THE CHILDREN'S PROSTHESIS CO-DESIGN TOOLKIT: ELICITING CHILDREN'S NEEDS FOR HAND PROSTHESES USING GENERATIVE DESIGN TOOLS

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ABSTRACT

THE CHILDREN'S PROSTHESIS CO-DESIGN TOOLKIT: ELICITING CHILDREN'S NEEDS FOR HAND PROSTHESIS USING GENERATIVE DESIGN TOOLS

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When designing assistive devices for children with disabilities, designers mostly consider technical and functional aspects and overlook factors that affect their usage from children's perspective. Therefore, in most cases, assistive devices do not fully meet the needs of the children and may create a negative effect on children's well-being. To explore the opinions of children using 3D printed hand prosthetics in Turkey, individual co-design sessions were conducted with four children with upper limb deficiency. Generative tools are used to engage children and encourage them to express themselves in relation to prosthesis use. The main aim was to investigate how children provide design relevant information that may help designers to achieve improved assistive devices that support children's physical, emotional, and social wellbeing. Children's feedback related to prosthetic usage categorized under three topics; (i) daily prosthesis needs of children, (ii) prosthesis design expectations by children and (iii) children's priorities for the expectations related to prosthesis usage.

The findings are argued to be useful and usable by NGOs, product designers and design researchers who work with children with disabilities.

Keywords: Participatory Design, Design with Children, Generative Design Methods, Co-Design, Prosthesis Design

ÖZ

ÇOCUKLARIN PROTEZ ORTAK TASARIM ARAÇ SETİ: ÜRETKEN TASARIM ARAÇLARI YOLUYLA ÇOCUKLARIN EL PROTEZLERİ İHTİYAÇLARINI ORTAYA ÇIKARMA

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Tasarımcılar engelli çocuklar için yardımcı cihazlar tasarlarken çoğunlukla teknik ve işlevsel yönleri göz önünde bulundurur ve çocukların bakış açılarından cihazların kullanımını etkileyen faktörleri gözden kaçırır. Bu nedenle çoğu durumda yardımcı cihazlar çocukların ihtiyaçlarını tam olarak karşılamamakta ve çocukların iyi oluşunun üzerinde olumsuz bir etki yaratabilmektedir. Bu bağlamda, Türkiye'de üç boyutlu yazıcıyla üretilmiş el protezi kullanan çocukların görüşlerini incelemek için uzuv yetersizliği olan dört çocukla bireysel olarak üretken tasarım seansları yürütüldü. Üretken tasarım araçları, çocukların ilgisini çekmek ve onları protez kullanımıyla ilgili olarak kendilerini ifade etmeye teşvik etmek için kullanılmıştır. Temel amaç, tasarımcıların çocukların fiziksel, duygusal ve sosyal iyi oluşlarını destekleyen yardımcı cihazlar geliştirmelerine yardımcı olabilecek tasarımla ilgili bilgileri nasıl sağlayabileceklerini araştırmaktır. Protez kullanımına ilişkin

çocukların geri bildirimleri üç başlık altında toplanmıştır; (i) çocukların protez ihtiyaçları, (ii) çocukların protez tasarım kriterleri ve (iii) çocukların protez kullanımına ilişkin kriter öncelikleri. Araştırmanın sonucunda, elde edilen bulgular engelli çocuklarla çalışan sivil toplum örgütleri, ürün tasarımcıları ve tasarım araştırmacılara fayda sağlayabilecek şekilde tartışılmıştır.

Anahtar Kelimeler: Katılımcı Tasarım, Çocuklarla Tasarım, Üretken Tasarım Araçları, Ortak Tasarım, Protez Tasarımı

To special children

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CHAPTER 1

INTRODUCTION

1.1 Background and Motivation for the Research

Today, 7 to 22 per 10,000 children are born with limb deficiencies (Aucourt et al., 2012). Congenital limb deficiencies have a critical impact on children's mental and physical development from the early stages to adulthood. However, providing assistive devices for children is a complex issue in developing countries due to technical requirements and economic restrictions (Burger, Brezovar & Marinček, 2004). Therefore, the children's needs and expectations are rarely taken into consideration while developing these assistive devices. However, variables, including still-developing self-image and constant physical growth, affect children's both physical and emotional needs that are essential to consider when designing prosthetic devices for children. In addition, it is still difficult for children to verbalize their needs and expectations about the difficulties or situations that affect them (James, 1995). Especially, children with such disabilities cannot sufficiently express their feelings and emotions about physical problems affecting them (Lukash, 2002). Therefore, when designing for children, designers tend to investigate children's perspective through parents, family members or sometimes teachers instead of directly talking to them (Druin 2002). However, in the design literature, various techniques have been developing different practices to encourage children to express their opinions in a comfortable way.

In this context, a participatory design approach and co-design have been commonly applied when designing for and with children as traditional data collection methods for adults may not be entirely suitable for children (Druin, 1999). According to

Hussain (2012), generative design tools as a part of participatory design methods are essential for designing with children, because they facilitate both verbal and non-verbal forms of communication using visual material. Through such tools, even non-designers can be encouraged to talk about their needs, frustrations, and dreams. In the context of 'designing for' and 'with children' with disabilities, the benefits of these approaches take on more importance (Frauenberger, Good & Alcorn, 2012). It has been argued that the lives of these children are far removed from adults' experiences; therefore, their needs should be investigated deeper rather than trying to solely empathise with them. In addition, giving children a stake in the design development gives them a sense of empowerment which may the biggest contribution to their wellbeing (Frauenberger, Good & Alcorn, 2012). However, very few studies focus on understanding children's point of view regarding their prosthesis experience, and to extract design-relevant information that will help designers, researchers and NGOs to improve assistive devices.

The researcher's motivation for the research came from her volunteer background in an NGO called Robotel. A few years ago, Robotel, an NGO based in Turkey, started to provide children in need with relatively low-cost, mechanical 3D printed prostheses having a grasping function which is controllable by elbow or wrist movement. The researcher has been voluntarily working in Robotel with the responsibility of organizing the children's applications for 3D printed prosthetic hands, match the applicants with the volunteer teams and organizing events for both parents and children in order to build a local community in which children can feel comfortable and accepted. During the researcher's four years' experience with these children, she noticed the difficulties they encounter during the 3D printed prosthetic use. As the researcher observed, the prosthetic devices' functionality is limited; however, these devices are commonly used for providing rehabilitation for muscles until children complete their physical growth. The volunteer group in which the researcher coordinates aim to achieve assistive devices that support the children's physical and psychological well-being. Nevertheless, the life of a child with upper

limb deficiency, in terms of their needs, concerns, and experiences, can be significantly different from adults' assumptions, making it challenging to bring an empathic understanding. Therefore, this research focuses on eliciting children's needs and expectations through a generative design toolkit to explore the ways which may improve their overall wellbeing.

1.2 Scope of the Research

The research focuses on the prosthesis experience of children with upper limb deficiency aged between 8-12. The research includes children who have both congenital and traumatic upper limb deficiency. It covers children with all disability levels (e.g., arm deficiency or finger deformities). Lower limb deficiencies (e.g., leg, foot, pelvis) are outside this research scope. However, it is noted that some of the results concerning their prosthesis usage may also be relevant to lower limb deficiencies.

1.3 Aim of the Study and Research Questions

The research aims to present suggestions for future developments of child hand/arm prostheses that support children's physical, emotional, and social wellbeing by considering their past experiences and future dreams related to prosthesis usage.

The research will also present the development of (a physical) co-design toolkit that facilitate children's communication about their physical deficiencies. It is believed that a toolkit will be helpful to encourage the knowledge sharing and idea generation of the children and overcome the barriers of communication, which is caused by the sensitive nature of talking about the physical deficiencies. It also aims to support designers and/or researchers who work with children to gather more insightful information about the lives of children with upper limb deficiency. The early version

of the toolkit aims to be developed by the researcher based on the literature findings for eliciting the needs and expectations of children with upper limb deficiency on prosthesis usage. Then, it will be used in co-design sessions with children to evaluate its relevance and usefulness, and the necessary iterations will be made.

The research objectives seek to explore: i) daily prosthesis needs of children, ii) prosthesis design expectations by children, and (iii) children's priorities for the expectations related to prosthesis usage.

With the aims mentioned above and objectives in mind, the research aimed to find answers to the following questions.

- In what ways children can be encouraged to express their feelings about the physical deficiencies they experienced during daily activities?

o Which existing design approaches, methods and tools have been implementing for obtaining knowledge from children with upper limb deficiency?
o How can the existing design methods and tools be reinterpreted to encourage children to express their needs and expectations related to hand/arm prosthesis usage?

- How can child prostheses be enhanced to influence the wellbeing of children with upper limb deficiency positively?
- What are the needs and expectations of the children related to hand/arm prosthesis usage?

o To what extent the 3D printed prosthesis hands fulfil the children's needs and expectations? What are the areas of satisfaction and dissatisfaction regarding the hand/arm prosthesis use of the children?

o Which design considerations should be implemented while designing hand/arm prosthesis from the children's perspective?

1.4 Structure of the Thesis

The thesis consists of seven chapters, details of which are as follows.

Chapter 1 presents a brief introduction to involving children with upper limb deficiency into the design process and explains the motivation of the researcher for the research. Also, the aim of the research, research questions and the structure of the thesis are introduced.

Chapter 2 presents the literature review on children's participation in research and design, participatory design, co-design, the roles of the children in the design process, generative design tools and advantages of involving disabled children in design process. Then, a review of limb deficiency in children, prosthesis use by children and the role of prosthesis in psychological wellbeing of children are presented. Lastly, information on wellbeing and its relation with positive psychology and design for wellbeing are given.

Chapter 3 includes the proposed methodology and the fieldwork focusing on the development of co-design toolkit. In this chapter, the tools and methods devised for the study, and the development of the co-design toolkit are explained in detail.

Chapter 4 presents an overview of the fieldwork analysis, then it continues with the results including children's daily prosthesis needs, areas of satisfaction and dissatisfaction for 3D printed prosthetic devices, expectations for the prosthesis design, and children's priority expectations.

Chapter 5 presents a guideline for implementing the co-design toolkit as a procedure to elicit children's needs and expectations.

CHAPTER 2

DESIGN FOR AND WITH CHILDREN, LIMB DEFICIENCY IN CHILDREN, WELLBEING

A comprehensive investigation of participatory design with children, including frameworks for evaluating children's contribution to the design tools, will be made. Then, the literature on participatory design approach and co-design, along with the frameworks related to the roles of the participant and researcher in co-design processes, will be reviewed. Lastly, this chapter is concluded with generative tools and materials designing with children.

2.1 Children's Participation in Research

There has been growing interest in childhood studies in various fields; children's education, pedagogy, development, sociology, and psychology. Historically children were seen as incompetent (Barker & Weller, 2003) until the UNCRC (United Nations Conventions on the Rights of the Child) has highlighted that children have the right to have a voice in society. Then, with the emergence of "new social studies of childhood" (James, 1998), children have started to be viewed as experts in their own lives (Mauthner, 1997, Kellet & Ding, 2004). In the research context, children's roles transformed from being the subjects of study to research partners (Greig, Taylor & MacKay, 2012; Christensen & James, 2008). The emergence of the new approach provided a ground for accepting children as social actors and active participants to determine their experiences rather than giving them a passive role in society (Harwood, 2010). Therefore, the "new studies of childhood" aims to understand the

children's lives from their point of view instead of identifying child development's standard patterns (Jorgenson & Sullivan, 2010). In the meantime, there is a growing body of literature that recognizes the importance of children's participation in the research process (Christensen & Prout; 2002; Alderson, 2008). Christensen and Prout (2002) propose four ways of involving children in research; the child as object and the child as subject, which are identified for traditional research approach (Christensen & James, 2008), the child as social actor and child as participant, which stands for a new approach. In that sense, Hill (1997), the children's participation refers to "the direct involvement of children in decision-making about matters that affect their lives".

