible future usability issues for new solutions. Furthermore they would like to identify blank spots on these topics.
- Researcher: evaluate the developed Envisioning Use Workshop technique with a case that is in a predevelopment or early development phase.

Company: the project is a successor product with a better level of usability than its predecessor. A lot of knowledge about current issues is available. However, the question is if new solutions will solve those issues or will carry new issues. The goal of the workshop therefore is to get an overview on the current status on use issues and use situations, explore new solutions and usability issues and define blank spots on which knowledge lacks and should be gained.

Researchers: the Envisioning Use workshop technique was developed based on an analysis of the researchers on how designers deal with usability, more specifically with the different use situations that a product encounters. Designers often make use of their personal knowledge of use while designing, but this knowledge is often not shared in the development team. The goal of the workshop is to bring as much information about use issues together, both implicit knowledge (memories and assumptions) and explicit knowledge (results of usability tests, on the spot experience of use) and create a common focus of the use issues and situations that should be targeted and possibly need more analysis.

Participants

Participants in the workshop will be the usability expert, designer, system architect and two or three developers.

Case details

Confidential

Planning

The workshop will take maximum 4,5 hours

Preparations

From the company the following preparations are requested:

- plan the workshop with the development team
- organize a room to execute the workshop. There needs to be space to put approximately six flipcharts on the wall. For the role-play part of the workshop a realistic setting would be appropriate
- provide reference products for the role-play (predecessor, competitors, mockup)
- provide other tools necessary to execute the role-play
- bring results of previous user tests to the workshop (digital, just as back-up for reference)

All other workshop materials are provided by the researchers.

Time schedule

The time schedule is as follows:

Time	Min.	What		Materials researchers	Materials company
				Video camera, photo camera, tripod	
11:00	20	Introduce people	Introduction of participants and gathering of expectations		
11:20	10	Introduce workshop	Introduction to the workshop steps	Powerpoint	
11:30	15	Preparation	Define categories of use phases/ roles to put on the flip-overs	Markers	Flipcharts
11:45	5		Explain structure of the mind map	PowerPoint	
11:50	20	Remembering	Participants are asked to share their own 'usability' stories including stories from user tests.	Pink, yellow post-its ,markers (black/red)	Results user tests
12:10	20	Imagining	Associative materials are used to imagine other possible use issues.	Associative materials	
12:30	10	Cluster	Structuring of the results	Orange post-its	
	extra	Evaluate structure	Go through clusters and add more results		
12:45	30	Break			
13:15	15	Prepare experiencing	Decide upon scenarios for the role-play	Pink cards	
13:30	30	Experiencing	Role-play scenarios with two or three products and gather results on flip-overs	Props	realistic environment, reference products, tools
14:00	20	Evaluate experiences			
14:20	15	Targeting	Discuss relevant scenarios and target important usability issues. (first individually, then group discussion)	Stickers	
14:35	20	Envisioning	Brain dump of current ideas for the set target +	Drawing materials, Tinkering materials	
14:55	10	Evaluation of ideas	evaluation of the ideas	Blue post-its for evaluation of the ideas	
15:05	15	Questioning	Define which knowledge lacks in the mind map	Green post-its, extra flip chart	
15:15	15	Wrap up	and define steps to get answers		
15:30		Evaluation	Short evaluation of the workshop	Interview questions Memo recorder	

Appendix 8 Survey Envisioning Use workshop

On [date] of this year you participated in our Envisioning Use workshop to create a shared vision on usability for project [project name]. We would like to know what the added value has been of this workshop for the development process and if and how the results were used in the development process. Therefore we would like to ask you to fill in this questionnaire.

What is your role in the product development team?

1. What was the added value of this workshop for the development process?

2. Which decisions were made based on the results of the workshop?

3. Can you give examples of product ideas/ features that were inspired on the results of the workshop?

4. To what extent do you agree with the following statement? *Doing the workshop makes participants become more dedicated to usability in the project* [place X under appropriate answer]

strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

Explanation:

5. To what extent do you agree with the following statement: *the workshop gave me more insight in the broadness of use situations (users, goals, contexts) [product name] can encounter.* [place X under appropriate answer]

strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

Explanation:

6. To what extent do you agree with the following statement: *I feel the workshop helped in generating a shared view on product use.*

strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

Explanation:

The picture below shows the target usability issues as defined in the workshop.