On the other hand, with the children's participation in research, the problematic aspects of involving children were discussed (Mauthner, 1997; James, 1998, Valentine, 1999; Davis, Watson & Cunningham-Burley, 1999). Despite its advantages for better understanding children's lives, the participation of children in the research context has complex dynamics in terms of roles of both the child and adult in the research process. To further investigate this issue, Mauthner (1997) and Valentine (1999) carried out their research and identified that power dynamics in adult-child relationships have a critical effect on children's participation in this social context. In this respect, Punch (2002) presents three approaches for researching with children:

1. Considering children same with adults and adopting the same techniques as those used with adults.
2. Perceiving children different from adults and uses observation to examine their world.
3. Seeing children similar to adults and causes the need for innovative techniques.

In order to overcome the issues of the participation of children, several studies suggested that the concept has required the emergence of new 'participatory' research methodologies instead of traditional observation and questionnaires (Punch, 2002). Similarly, Scott (2000) indicates that adopting different communication forms is necessary while working with children due to language use limitations, literacy, and various cognitive development stages. Nieuwenhuys (1996) also suggests that appropriate methods to gather information from children can be through their favourite activities such as storytelling and drawing since these are more appropriate ways in bringing out children's experiences than methods used for adults.

Ever since children have been actively involved in the research, their participation spread into various design practices (Druin, 1999; Pardo, Vetere, & Howard, 2005). There has been a growing interest in giving children a voice to be heard and supporting them actively involved in society (Ghaziani, 2008; Tonucci & Rissotto, 2001; Burke & Grosvenor, 2003; Matthews, 2003; Hussain, 2010).

2.2 Children's Participation in Design

Since the transition of children's roles from being subjects to research partners, their roles have also transitioned in the design context (Greig, Taylor & MacKay, 2013; Christensen & James, 2008). In design literature, most studies on children's participation have generally concentrated on the interaction between children and computational technologies, which Human-Computer Interaction inspires (HCI) (Druin, 1999; Iversen, 2005; Antle, 2013; Read & Markopoulos, 2013). In the context of HCI, children's involvements require the transformation of the user-centred design into the child-centred design. Several studies on child-centred design commit the children's contributions in different phases of design with various roles (e.g., end-user, design partner) and emphasise collaboration between designer and children. Iversen (2005) states that there are two aspects of designing with children;

'product-oriented', which concentrate on developing products for children, and 'process-oriented', which focuses on children's participation in the design process. Many studies in user-centred design practices suggest the product-oriented with limited participation of children (Hanna, Risden, Czerwinski and Alexander, 1999; Pardo, Vetere & Howard; 2005).

Traditionally, users are involved in the design process for usability testing or evaluation of the final product. However, the child-centred design addresses children' involvement in different stages of the design process (Pardo, Vetere & Howard, 2005). Gould and Lewis (1985) emphasise the value of the users' contribution in the early phases in design processes. In this way, children may be more engaged and involved with a more central role in the design process, which may positively affect the design outcomes (Scaife, Roger, Aldrich & Davies, 1997). Furthermore, Kelly, Mazzone, Horton and Read (2006) present guideline for involving children in child-centred product development. They highlight 1) using familiar topics, 2) for each activity, reminding the outcomes of the previous activities, 3) allowing children to express their ideas in ways they are more comfortable with 4) collect children's ideas in different formats. As the guideline proposed, these four aspects should be considered when designing with children.

2.2.1.1 From Participatory Design to Co-Design

The participatory design approach emerged in the 1970s when computer professionals and managers decided to involve workers in decision-making about computer systems in the workplace in Norway (Winogard, 1996). Ever since, participatory design is being used in various fields, including products design, architecture, urban design, organizational development, and information technologies (Sanoff, 2007). The core idea of the participatory design approach is enabling users, stakeholders, and designers to collaboratively work in the design

process (Sanders, Brandt & Binder, 2010). Schuler and Namioka (1993) define the aim of participatory design as including people who are affected by a decision to have a chance to influence it.

Several studies have explained that participatory design approach with different variables in collaborating with users (Sanoff, 2007; Sanders, Brandt & Binder, 2010; Halksov & Jansen, 2015). According to Sanoff (2007), there are three characteristics of participatory design; 1) design solutions can be achieved by collaborating with participants from different backgrounds, 2) designers should spend time in the users' environment 3) users' opinions should be considered in the decision-making process. In addition, Halskov and Hansen (2015) highlight several aspects to explain the concept of participation: participants, types, degrees, durations, and areas of participation. According to Halksov and Hansen (2015), it is essential to consider these aspects of defining participation. Also, Halksov and Hansen (2015) present the principles of participatory design with children. Firstly, children have a right to be given a voice in society. Secondly, children are experts in their own lives. Thirdly, in order to encourage children to participate, they should be familiar with the research topic. Fourthly, child-centred methods should be implemented. Lastly, the outcomes of the process have the potential to improve children's wellbeing.

Since the value of child participation is widely accepted, participatory design has been studied extensively for working with children in regarding attracting children's interest, facilitating the process while encouraging them to participate in design activities (Baek & Lee, 2008; Frauenberger, Good & Alcorn, 2012; Hussain & Sanders, 2012; Iivari & Kinnula, 2018). However, specific issues are essential to consider children's participation in children's communication skills and cognitive abilities. Baek and Lee (2008) indicates three benefits of the participatory design approach for overcoming such issues. Firstly, it enables children to visualize their ideas by generative tools instead of expecting to express their needs with their

immature language and social skills. Secondly, the participatory design process may stimulate their interest and encourage them to overcome their shyness. Lastly, participatory design enables designers to achieve more solid design solutions generated from the children's point of view. In other words, participatory design gives designers a chance to understand a child's perspective while overcoming communication barriers with its less dependent nature on language skills (Hill, 1997, Baek & Lee, 2008).

In addition, there are two controversial topics regarding involving children in the design process; the best way and time to involve users in the design process and the roles between designers and other stakeholders (Scaife, 1997; Druin, 1999; Kelly, Mazzone, Horton & Read, 2006). When the participants are children, some issues emerge, including subject knowledge, skills, and power relationships that affect the influence children apply (Read, Mazzone & Hoston, 2005). Therefore, researchers have been conducted a significant amount of study to explore children's contribution in various roles in the developmental process in design (Druin, 1999; Scaife, Rogers, Aldrich & Davies, 1997; Hart, 1992).

More recently, there has been growing interest in the terms' co-design' and 'co-creation' when discussing the collaboration between designers and users. Sanders (1999) first introduces the term co-creation in the design practice by presenting an example of a co-creation toolkit. She presents the differences between traditional design methods that focus on what people do, say, and think and co-design practise that shifts the focus on what they know, feel, and dream (Sanders, 1999). According to Sanders (1999), co-design provides designers to elicit tacit and latent knowledge which may not be achieved from conventional research methods (Figure 2.1)

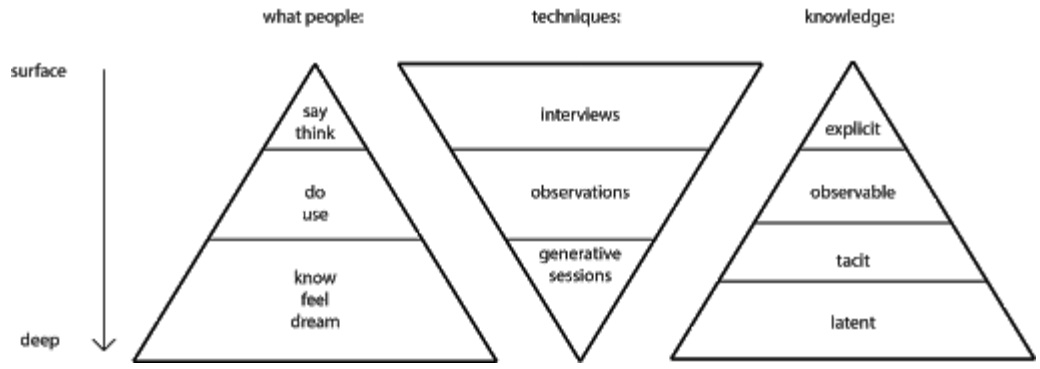


Figure 2.1 Different levels of knowledge about experience are accessed by different techniques (Sanders, 2005)

Co-design, a method for collecting information through user involvement, requires changes in designers' roles for facilitating, listening, and observing in the design process (Shackleton, 2010). Therefore, collaboration with users depends on the designer's skills to design tools and techniques for adapting different contexts (Kuajala, 2003). However, co-design supports utilizing insights from users' contribution and not completely giving the user a designer role (Mazzone, 2012). Rather than substituting the designer with the user, the co-design practice requires the designer's ability to examine, understand, and analyse and translate the obtained knowledge into design-relevant information, which enriches the overall inputs for design (Sanders, 2001). Since there are an increasing variety of user groups and contexts, the designers should also be responsive to the needs of different user groups (Mazzone, 2012). Children are one of the most critical user group which have been started to explore since the 1990s, and their numbers are significantly growing (Markopoulos & Bakker, 2003).

2.2.1.2 Children's Participation Level in Design

Children's roles have been defined according to different approaches and children's contributions in the last two decades (Scaife, 1997; Druin, 1999; Kelly, Mazzone,

Horton & Read, 2006; Lozanovska & Xu, 2013). With the growing interest in children's contributions in design research, the emergence of new roles has been discussing in several studies in accordance with the nature of child development (Scaife, Rogers, Aldrich & Davies, 1997; Druin, 1999; Kelly, Mazzone, Horton & Read, 2006; Barendregt et al., 2016; Iivari & Kinnula, 2018).

Hart (1992) proposes a framework that includes eight levels of participation of children in the research process. The model is not specifically developed for design projects; however, it addresses different projects and practices explicitly implementing with children. Hart (1992) illustrates the first three levels of child participation as not ensuring children fully contribute and impact the outcome of the process. The five highest levels represent ways of involving children that can be considered as 'real participation.

1. *Manipulation:* Children are invited to participate in projects only to evaluate the final product or service.
2. *Decoration:* Children take parts in the process without given much information about the project.
3. *Tokenism:* Children are given a chance to express their opinions without providing guidance and support to express their opinions.

4. Assigned but informed: Children are invited to participate in the process and given information about the project; however, they do not have a chance to influence the project itself.

5. Consulted and informed: The process is designed specifically for encouraging children to share their opinions.

6. Child-initiated and directed: Children themselves design and carry out the projects without adult participation.

7. Child-initiated, shared decisions with adults: The project is started by children and accepts adults' interference.

First, Scaife, Rogers, Aldrich and Davies (1997) argues the participation of children in the design context and defines the child participants as "informant", which refers to children's awareness of a decision or an event that they have experienced in the design process. In their study, they emphasize the value of children's participation in the design process for providing comprehensive information reflecting their perspective. However, they stated that seeing children as equal partners as adult designers is not a realistic approach. According to their work, children are not competent or expertise to collaborate with designers as design partners. Rather than involving children as a member of a core team, children are invited solely to inform the design process similar to other stakeholders (Scaife, Rogers, Aldrich & Davies, 1997). According to Mazzone, Read and Beale (2008), this approach does not intend to underestimate the outcomes of participation of children in the design process, even it elaborates their roles as field experts, which can be defined as the role of informing and directing the design decisions with the reflections regarding their experiences.

Druin (1999) suggests a framework of Cooperative Inquiry to engage children in the long-span design process by considering children equal design partners. In comparison with previous methods, Cooperative Inquiry focuses on the collaboration of experts from diverse disciplines and children as experts of their own lives in design. The collaboration between adults and children benefits from various techniques for investigating the children's experiences and generating solutions cooperatively. However, giving children a role as design partners have been discussed in several studies in terms of the requirement of resources and the difficulty of implementing comparing to the role of the informant (Scaife, Rogers, Aldrich & Davies, 1998; Williamson, 2003). Another influential framework on children's potential roles is established by Druin (2002) with a conducted significant amount of research. Druin (2002) defined four roles for children's participation in design: user, tester, informant, and design partner by considering the researcher and

children relationship, children technology relationship and the objectives of the researcher for children's inclusion.

1. *User:* Children are invited to test current products while adults observe.
2. *Tester:* Children are joined to test prototypes of products before they are released while adults observe and ask to get feedback about their experiences.
3. *Informant:* Children are participated in the design process at different stages to give important information.
4. Design Partner: Children are included in the design process as equal partners with adult designers.

Nevertheless, Druin (2002) suggests that the most useful role is to design partner to ensure the usability of the product. Read et al. (2002, 2005) indicates that children have acted in multiple roles between informant and design partner during the design process.

Hussain (2010) proposes a model, 'The Design Participation Ladder', for categorizing the participation level of children. The model is adapted by Hart's and Druin's frameworks and reinterpreted specifically for disadvantaged children. According to the model, there is three-level of participation, empowered, consulted, and included:

1. The included level refers to observing children while testing products and asking simple questions without opening discussions about needs or expectations.
2. The consulted level includes giving opportunities to children to express their needs and expectations however, they are not involved in the development of products or services.

3. The empowered level refers to enabling children to learn design skills and being part of a design team to influence the product or services being designed.

Recent studies have investigated to include children with special needs in the process of design (Guha, Druin & Fails, 2008). Guha, Druin & Fails (2008) suggests a model for including children with special needs in design processes. The model has three aspects: 'Druin's level of involvement', 'the nature of the disability, and the availability and intensity of support'. In their influential work, they demonstrate that an effective inclusion requires to provide a child all the support needed – both physical (i.e., assistive technology such as hearing aids) and assistant (i.e., a trained aide); and when the level of the disability do not negatively affect the environment into which the child is placed. Also, they suggest that children with physical and learning disability should play an informant role in the process of design.
Since children have not professional designer skills, generative tools and techniques are developed to include them in the design process (Druin et al, 2012).

2.2.1.3 Generative Tools for Co-Designing with Children

As with any non-designer participant, children cannot be expected to have the designer's skillset; generative tools and techniques are developed to include them in the design process (Druin, 2002). Generative tools refer to application materials of participatory design methods, and these materials serve as a starting point for designers while encouraging children to express their needs and dreams (Hussain, 2012). In order to enhance the information given by users, several methods and techniques and tools are developed to uncover users' needs by encouraging them to express their opinions considering their past experiences and future dreams (Sanders, 2000). According to Hussain (2012), the information is not given only by the user; it is elicited from a shared understanding through the communication between the

designer, user and the artefact created with generative tools. According to Sanders (2000), the tools can be collages, maps, drawings, or prototypes.

Sanders (2000) suggests using toolkits for expression as an essential part of generative techniques. In her study, she discusses the significance of 'make toolkits' to support participants in different activities for various aims such as recalling memories, making connections, explaining feelings, or imagining future experiences. After the participants create an artefact, they are expected to present it by describing and explaining it (Sanders, 2000). Through experiencing design tools and sharing opinions through the artefacts, both designers and participants broaden their horizons (Hussain, 2012).

In her research (Hussain, 2012), she presents principles for working with children through generative tools.

1. *All people are creative.* However, they are not often invited to participate in creative activities because they may need some preparation and support.
2. *All people have dreams.* Nevertheless, they may not have had the opportunity to share their dreams with others and will need facilitation to do so.
3. *People will fill in what is unseen and unsaid based on their own experience and imagination.* By asking them to make artefacts from ambiguous components, we can see what is important and meaningful to them.
4. *People project their needs onto stimuli because they are driven to make meaning.* Therefore, the artefacts that participants created through the generative design tools can be used to initiate conversations about their needs and dreams.

2.2.2 Advantages of Involving Disabled Children in the Design Process

In designing with children, adopting a participatory design approach is necessary to understand in order to elicit expectations, frustrations and needs of children with disabilities. Frauenberger, Good and Alcorn (2012), presents the three benefits of participatory design in the context of designing technology for children with disabilities:

1. It is challenging for designers or researchers to develop solutions from a position of empathy; therefore, understanding the needs of these children is essential to bring effective solutions.
2. Building up realistic expectations of what technologies can and cannot do has a positive effect on its further use.
3. Moreover, most importantly, giving children with disabilities a role in the design process, which enables them to shape their own experiences, gives them a sense of empowerment, contributing to children's wellbeing.

The participatory design approach has the potential for empowering and disempowering processes depending on the participants' role and the way the approach is implemented (Zimmerman, 1995). Especially when involving children, it is the responsibility of the designer to define the considerations and find suitable methods that fit the competence and skills of the children (Hussain, 2010).

2.3 Limb Deficiency in Children

This section presents a review of related literature and describes upper limb deficiency in children as a widespread disability (disadvantage or limitation) for children.

The primary cause of limb deficiencies in children is congenital (Wright et al., 2001). Children's adaptation to their physical deficiency shows variability; some children function well and do not psychologically, while other children have psychological and social adjustment problems (Wallander et al., 1988). Besides its functional importance, the hand has the social and psychological roles for sensory exploration and contact (Didierjean-Pillet, 2002). Most children with limb deficiency rely on an assistive device depending on their physical deficiency level for performing daily activities (Wright et al., 2001). However, due to technical requirements and economic restrictions, providing prosthetic devices for children is problematic in developing countries.

Furthermore, children's prosthetics usage is not recommended because they should be replaced from time to time due to children's constant growth (Burger, Brezovar & Marinček, 2004; Krajbich, 1998). Therefore, the children's needs and concerns are rarely taken into consideration while developing these assistive devices (Andersson et al., 2011). Studies on exploring pediatric prosthesis considerations emphasize the role of emotional and aesthetic needs on building body image as an essential determinant for an individual to accept to use these devices (Sansoni, 2014). To take these important issues into consideration, psychological needs are essential to consider when designing prosthetic devices for children due to still-developing self-image and their constant physical growth (Didierjean-Pillet, 2002). Organizations providing assistive devices should consider children's views as the bearers of human rights about the aid they receive (UN, 1989). "A mentally or physically disabled child should enjoy a full and decent life, in conditions which ensure dignity, promote self-reliance and facilitate the child's active participation in the community" (UN, 1989, article 23, para.1). Prostheses for children are developed for reducing their physical limitations and support their social and physical growth (Davidson, 2002). According to Burger, Brezovar and Marinček (2004), the wellbeing of children only is achieved by using an assistive device. Therefore, studies on technical aspects of prosthetics (Glynn, Galway, Hunter, Sauter, 1986; Pruitt, Varni & Setoguchi, 1996;

Shaperman, Lansberger & Setoguchi, 2003; Ccorimanya et al., 2019) but there is a scarcity of research published on factors that affect prosthetic usage from children's viewpoint.

2.3.1 Prosthetic Hand Use in Children

Children with congenital upper limb deficiency face various difficulties depending on the deficiency level (Zuniga et al., 2018). Therefore, most children with limb deficiency need assistance and rely on a prosthetic device to perform daily activities such as self-care, sports, and specific movements (Wright, Hubbard, Jutai, Naumann, 2001). The congenital cause of the disability increases prosthetic devices' acceptance rate by the children (Scotland & Galway, 1983). Also, children accept the prosthetic hand as part of their body image easier comparing to adults (Sörbye, 1980). However, children with congenital upper limb deficiency have difficulties controlling the prosthetic device since the lack of muscle growth (Zuniga et al., 2018). Therefore, the early usage of prosthetic devices has the potential to increase children's ability to control with training their motor control abilities (Mano et al., 2018).

The prosthetic hand rejection of the children has various reasons to address, including the difficulty to wear, operating the prosthetic, causing soreness on the arm. (Reinkingh et al., 2014). Also, emotional, and aesthetic needs are essential motivation factors for using an assistive device (Murray & Fox, 2002). According to Kruit and Cool (2009), the ideal prosthetic hand should be three main dimensions: affordability, lightweight and ease of use.

In order to avoid the prosthesis rejection from the children, Ccorimanya et al., 2009 presents principles that should be taken into consideration; 1) the prosthetic hand should be lightweight and low powered to be able to be controlled by children, 2) using soft materials decrease the discomfort 3) prosthetic hands should be designed

simple, scalable and economically viable 4) prosthetic hand should be easy to use to motivate children for long-term usage.

Many assistive devices are developed to increase muscle activity and facilitate the lives of these children (Ccorimanya et al., 2019; Zuniga et al., 2018). However, families' financial resources play a crucial role in the prescription of prostheses for their children. Electronic and mechanical devices have been developed to fulfil children's unmet needs, but the cost of replacement is an obstacle for many families (Sansoni, 2014). However, today, with advancements in 3D printing technology, designing, printing, and fitting prosthetic hand devices are possible at a distance and a low cost for children.

2.3.2 The Role of Prosthesis in the Psychological Wellbeing

Prosthesis usage is a significant contributor to the psychological wellbeing of individuals with limb deficiency. There is growing interest in the role of the prosthesis in supporting the psychological wellbeing of people with limb deficiency (Carroll & Fyfe, 2004). The functionality of the prosthesis is considered a significant impact on wellbeing (Sansoni, 2014). It has been shown that prosthesis usage supports individuals in gaining mobility and performing daily activities (Pohjolainen, Alaranta, & Karkainen, 1990). Also, it has been argued that improving mobility and learning new skills has benefits for both overcoming unpleasant feelings that deficiency may cause. In that sense, Dunn (1996) suggests focusing on three aspects for achieving better psychological wellbeing: 1) finding positive meaning in having limb deficiency, 2) adopting an optimistic attitude and 3) perceiving control over disability. In the context of adaptation to disability, it has been discussed that various factors such as daily activities, social support and level of deficiency should be considered when understanding one's wellbeing (Bosmans et al., 2007). Besides the functional role of the prosthesis, several studies present the

influence of aesthetics of the prosthesis on the psychological wellbeing of people (Murray, 2005; Bhuvaneswar, Epstein & Stern, 2007; Rybarcyzk & Behel 2008; Nguyen, 2013). Millstein, Heger and Hunter (1986) argue that "the prosthesis must be comfortable functional and have a pleasant appearance" to be accepted by users. Similarly, Bhuvaneswar, Epstein and Stern (2007), emphasize the importance of cosmetic appearance in the user's psychological wellbeing as much as the functionality of the assistive device.

On the other hand, few studies argue non-cosmetic aesthetics of prosthetic design for enhancing users' experiences. To illustrate, Capestany and Esparza (2011) present their process of developing prosthetic devices specifically designed for a user who required golf-prosthesis without concerning aesthetics. In that context, Hilhorst (2004) highlights designing personalized prosthetic hands for children for giving them a sense of identity.

2.4 Wellbeing, Positive Psychology and Design for Wellbeing

This chapter presents the concept of wellbeing and continues with the discussion on positive psychology literature.

2.5 Wellbeing

Wellbeing is a broad concept with various dimensions that stands for an individual's quality of life (Mattelmäki & Lehtonen, 2006; White & Pettit, 2007, Ryan & Deci, 2011, Keinonen, Vaajakallio & Honkonen, 2013). World Health Organization defines "wellbeing" as "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity" (World Health Organization, 1948). With the rise of wellbeing by WHO, many studies brought different definitions for wellbeing. Some studies on wellbeing have described this as an assessment of the

quality of life in individuals' prescription about their current situations (Shin & Johnson, 1978; Felce & Perry, 1995). Studies also define wellbeing as optimal psychological functioning and associated wellbeing with the concept of positive mental health (Thieme et al., 2012; Ryan & Deci, 2017). In the literature, wellbeing can be categorized into two interconnected dimensions; objective wellbeing and subjective wellbeing (Desmet & Pohlmeyer, 2013). Keinonen, Vaajakallio and Honkonen (2013) explain objective wellbeing as high quality of life that external requirements are met; in contrast, subjective wellbeing refers to internal factors that differ from person to person (Diener, Lucas & Oishi, 2002; Dolan & Metcalfe, 2012). Therefore, the meaning of wellbeing can be defined with different aspects of life, such as values, preferences, and culture. Despite the versatile nature of wellbeing, all the studies on wellbeing shows an agreement on not denying the negatives but mostly focusing on enhancing positive aspects of life is essential to achieve wellbeing.