[photo of list of target usability issues]

7. To what extent did the workshop help in making the targets more explicit? [place X under appropriate answer]

not at all	little extent	some extent	large extent	very large extent

Explanation:

8. Did priorities in the targets change because of the workshop? If so, how?

Below you see a picture of the created ‘product use mind map’ (flip chart with post-it notes)

[photo of product use mind map]

9. How did or would you use the data generated in the product use mind map in subsequent design activities?

10. Did the results of the workshop contribute to the creation of a frame of reference for development (for example in requirements, specifications or scenarios)? If so, how?

11. To what extent do you agree with the following statement? *doing the workshop made me more aware of the missing information on the use of the [product name]* [place X under appropriate answer]

strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

Explanation:

12. Would you like to do a comparable workshop in a future project? If so, for what kind of project?

13. Do you have any other comments or recommendations for our workshop?

The last questions are for the usability expert:

14. How did you process the results of the product use mind map? (the flipchart with notes). If so, was this difficult to do? If not, why not?

15. How did you communicate the results to team members that were not present in the workshop?

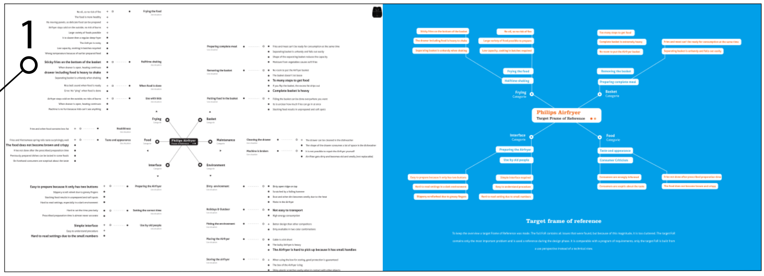
Thank you for completing this questionnaire!

Appendix 9 Evolution frames of reference course 2

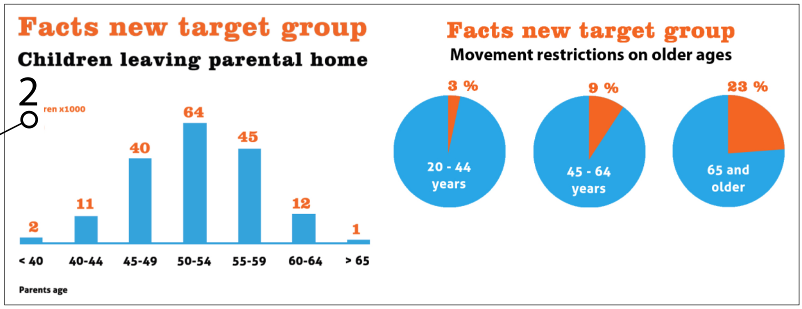
Evolution frame of reference team 1 (study 2)

start

envisioning use



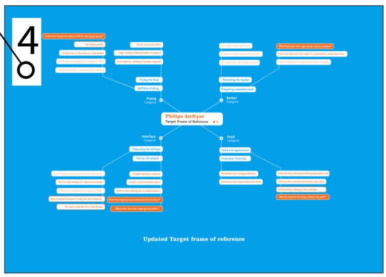
external
explorations



intermediate
presentation

envisioning use

user test

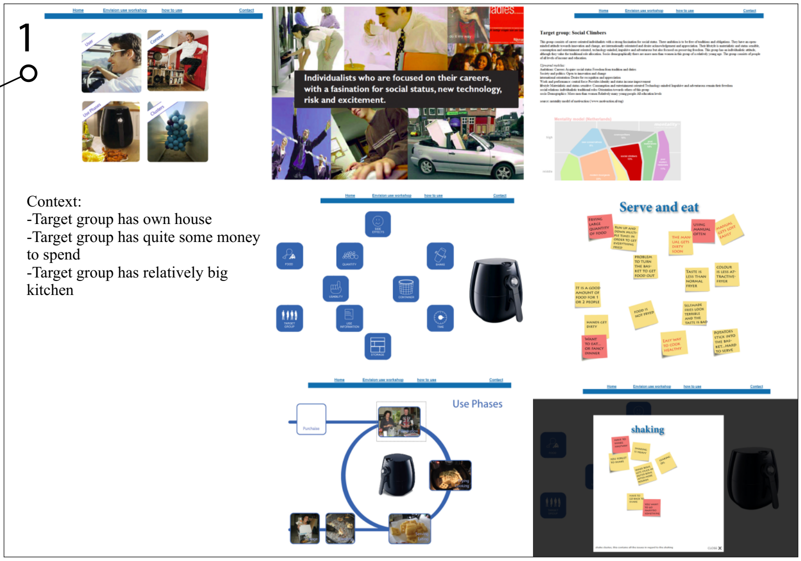


1: first FoR: complete and target mind map
2: results external explorations
3: visual representation with main issues and two concepts presented in the use context
4: second target FoR updated based on EU, input to user test.