2.5.1 Positive Psychology

Positive psychology, which is defined as "the study of human flourishing" (Seligman & Csikszentmihalyi, 2000), emerged from the need to look from the positive side rather than focus on negative aspects a new perspective for the study of wellbeing (Kanis, Brinkman & Perry, 2008). Studies on positive psychology present the value of understanding positive emotions. Rather than focusing on negative aspects of human life, such as mental illnesses, positive psychology highlights positive emotions, wellness. Fredrickson (2003) reflects that positive emotions have a significant impact on the development of psychological resilience. Argenton et al. (2013) state that positive psychology's role for improving an individual's physical and mental health and fulfilment rather than putting effort to minimize the individual's deficits. However, positive psychology does not entirely deny the negative aspects of life; it aims to consider both positive and negatives as a whole

experience (Gable & Haid, 2005). Within the emergence of positive psychology, new theories, frameworks, approaches and constructs have been developed (Richardson & Guigon, 2008).

Most researchers investigating positive psychology discuss happiness from two contrast concepts: hedonic and eudaimonic wellbeing (Waterman, 1993; Ryan & Deci, 2001). The hedonic view of happiness focuses on studying human happiness and the effect of positive emotions on this (Lee Duckworth, Steen & Seligman, 2005). Many studies on the benefits of positive emotions, such as expansive or exploratory behaviours, can create meaningful human resources for the long-term (Fordyce, 1988; Fredrickson & Joiner, 2002). These resources, such as psychological resilience and social relationships, can also help individuals find a way to cope with negative events and circumstances in life (Fredrickson & Joiner, 2002). Other studies focus on the happiness that represents meaning, self-actualization at the individual level and commitment to shared goals at the social level (Argenton et al., 2013; Massimini & Delle Fave, 2000). Ryff (1995) defines the eudaimonic concept of happiness as "seeking perfection for the realization of an individual's true potential". Besides, many studies investigate the relationship of meaning with happiness, achievement, purpose in life and development of personal skills (Chamberlain & Zika, 1988; Linley et al., 2009; Steger, Frazier, Oishi, Karler, 2006; Waterman et al., 2010). To better explain the eudaimonic aspect of happiness, Ryff and Singer (2008) emphasize six aspects of self-actualization for psychological wellbeing: self-acceptance, positive relations with others, personal growth, purpose in life, mastery and autonomy. They explain that *self-acceptance* as "evaluating self with awareness, and acceptance of, both personal strengths and weaknesses"; *positive relations with others* as "an achievement of building healthy relationships with others"; *personal growth* as "the continual process of developing one's potential"; *purpose in life* as "actively engaging in life for meaningful goals"; *mastery* as "the capacity to change

surrounding through mental and physical needs"; *autonomy* as "capability for being independent".

On the other hand, recent studies focus on hedonic and eudaimonic concepts of happiness as a holistic approach. McGregor and Little (1998) state that the concept of mental health consists of two interrelated aspects: positive emotions and meaningfulness. Similarly, Compton et al. (1996) claim that positive emotions and personal growth is strongly linked. Seligman and Peterson (2004) developed an integrated framework that presents three aspects of happiness: *pleasure, engagement and meaning.* Also, Seligman presented a PERMA model that identifies five principles of wellbeing: positive emotions, engagement, relationships, meaning and accomplishment (Seligman, 2011). For that reason, hedonic and eudaimonic concepts of happiness could be explained as inseparable parts of wellbeing rather than using one of them.

In conclusion, wellbeing is a broad concept that represents the quality of life. It comprises two aspects: hedonic and eudaimonic wellbeing. There are also different approaches for explaining wellbeing with the consideration of both aspects, happiness, and self-actualization. Similarly, positive psychology focuses on achieving pleasant, engaged, and meaningful life qualities by holistically addressing human experience. Therefore, in this study, wellbeing refers to a positive state of being that embodies interrelated aspects and subjective and objective dimensions of wellbeing.

2.5.2 Design for Wellbeing

The multifaceted nature of wellbeing is reflected in the design literature from different perspectives that focus on subjective wellbeing. Nevertheless, many design researchers agree that design has a vast potential to bring fulfilment in one's life

(Desmet & Pohlymeyer, 2013; Kanis, Brinkman & Perry; 2008). Papanek (1985) reflects the potential of design to change conditions to support wellbeing both individually and socially. The recent studies on design explore the possibility of increasing individuals' subjective wellbeing and communities with design (Boddington et al., 2008; Desmet., 2003; Margolin, 2007). According to Petermans and Cain (2019), with the consideration of objective aspects of wellbeing, supporting people to experience pleasurable and meaningful activities is valuable for investigating design potential. Therefore, frameworks are developed to explore ways for transforming the desired conditions of wellbeing. Desmet and Pohlmeyer (2013) present a framework for positive design that aims to combine three ingredients for human flourishing: design for pleasure, design for virtue and design for personal significance (Figure 2.2). Ryan and Deci (2001) define human flourishing as "optimal human functioning and living to one's full potential". According to Desmet and Pohlmeyer (2013), the three ingredients can be used as a guide for design for wellbeing and a positive design. 'Design for pleasure' addressing "the presence of positive emotions and the absence of negative emotions". Various frameworks proposed to focus on enabling designers to generate pleasure-based experiences (Tiger, 1992; Desmet & Hassenzahl, 2012; Hassenzahl, 2013). 'Design for personal significance' focuses on personal goals and aspirations. According to this aspect, products can be sources of personal significance derived from sense of achievement. 'Design for virtue' addresses the ideal mode of behaviour for achieving a sense of perfection. Behaviour focused approaches in design have been discussing to support individuals to be virtuous. Lastly, design for flourishing refers to achieving the full potential in one's life. According to Desmet (2012), when the goal is only

experiencing pleasure in life without any purpose and meaning, actual wellbeing cannot be achieved.

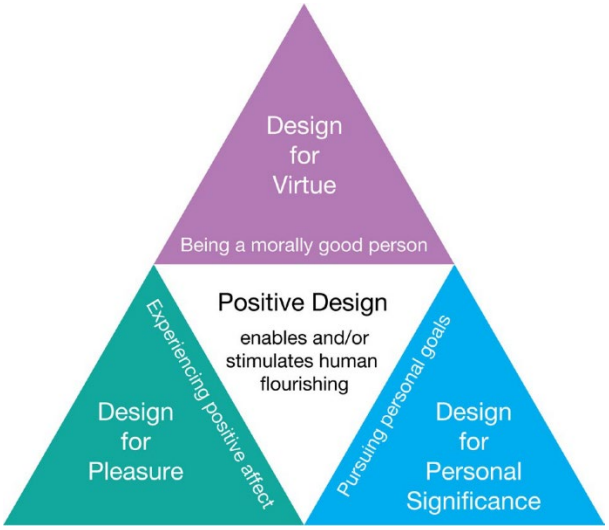


Figure 2.2 A framework for positive design (Desmet & Pohlmeyer, 2013)

Desmet and Hassenzahl (2012) indicate that design can be a source of positive experiences or increasing awareness of people regarding their abilities or transforming users' behaviours or thinking positively. In that sense, they suggest a possibility-driven design approach for designing wellbeing with assistive technologies. The possibility driven approach mainly focuses on existing potentials to enhance rather than concentrating on bringing solutions to current problems. Desmet and Hassenzahl (2012) propose four approaches to design for happiness depending on two distinctions; promise versus problem focus and activity versus product focus (Table 2.1). The first distinction is 'promise versus problem focus', which refers to promoting wellbeing with achieving different aspects. According to Desmet and Hassenzahl (2012), designers may focus on potential sources of wellbeing or put effort into eliminating sources of problems such as displeasure and discomfort. The second distinction is 'activity versus product focus' this distinction

addresses differences between stimulating positive emotions from product experience and meaningful activities.

Table 1 Four approaches to design for happiness

	ACTIVITY FOCUS
PROMISE focus	Products that inspire and enable people to engage in activities that stimulate happiness.
PROBLEM focus	Products that inspire and enable people to engage in activities that reduce causes of unhappiness.
	PRODUCT FOCUS
PROMISE focus	Products that stimulate happiness by creating pleasurable experiences.
PROBLEM focus	Products that stimulate happiness by reducing causes of unpleasant experiences.

In conclusion, positive psychology can be utilized for designing better products and services to strengthen users' subjective wellbeing. The use of positive design should focus on adopting a possibility-driven approach that may help achieve design solutions that fulfil users' expectations and increase their overall wellbeing.

2.6 Chapter Conclusions

The effects of involving children in the design process and its benefits for children with disabilities, limb deficiency in children and how prosthesis use to increase

wellbeing, positive psychology and aspects should be considered while designing for wellbeing has been investigated so far. The co-design approach has the potential to elicit the needs of children with limb deficiency to be used to strengthen these children's overall wellbeing. The literature review on designing for and with children showed the advantages of the co-design for both children and design practitioners. These advantages can be summarised as below:

- Enabling children to visualize their ideas by generative tools instead of expecting to express their needs with their immature language skills,
- Attracting children's interest and encourage them to overcome their shyness when they are with adults,
- Enabling designers to achieve more solid design solutions that are generated from the children's point of view.

In order to involve children in the design process, these advantages helped to decide on the approach that should be adopted in this research. In addition, there are two controversy issues; how and when to involve children in the design process. Children take different roles in the design process at various levels of participation. Recent studies focus on children's engagement in the long-span design processes for achieving product design that children desire. The literature review on designing for and with children is mostly focused on participatory design methods. Participatory design is a broad context that embodies different methods and techniques to facilitate children's participation in design.

Another insight from the literature on designing for and with children is 'make toolkits' used for supporting children in different activities for various aims such as "recalling memories, making connections, explaining feelings or imagining future experiences" for the data collection purposes. In that way, children can be directly

asked what they need, prefer, or expect product experiences that they specifically designed for them.

In addition, the examination of the literature on limb deficiency pointed reasons for prosthetic hand rejection in children. Moreover, principles should be considered for avoiding prosthesis rejection. Children accept the prosthetic hand as part of their body image easier comparing to adults. The congenital cause of the disability increases prosthetic devices' acceptance rate by the children. Therefore, the early usage of prosthetic devices has the potential to increase children's ability to control with training their motor control abilities.

On the other hand, prosthetic hand rejection in children has various reasons to address, including the difficulty to wear, operating the prosthetic, causing soreness on the arm. According to Kruit and Cool (2009), the ideal prosthetic hand should be three main dimensions: affordability, lightweight and ease of use. In that sense, Dunn (1996) suggests focusing on three aspects for achieving better psychological wellbeing of people having limb deficiency: 1) finding positive meaning in having limb deficiency, 2) adopting an optimistic attitude and 3) perceiving control over disability. In the context of adaptation to disability, it has been discussed that various factors such as daily activities, social support and level of deficiency should be considered when understanding one's wellbeing.

In that sense, the design for wellbeing literature suggests possibility driven approach which focuses on existing potentials rather than concentrating on bringing solutions to current problems. Therefore, in this research, the results will be discussed the context of the possibility-driven approach, which may generate design ideas that fulfil users' expectations and increase their overall wellbeing.

CHAPTER 3

FIELDWORK, SET-UP AND PROCEDURE

Turkey is one of the countries where the use of a prosthesis for children is not encouraged due to their continual growth. A few years ago, Robotel, an NGO based in Turkey, started to provide children in need with relatively low-cost, mechanical 3D printed prostheses having a grasping function controllable by elbow and wrist movement. Although the functionality of the prosthetics is limited, they provide rehabilitation for muscles until children complete their physical growth. The fieldwork study was carried out as individual co-design sessions with four children, who use the 3D printed prosthetic devices provided by "Robotel". Robotel is a partner of a wider online digital global community called 'Enabling the Future' (e-NABLE, 2020), bringing together digital humanitarian' volunteers from all over the world who are using their 3D printers to make free and low-cost prosthetic upper limb devices for children and adults in need. Therefore, the sessions aimed to explore the children's daily needs and expectations about their 3D printed prosthetic hands and investigating the ways to encourage them to share their frustrations and dreams related to prosthesis usage. The information collected from children believed to show the right directions to designers about what they should consider answering children's expectations for a future prosthesis.

The importance of involving children in the design process using generative design methods, tools, and techniques is stated in Chapter 3. Based on the literature findings, a co-design toolkit was developed. In this chapter, this toolkit's development will be

described by presenting the methods and tools with their planning, implementing, and analysing.

3.1 Research Approach and Expected Results of the Field Study

The literature review highlights the benefits of using generative design tools when co-designing with children to understand children's opinions (Hussain & Sanders, 2012; Sanders, 2000). According to Sanders (1999), generative design toolkits can be used to involve non-designers in the design process by providing a new language that composes verbal and visual communication forms and allows participants to express their abstract ideas in a more concrete form. In the light of the literature review, the methodology is constructed on a generative research approach which aims to design with children in individual co-design sessions.

In that sense, co-design toolkits are commonly applied in facilitated generative activities and as an outcome of these activities, artefacts prepared by the participants are analysed to reach design relevant information. Therefore, co-design toolkit is developed to guide children to experience generative design activities to encourage them to share their needs and expectations that provide comprehensive knowledge for the design process.

In the sessions, the children were given the “informant” role for giving significant information to enhance design outcomes (Druin, 2002). The researcher acted as the “facilitator” for opening discussions about their experiences and guiding them to make design decisions regarding these experiences using generative design tools.

The following aspects are investigated in the individual co-design sessions.

- Children's unmet needs in daily activities

- Children's reflections on current hand/arm prosthetic devices
- Children's expectations & priorities related to hand/arm prosthesis usage.

Although, it was essential to adopt this approach for facilitating children's expressions about their deficiency and providing them with different forms of communication, the obtained knowledge from the co-design sessions will be analysed like an interview data.

In the following section, the development of co-design toolkit will be presented, and the reasons for selecting the utilised tools will be explained.

3.2 The Development of 'Child's Prosthesis Co-design Toolkit'

In order to organize which design, tools and techniques to use for engaging non-designers (i.e., children in this study) in the design process, Sanders (2010) proposes a framework that includes three dimensions: form, purpose and context. Accordingly, *form* is "a kind of action that is taking place between the participants in an activity, and is categorized as making, telling or enacting". *Purpose* can include four usages as for: 1) probing participants, 2) priming participants to immerse them in the domain of interest, 3) better understanding the participants' everyday experiences, and 4) generating ideas or design concepts for future. *Context* can be described as "where and how the tools and techniques are used" and classifies along these four dimensions:1) individual, 2) group, 3) face-to-face, 4) online. As stated by Sanders (2010), it is essential to understand the objectives of a research and then customize the tools and techniques accordingly. Depending on the purpose, the content of the tools and the context can vary. The following chart shows the categorization of the tools and techniques that are being implemented in the framework by "form" (i.e., making, telling, enacting) and where these tools and techniques are being used according to their "purpose" (i.e., for probing, priming,

understanding, and generating) and "context" (i.e., individual, group, face to face, online) (Figure 3.1).

Table 2 Framework for organizing tools and of participatory design (adapted from Sanders (2010)

	Tools and Techniques	Purpose	Context
Making Tangible Things	**2D Collages** using visual and verbal triggers on backgrounds with timelines, circles etc.	probing, priming, understanding, generating	individual group face-to-face online
	2-D mappings using visual and verbal components on patterned backgrounds	priming, understanding, generating	individual group face-to-face
	3-D mock-ups using e.g. foam, clay, Legos or Velcro-modeling	understanding, generating	individual group face-to-face
Telling	**Diaries and daily logs** through writing, drawing, blogs, photos,video, etc.	probing, priming, understanding	individual group face-to-face online
	Cards to organize, categorize and prioritize ideas	understanding, generating	individual face-to-face online
Acting	**Game boards and game pieces**	priming, understanding, generating	individual group face-to-face
	Props and black boxes	understanding, generating	individual group face-to-face
	Participatory envisioning and enactment	generating	individual group face-to-face
	Improvisation	generating	individual group face-to-face
	Acting out, skits and play acting	understanding, generating	individual group face-to-face

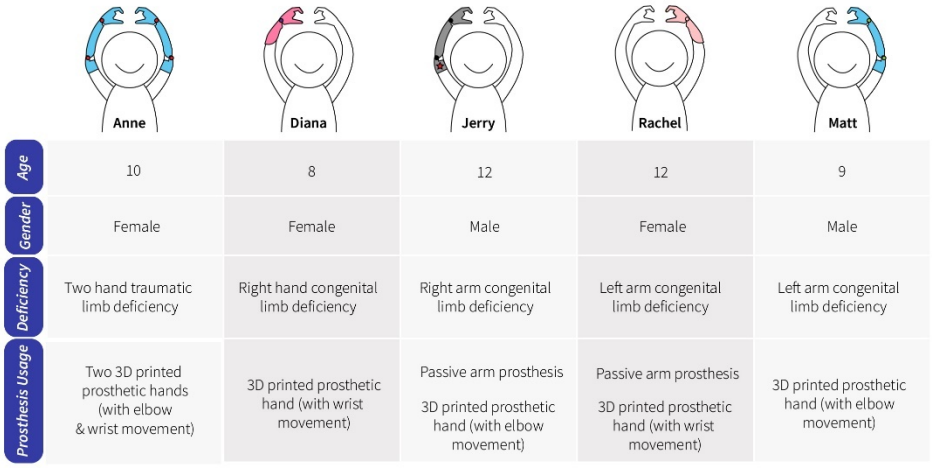
According to the framework, 2D mappings and cards are selected as tools facilitate information sharing and idea generation based on children's own reflections. Conducting the sessions with each child individually was found reasonable in terms of exploring the differences of the children's needs and expectations. In the light of

this framework, selected tools were designed and reinterpreted according to the objectives of the components. The toolkit has gone through two design iterations for ensuring to obtain the intended information. According to the findings, the necessary improvements were made, and new components were added.

3.2.1 Participants of the Fieldwork, Sampling and Background Information

Children participants were selected among the Robotel's (see Section 1.1) contacts, in which the researcher has been working voluntarily for four years and had known the children and their families in person. Since they have known each other, it made it easier for the researcher to approach children and their families, explain the purpose of the research, and ask whether they would be interested in participating. Consequently, five children (Matt participated in the pilot study) were secured with the consideration of age group, 3D printed prosthetic hand experience and consent criteria. Of the five participants, three were female, and two were male between the ages of 8-12. No criteria were set for the cause of upper limb deficiency; only one participant has traumatic upper limb deficiency; others have congenital upper limb deficiency. All of them use personalized 3D printed prosthetic hands that the NGO provided them. In order to keep their identity confidential, all four children are assigned a nickname (i.e., Anne, Diana, Jerry, Rachel, Matt), and they will be

referred to with these names. Figure 3.2 shows children participants' demographic information.



	Anne	Diana	Jerry	Rachel	Matt
Age	10	8	12	12	9
Gender	Female	Female	Male	Female	Male
Deficiency	Two hand traumatic limb deficiency	Right hand congenital limb deficiency	Right arm congenital limb deficiency	Left arm congenital limb deficiency	Left arm congenital limb deficiency
Prosthesis Usage	Two 3D printed prosthetic hands (with elbow & wrist movement)	3D printed prosthetic hand (with wrist movement)	Passive arm prosthesis 3D printed prosthetic hand (with elbow movement)	Passive arm prosthesis 3D printed prosthetic hand (with wrist movement)	3D printed prosthetic hand (with elbow movement)

Figure 3.1 Children participants' demographics

Anne. Anne has two hands traumatic upper limb deficiency. When she was four years old, she had lost her two hands due to a fire that started in their home. Now, she is ten years old; and she is living with her mother and two brothers. Her family rarely allows Anne to go out except going to school due to being disturbed by people's reaction towards her appearance. However, she is enthusiastic about taking up new hobbies, improving her skills and spending time with her friends.

Diana. Diana has right-hand congenital upper limb deficiency. When she started to wear her first 3D printed prosthetic device, she was six years old. Her hobbies are taking photos, designing clothes for her Barbie babies, and playing with friends. She wants to be a fashion designer in the future.

Jerry. Jerry is 12 years old, and he has right-hand congenital upper limb deficiency. He has used three prosthetic devices before; the first one is a passive prosthesis; however, he could not use it due to its weight and causing too much perspiration. His second prosthesis was a 3D printed wrist-powered prosthetic; however, his wrist could not be enough to bend the mechanism. Therefore, he started to use an elbow-powered 3D printed prosthesis designed as a gladiator arm concept. He loves playing football and wants to be a famous goalkeeper in the future.

Rachel. Rachel is twelve years old, and she has left-hand congenital upper limb deficiency. She has used three prosthetic devices before; the first one was passive arm prosthesis which she did not want to use because of causing perspiration. The second assistive device she has used was 3D printed wrist-powered prosthetic; however, due to causing pain while bending her wrist, she started to wear an elbow-powered prosthesis two years ago. Her dream is to play the violin with an assistive device.

Matt. Matt is nine years old, he has left-arm congenital upper limb deficiency. When he was started to use his first prosthetic, he was 7 years old. He is using 3D printed elbow-powered prosthetic device. He is a professional ping-pong player. His hobbies are drawing and playing with his friends.

3.2.2 Setting the Right Environment and Atmosphere

Creating a comfortable atmosphere for children is essential for them to express their thoughts and opinions with the researcher. The sessions with children were carried out at the researcher's office at the university on an individual basis to eliminate other family members' inferences (e.g., especially the participants' little brothers or sisters). Children are invited with an accompany (e.g., parent, older sister/brother);

however, the companion was kindly asked to wait outside. The sessions were tape-recorded with a smartphone. The recordings were transcribed for data analysis.

3.2.3 Selection of Stationary Materials Used for the Toolkit

For the co-design sessions, children were free to express themselves with the tool they chose, play dough, a blank paper and images of different prostheses were supplied to participants. Since the components of the toolkit are assumed as a discussion starter, different ways of representations would be suitable for the activity. Whilst deciding on the stationary materials, the researcher considered the following criteria: the ability to use with one hand, easy to carry, easy to hold, safety, and child-centredness.

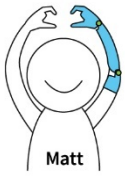
The toolkit included the following stationary:

- A3-sized sheets for each activity,
- blank cards (to children express themselves with writing or drawing for each activity),
- colour pencils,
- coloured papers,
- glue stick,
- a pair of scissors.

3.2.4 The Pilot Study

The pilot study was performed with nine years old male child. The participant was selected from the database of the NGO that provided free prosthetic devices to children. The participant was selected according to the willingness to participate in the session and ease of communication with the researcher. Figure 3.3 shows children participant's demographic information. In order to keep their identity

confidential, the participant was assigned a nickname, and he will be referred to with this name.



Age	*Gender*	*Deficiency*	*3D-Printed Prosthesis Usage*
9	Male	Left arm congenital limb deficiency	with wrist movement

Figure 3.2 Demographics of the participant of the pilot study

3.2.4.1 Data Collection Tools of the Pilot Study

By considering the Sander's framework for organizing tools and techniques, the toolkit which includes the following components: i) daily activity journey; ii) personal 3D-printed prosthesis hand evaluation; iii) if I were a prosthesis (see Figure 3.4) was developed for the pilot study.

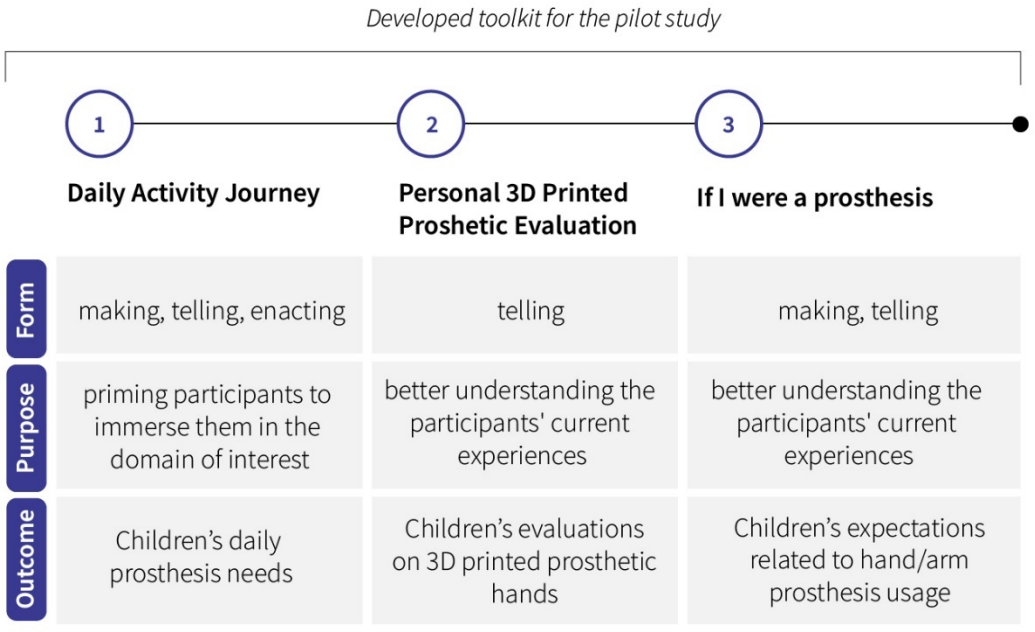


Figure 3.3 Components of the toolkit developed for the pilot study

Daily Activity Journey: The Daily Activity Journey component aims to explore children's daily activities and understand their daily needs while priming participants for the next activities. To initiate the discussion around their daily activities and make children reflect on them, questions such as: "What is your typical weekday evening like?" help the researcher learn about children's current abilities and needs. Therefore, a timeline with blank areas is designed to support children to describe their everyday activities. The participant is asked to fill the timeline with a set of words or drawings related to their daily activities (Figure 3.5). When talking about physical difficulties, explaining the activity with enacting was beneficial to better understand the participant.