Evolution frame of reference team 2 (study 2)

start

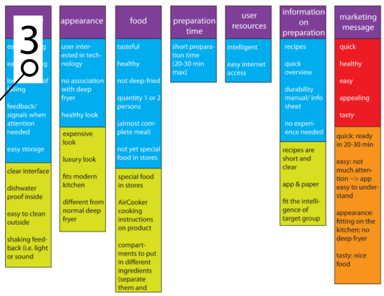
envisioning use



external explorations: questionnaire/ interview

intermediate presentation

focus session



1: first FoR: example pages of complete FoR in website format
2: second version of FoR based on verification, addition of goal definition in words
3: third FoR in table format connects use issues to requirements
4: three narrative scenarios to show how the final concept works.

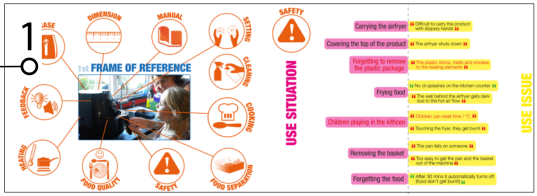
scenario session

user test

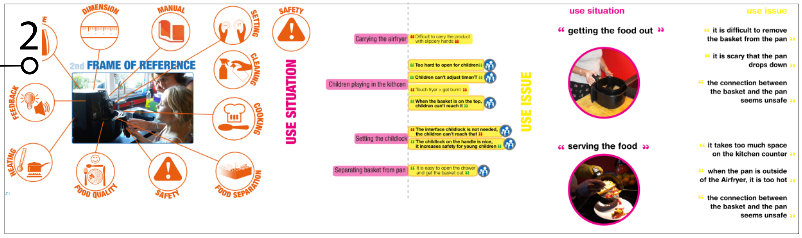
Evolution frame of reference team 3 (study 2)

start

envisioning use

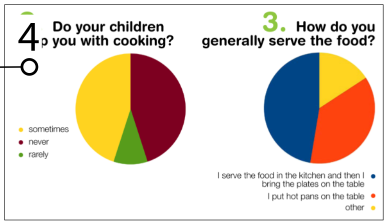


external explorations: family observations

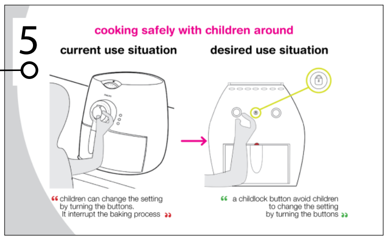


intermediate presentation

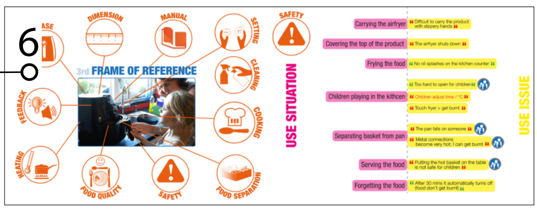
interviews



concept generation



user test



1: first FoR: Prezi main page + example sub page
2: second FoR: Prezi main page, sub page and target representation
3: visual representations
4: results of interviews
5: third FoR, target representation which compares original and new design in storyboard format
6: fourth FoR, Prezi main page + sub page

Appendix 10 The revised and final workbook

Appendix 10 is available online at:

http://www.ctw.utwente.nl/exploringusability

The final workbook can furthermore be downloaded at:

http://www.designforusability.org/results/methods-tools

About the author

Mieke van der Bijl-Brouwer was born in Middelburg in 1975. After finishing secondary school at the CSW Middelburg, she studied one year at a Liceo Scientifico in Ancona (Italy) as an AFS exchange student. She obtained her MSc degree Industrial Design Engineering (cum laude) from Delft University of Technology in 2001. Her graduation assignment, executed at Philips Consumer Electronics, concerned the design of an innovative user interface for television. For this project she was awarded 'Best Graduate Industrial Design Engineering of the year 2001'.

From 2002 she has been working as assistant professor at the University of Twente. Her research interests include design for usability, scenario based product design and user experience design. Her PhD research was partly funded within the IOP-IPCR research project 'Design for Usability'. She combines her research with teaching courses related to usability and human-product relations to BSc and MSc students Industrial Design Engineering. Her teaching tasks include lecturing, tutoring design projects, supervising graduation assignments and coordinating one of the first year design projects. She is also part of the team of study coaches and the committee that develops a new BSc curriculum for 2013.

Next to work she enjoys going to concerts and theatre, visiting museums, running, and playing the guitar. Mieke is married to Willem Mees van der Bijl.