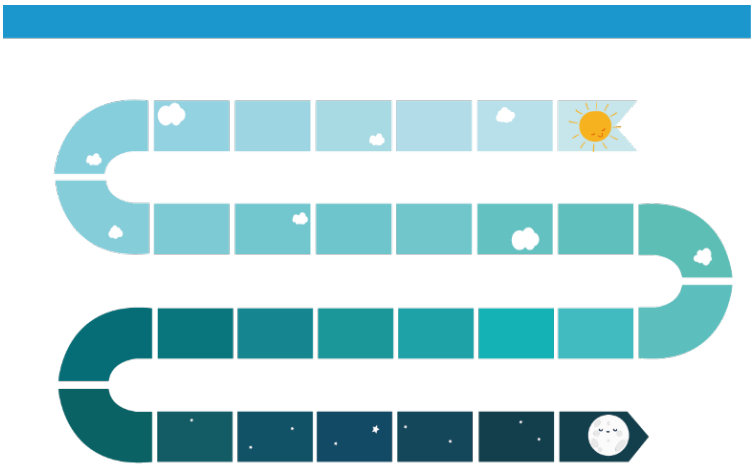


Figure 3.4 An early version of the ‘Daily Activity Journey’ tool

Also, an emoji sticker set provided by the researcher, and the participant is expected to put one of the emoji stickers indicating whether the activity is giving him negative or positive feelings (Figure 3.6).

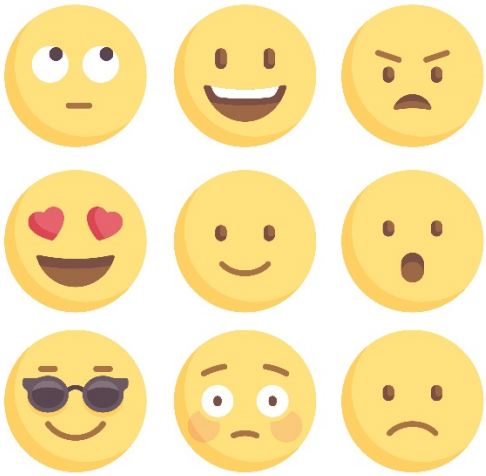


Figure 3.5 Emoji sticker set

3D Printed Prosthetic Hand Evaluation: As all participants were using 3D printed prosthetic hands, their opinions were essential to investigate to what extent the 3D printed prosthetics hands fully answer children's daily needs. A 5-point Likert-scale was used for children to evaluate their assistive devices. According to Hill (1997), children tend not to choose negative expressions; therefore, each of the Likert scale emotions needs to be represented with a positive expression. Therefore, a 5-point Likert-scale, associated with degrees of 'smile' that represent an increasing rate of satisfaction, is prepared for this component (Figure 3.7). In the session, the participant was expected to rate the prosthetic hand according to the daily activities mentioned in the daily activity journey' through the Likert-scale.

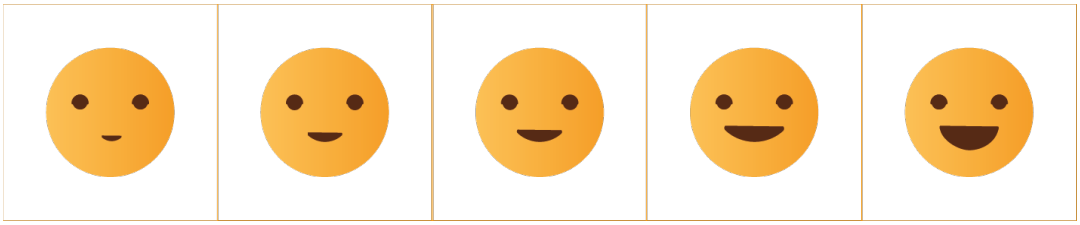


Figure 3.6 A 5-point Likert-scale prepared for ‘3D Printed Prosthesis Evaluation’

If I were a Prosthesis: This activity was designed with the things-centred approach, which aimed to enable the user to express their experiences, emotions, and opinions from the prosthesis mouth (Cila et al., 2015). In the pilot study, the participant was asked to think about the prosthesis' perspective and reflect on what difficulties, needs, and expectations the prosthesis might be experiencing during its usage. At this point, the image set was presented to the participant to open a discussion (Figure 3.8). The participant was asked to look at the images and imagine the prosthesis' needs, likes, dislikes, frustrations, and capabilities.

Figure 3.7 Image set of the 'If I were a prosthesis' activity

3.2.4.2 Findings of the Pilot Study

- The graphic representation of the tool designed for 'Daily Activity Journey' limited the participant to think freely. The participant tried to fill all of the designed timeline blocks, although he had nothing to write. Therefore, the timeline with blocks is revised into a timeline with a single line. The line is extended to giving free space for filling with all the information related to daily activities.

- Associating the daily activities with emotions were found challenging for the participant. The activities were evaluated according to whether the participant liked doing the activity or did not like doing it instead of evaluating the activity in prosthesis usage. Hence, the outcomes of the

method were not relevant to the objectives of the study. Therefore, investigating emotions was not within the scope of the study.

- The tools which are designed to facilitate the children's expressions on sensitive issues should be reconsidered. To illustrate, the participant could not understand the "If I were a Prosthesis" activity and asked: "should I talk for myself or prosthesis?". Also, the participant's narrations did not reflect his real needs, expectations, or dreams but tended to include imaginary scenarios. Therefore, instead of embracing the 'things centred' approach, the user-centred approach is decided to be implemented.

- The participant comfortably expressed the physical difficulties he encounters during daily activities in the pilot study. Therefore, generative design tools should be designed to fit the children's different characteristics and flexible to adapt to different capabilities.

3.2.5 Designing the 'Child's Prosthesis Co-design Toolkit'

After conducting a pilot study, the necessary improvements in the components were made. According to the research objectives, the third component of the toolkit was reinterpreted for exploring the children's expectations. Also, in order to understand the priorities of these expectations, an additional tool, Dream Prosthesis Map was added. Lastly, by considering the needs and expectations of the children, an ideation tool that aims to understand children’s dreams regarding the prosthesis usage were also added. After revising the toolkit, the toolkit re-tested with a participant. This

session successfully gathered intended information; therefore, it is included in the analysis (Figure 3.9).

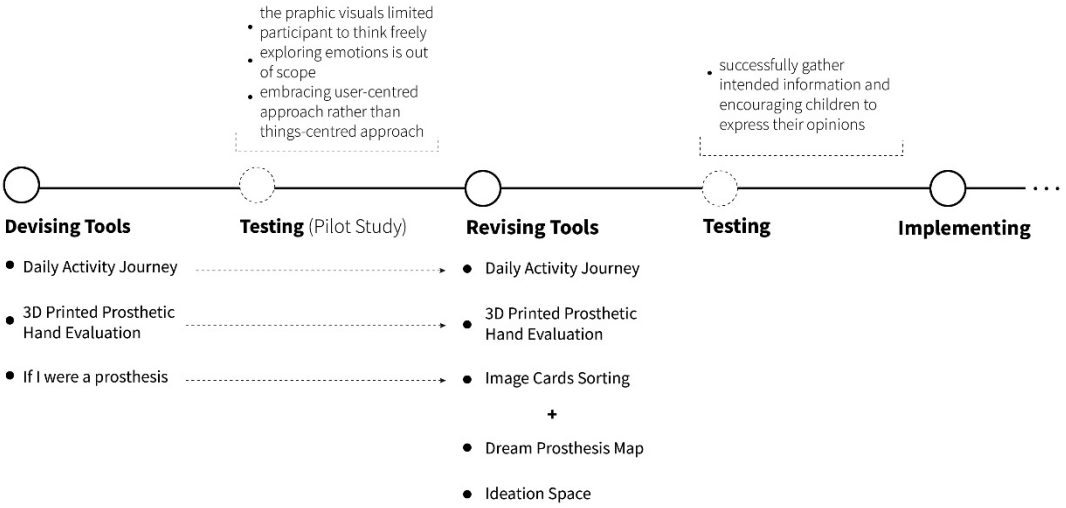


Figure 3.8 Design iterations for developing 'Child's Prosthesis Co-design Toolkit'

Considering Sander's framework (2010) and the findings of the pilot study (see section 3.2), 'Child's Prosthesis Co-design Toolkit' was developed, which consists of the following components: i) daily activity journey; ii) personal 3D-printed prosthetic hand evaluation; iii) image sorting cards; iv) dream prosthesis map; and v) ideation space (see Figure 3.10).

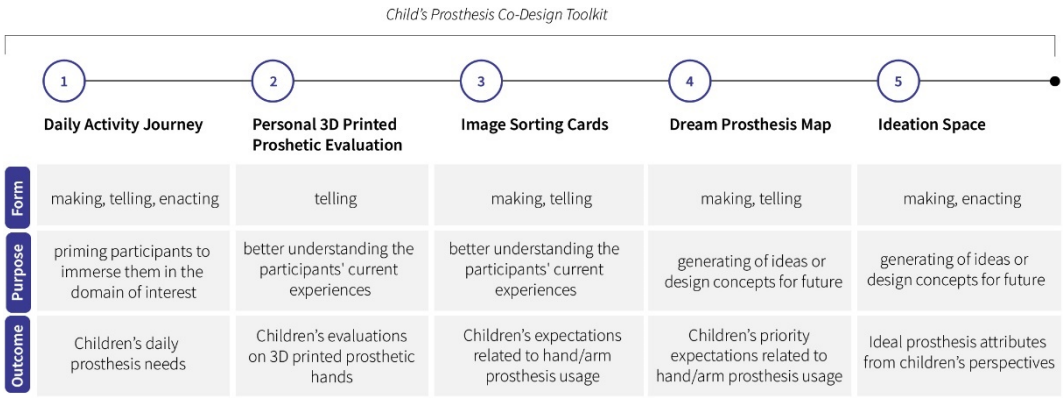


Figure 3.9 The development of the 'Child's Prosthesis Co-design Toolkit'

Daily Activity Journey: The Daily Activity Journey component which aims to explore children's daily needs was revised after the participant's feedback (see Figure 3.11). Additionally, activity cards were added to be filled by the participants (see Figure 3.12). The cards have three icons to be checked to understand i) "the activities the participant needs a prosthesis for", ii) "the activities the participant can do with his / her hand", iii) "the activities the participant has a solution for doing the activity". It is aimed that children are primed for the co-design session by giving them a chance to mention their daily lives with this activity. The tool can be used with making, telling, and enacting.

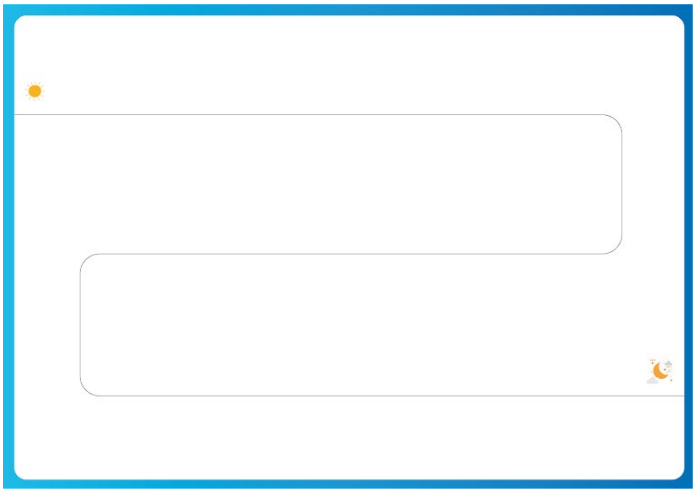


Figure 3.10 Revised version of the 'Daily Activity Journey' tool

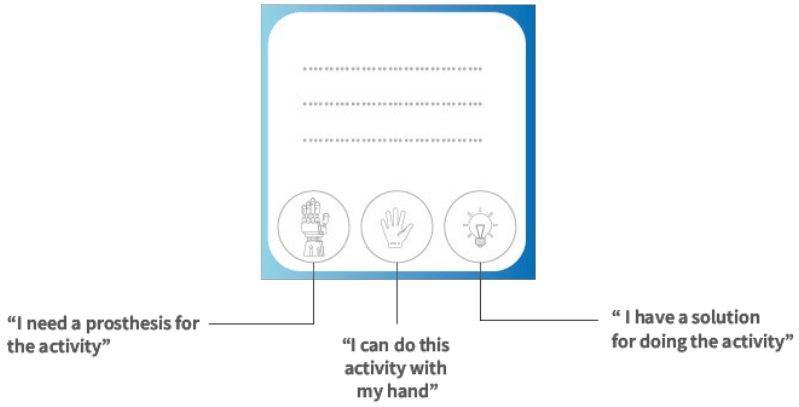


Figure 3.11 Cards of the 'Daily Activity Journey' tool

3D Printed Prosthesis Evaluation: The tools designed to understand the children's unmet needs were quite successful in the pilot session. The activity created an engaging and enjoyable evaluation for the participant. Therefore, no further improvement was implemented for this activity after the pilot session. A 5-point Likert-scale was decided to be used for children to rate their assistive devices for their daily needs.

Image Cards Sorting: The tool designed for eliciting expectations was not successful in facilitating the children's expressions. Therefore, the new tool was designed as a prosthesis image set to be sorted by the participant and a sorting sheet (see Figure 3.13). Different prosthesis images aim to initiate a discussion about children's expectations related to their prosthesis usage. Internet sourced prostheses images were devised from 3D printed prosthetic hand options in the market. These options were divided into five different categories: hand-like, hobby specific, futuristic, electronic, activity-specific. Two prosthesis images from each category were chosen by considering aspects including suitability to objectives of the study, the context

that prosthesis in and the clarity of the image. The image set was composed of ten images (Figure 3.14).

Figure 3.12 Sorting sheet

After comparing the images, the researcher asks questions to gather information related to children's expectations. Then, the stated expectation is written on a given card by the researcher. The activity aims to open discussions about children's expectations for prosthesis design while helping them to visualize their dream

prosthesis. Children are expected to classify these images into their 'likes' and 'dislikes' and encouraged to express what aspects they like or do not like.

Figure 3.13 Prosthesis image cards

Dream Prosthesis Map: This component aimed at prioritizing children's design expectations for the prosthesis that they expressed as their likes and dislikes. With this activity, the priorities and relations between expectations were utilized in the ideation phase. Dream Prosthesis Map included an A2-sized sheet of concentric circles with an illustration of the hand-prosthesis designed at their centre (Figure 3.15). The closest circle to the centre represented the children's most critical expectations; the outer circles gradually represented less important ones. The participant was expected to place the expectation cards on the map according to their priority.

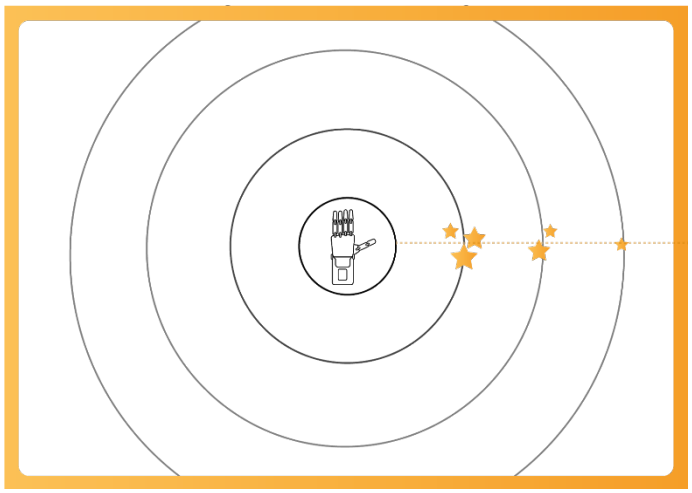


Figure 3.14 ‘Dream Prosthesis Map’ tool

Ideation Space: In the pilot study, a tool for generating ideas that may lead to achieving the desired prosthesis attributes from the children's point of view was missing. After the pilot study, it has been noticed that the toolkit has the potential to reach an outcome that reflects the children's needs and expectations. Therefore, the activity was designed to direct children to bring design solutions considering their needs, expectations, and dreams while conceptualizing their dream prosthesis in the 3D or 2D form (see Figure 3.16). The knowledge about past experiences and future dreams defined in the previous phases provides a general basis for the Ideation Space. To facilitate the ideation process, children are guided to complete sentences prepared by the researcher as an additional component for synthesizing the overall data. The additional component consists of sentences such as “I dream of a prosthesis that…”, “My dream prosthesis can…”, “My dream prosthesis helps me for…”. It is aimed to support children to think about significant aspects of their opinions they indicated in the previous activities. After completing sentences, the children were free to express themselves with the different tools in this activity: drawings, maps, models, stories, or collages. In this activity, additional tools such as image sets, or prototyping tool sets were added for eliminating possible struggles of participants

who have extreme upper limb deficiency struggle while using some materials (i.e., pencil, scissors)

Figure 3.15 ‘Ideation Space: My Dream Prosthesis’ tool

3.3 Procedure of the Study

Following procedure is followed during each co-design session carried out with children.

- At the start of the meeting, the child's companion is asked to fill in the consent form. (See Appendix B.)
- The session started with a short icebreaker activity, and the aim of the study is introduced.
- The tape-recording was started with the consent of the child.
- The child then was asked for her/his verbal consent for participating in the study and five activities (i.e., i) daily activity journey; ii) personal 3D-printed prosthesis evaluation; iii) image sorting cards; iv) dream prosthesis map; v) ideation space) that will take place in the session are explained briefly. The child is reminded that he/she is free to express himself/herself with different materials (e.g., drawings, collages, playdough).

- Then, 'Daily Activity Journey' activity started. Children are expected to mention their typical daily activities. After studying the Daily Activity Journey, children are asked to evaluate their 3D printed prosthetic hands on a Likert Scale '; they are then asked to state their reasons for the evaluation.
- Then, 'Image Cards Sorting' activity started. After studying the Image Sorting Cards, children are asked to sort them into their 'likes' and 'dislikes'; they are then asked to state their reasons for the likes/dislikes. This activity resulted in several expectation cards filled in with keywords by children. The intentions were to direct children to define their expectation for hand prosthesis, elicit design-relevant criteria while helping them visualize their dream prosthesis.
- Upon completing the first activity, the child is invited to indicate priorities within his/her proposed expectations by using the Dream Prosthesis Map.
- To the Ideation Space activity, children are expected to generate ideas regarding the needs and expectations they reflect on previous activities.

CHAPTER 4

RESULTS AND ANALYSIS OF THE FIELDWORK

4.1 Introduction

This chapter presents the overview of data analysis together with results and analysis of the fieldwork, followed by related discussions. Due to the differences in the toolkit components, the pilot session's outcomes were not included in the analysis of the main study. However, the second test session included in the analysis due to its help in gathering intended information.

4.2 Overview of the Fieldwork Analysis

The research aims to reveal both similar patterns and different aspects of children's needs and expectations to achieve assistive devices that answer children from different deficiency levels. Therefore, the overall data was analysed, considering these aspects in the children's responses. Although it was essential to adopt the generative design approach for facilitating children's expressions about their deficiency and providing them with different communication forms, the obtained knowledge from the co-design sessions was approached like interview data.

All data collected through the various components of 'Child's Prosthesis Co-design Toolkit' (i.e., Daily Activity Journey, 3D Prosthesis hand Evaluation, Image Sorting Cards, Dream Prosthesis Map, and Ideation Space) as detailed in Chapter 5 are content analysed. Twelve hours of audio files recorded during the sessions are

transcribed into a Microsoft Excel sheet by the researcher. The visual outcomes of the toolkit documented for each participant with images and related expressions. The categorising participants' expressions with related images of the outcomes were beneficial for making broad interpretations of the toolkit outcomes later.

Before the analysis start, two themes, need and expectations were revealed while designing the toolkit components according to the expected outcomes of the study. Daily Activity Journey and 3D Printed Prosthesis Hand Evaluation were designed to provide knowledge about children's physical difficulties in daily activities (needs), Image Cards Sorting and Dream Prosthesis Map were designed to obtain information about children's expectations for a dream prosthesis. Therefore, the overall data was analysed, considering the similar patterns and differences in the children's responses.

Analysis of the collected data divided into relevant paragraphs and meaningful phrasal were coded under four columns (Figure 4.1). The transcribed data were interpreted with the help of these columns and all statements were divided under these two heading and the codes were reconsidered and rearranged while new headings emerged during the analysis process.

Participant	Statement	Component	Tool	Sub-Themes	Themes	Interpretations
S01	**Ben iki parmak istemiyorum beş parmak istiyorum.** Çünkü bazen iki parmakla tutamam bazı şeyleri istediğim şeyleri tamam belki çanta tutabilirim ama o da bilmiyorum. **Beş parmak daha çok önemli. Bir şey tutmak önemli.** Bir şeyi yapmak istediğimde onu **daha çok kolay yapayım diye.**	Image Cards Sorting	Picture 7	Appearance Functionality	Expectation	Appearance is important criteria Easy to hold Multifunctionality
S01	Ve **hızlı yazmak** istiyorum.	Image Cards Sorting	Picture 7	Functionality	Expectation	Expressing difficulties of tool usage while answering questions
S01	**Çok değişik çünkü**. **Benim elimle bir farkı yok ki.** Yani ikisinin de bir farkı yok. Kendi elimle aynı yani. Ben şunu şurada anladım. Anahtar mesela ben kendi elimle de anahtar tutabiliyorum. **Elimle aynı**. Sonuçta orada yaptıklarımın ben evde de aynısını yaparım yani çok kolay olur. Anahtarı herkes tutar **ben bile iki elimle tutuyorum**. **O bir elle tutsa ne olacak ki.** Yani aslında şu şekil istiyorum. Orada aslında sadece bir şeyle tutuyor. İnsanlar normalde parmaklarıyla tutuyor ya ben sadece onu istiyorum. Sonuçta oradaki anahtarı tutuyor ama **nasıl tutuyor önemli**. Tuttuğum şey aynı.	Image Cards Sorting	Picture 8	Appearance Functionality	Expectation	Drawing attention in negative way People's thoughts What to carry is not important, how to carry is important
S01	Mesela oyun oynarken **ben iki elimi kullanıyorum** bir şeyleri fışkırtmak için **o sadece tek hareketle yapıyor** onu beğendim sadece. **Bir yandan birazcık tuhaf görünüyor onu beğenmedim. Sanki elinde silah varmış gibi hissediyorum.** Belki oyun oynarken kullanabilirdim.	Image Cards Sorting	Picture 9	Appearance Product Language	Expectation	product meaning not useful
	Aslında ben şunu istiyorum abla el yerine hem onun için hem de gereken şeyleri yapmak için kullanmak istiyorum. **Onu takayım onu çıkarayım onu yapayım bunu yapayım diye değil bir tane el olacak onu her şey için kullanacağım oyun oynadığımda da.**	Image Cards Sorting	Picture 9	Functionality	Expectation	Wearing constantly for both everyday activities and playing
S01	Çünkü topu tutabiliyor atabiliyor. Biz oyun oynadığımızda ben ben topu hızlı atamıyorum biraz yavaş atıyorum. **En azından böyle daha çok hızlı atarım.**	Image Cards Sorting	Picture 6	Sports	Needs	Playing with ball
	R- O zaman ne yazalım? S1- Top tutmak. **R- Top tutarken ne yapabilirsin mesela?** S1-Hızlı bir şekilde atmak.					

Figure 4.1 A screenshot extract from the transcript sheet during the content analysis

The code list under ‘expectation’ heading was analysed and subcategorised according to similar patterns. For example, the codes related to *usefulness* and *multifunctionality* of the prosthesis were categorised under the “functionality” that is located in the heading of “expectations” (Table 4.2). Lastly, the emerging categories and sub-categories were combined around explanatory categories under the main headings according to the relationship between them. For instance, categories of “Functionality”, “Usability”, “Durability”, and “Physical Comfort” were combined under the heading of “Pragmatic Expectations”. At the end of the coding, occurring themes and categorisation steps were repeated multiple times to see the data holistically and draw reliable conclusions. The fieldwork results showed that expectations of these children have similar patterns, and the needs of the children have differences from child to child according to different limb deficiency levels.

Table 3 Outcome of the Data Analysis

Themes and Sub-Themes		Categories and Sub-categories		
Prosthesis Expectations by Children	Pragmatic Expectations	Functionality	Usefulness	
			Multifunctionality	*Ability to make small, precise movements*
				Ability to grasp different kinds of objects
		Usability	Effectiveness	*Ability to keep objects without slipping*
			Ease of control	
			Adaptation need	
		Durability	Material Durability	*Frequency of need for repairs*
				Resistance to external factors
			Shape & Form	
		Physical Comfort	Comfort in use	*Not causing perspiration*
				Not causing pain and soreness
	Hedonic Expectations	Reliability		
		Aesthetic appeal		Colour
				Shape
				Material
		Other people's view		
		Hobby-specific		
		Age-appropriateness		

4.3 Results of the Fieldwork Analysis

Main headings were created with inductive coding (Thomas, 2006); after several rounds of data organization, sub-headings were created. The components of the 'Child's Prosthesis Co-design Toolkit' helped to analyse the below information:

1. *Daily Activity Journey* — provided information about children's daily needs for daily prosthesis use.*3D Prosthesis Hand Evaluation* — gave reflections

about the usage of 3D printed prosthetics and unmet needs of the children for prosthesis usage.

2. *Image Sorting Cards* — helped achieve prosthesis expectations of children.
3. *Dream Prosthesis Map* — provided insightful information about the priorities regarding the expectations of the children.
4. *Ideation Space* helped explore children's opinions related to prosthesis attributes that may fulfil their needs and expectations.

In addition to the intended outcome of the components, some of the activities gave insights about different aspects of prosthesis usage due to the discussion-opener nature of the tools. Therefore, the overall data is analysed collectively to reach holistic information, including similar patterns and differences in the collected information. The results present differences in the children's needs for daily prosthesis use, which also cause differences in children's reflections regarding 3D printed prosthetic hands. On the other hand, the results show similar patterns in expectations related to prosthesis qualities and children's priorities regarding these qualities. Deficiency differences of the children lead to the dissimilarity of the factors that affect prosthesis use child to child. To picture results comprehensively, different aspects and similar patterns in the responses of the children will be explained, respectively.

4.3.1 Children's Daily Prosthesis Needs

In this section, the information about children's daily prosthesis needs, obtained from the 'Daily Prosthesis Journey' activity, will be explained. The children's daily activity needs were constructed under the "daily needs" heading, which is related to the daily activities the children can perform or cannot perform without the prosthetic device. The statements of the children showed that daily needs differ according to

the deficiency. However, similar patterns of daily needs were categorized under four headings: daily activities, sports, hobbies, and mobility-related needs (Figure 4.2). Due to differences in daily needs, the results will be explained from each participant's perspective.

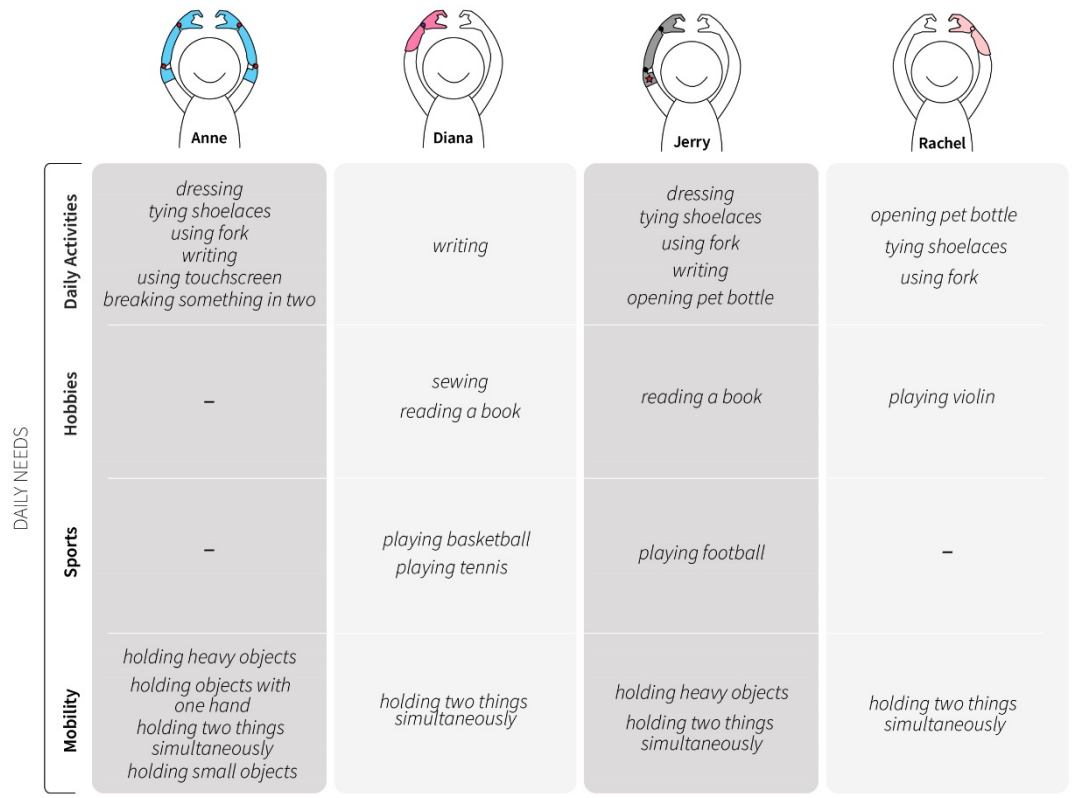


Figure 4.2 The prosthesis needs of the children

Anne (Two hand deficiency): In the morning, Anne changed her clothes and went to school without a prosthesis. She stated that she needs a prosthesis for activities in the school, such as opening zipper, tying shoelaces, writing, carrying two objects simultaneously. After she came home, she stated she plays games with her mother's phone, watches TV. She expressed she faces difficulties using the remote control, using the touchscreen. However, she had a method for using the touchscreen. She stated that she uses her tongue to touch the screen while holding the telephone with

her arms. She said her mother did not allow her to do household chores, but she could do it by herself. However, she stated that she encounters difficulties holding heavy objects and doing activities that needed two hands, such as breaking something in two. In the afternoon, she said she preferred reading a book or taking photos of her mother's telephone. She expressed that she could do these activities with her arms, but a prosthesis might help her hold a book comfortably (Figure 4.3).

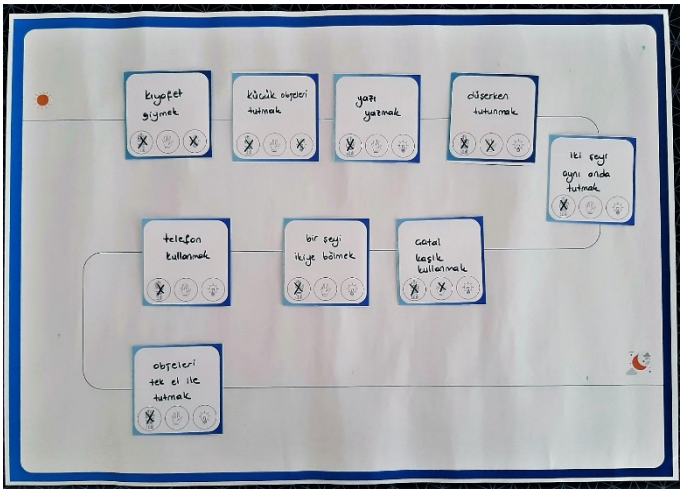


Figure 4.3 Anne's daily activity journey

> *"I hold the remote control with both hands, but I want to hold it with one hand. I also want to hold the glass with one hand. For example, if I buy something from the canteen, I want to go up the stairs like having a drink in one hand and food in another. Besides, I know a game that must be played with fingers, but I have to do it with two arms. Also, I hold the shampoo with my arms, but I want to hold it with one hand and squeeze it. I want to wear a necklace, but sometimes I can do it with my mouth."*

Also, she expressed that she needs to do activities faster:

> *"I want to write faster."*
>
> *"When we play the game, I cannot throw the ball fast, I throw it a little slow. At least I can throw faster."*

Consequently, she needs to use a prosthesis nearly in all daily activities such as food preparation and eating, dressing (e.g., zippers, buttons), hair styling, writing, personal hygiene. She especially needs a prosthesis for activities that require precise movements such as shoe tying, using a fork and holding objects with one hand. For most of the activities, she uses her two arms.

Diana (Right upper limb deficiency): Diana expressed that she could do most daily activities without difficulty. She mentioned that she encounters difficulties for the activities that require two hands; however, she said she developed some strategies to overcome these difficulties. She emphasized her need to use a prosthesis for playing games, doing sports such as tennis and basketball. Besides, holding two objects at the same time was also needed for using a prosthesis. In school, she had difficulties writing with her left hand since she was right-handed. While talking about her daily activities, she also mentioned her hobby for sewing, and she expressed her dream of being a fashion designer in the future. She said she had a method for sewing with one hand and needed a prosthesis for improving her skill (Figure 4.4). Also, she mentioned the need for having a second hand for her dream profession:

> *"I need a prosthesis for sewing. I want to be a designer."*

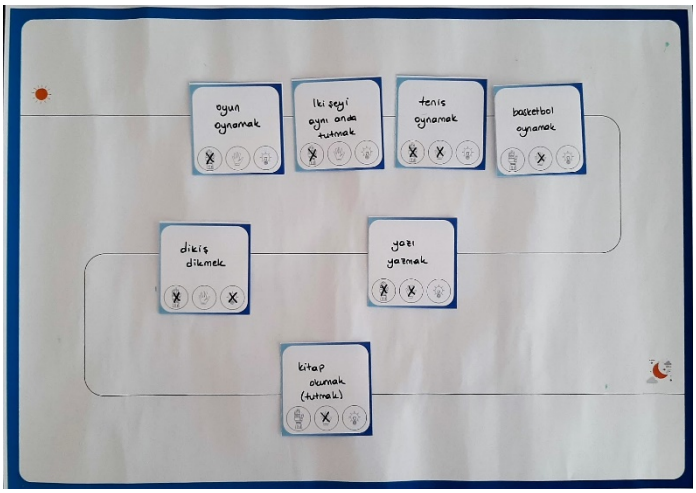


Figure 4.4 Diana's daily activity journey

Jerry (Left Upper limb deficiency): In the morning, Jerry said he struggles while changing his clothes and stated that he needs a prosthesis for this activity. According to his responses, he can write by himself without any struggle. However, he needed a prosthesis while playing football with his friends. As a goalkeeper, he said he has difficulties while catching the ball with his hands. Besides, he stated his need for opening a pet bottle in the school; he expressed he had a method for opening the bottle; however, he said it would be better if a prosthesis design could help him. Also, he said that he cannot tie his shoelaces in school. He stated that he asks his friends for help with tying his shoelaces. He said his arm did not limit him while eating, and he could use a fork without a struggle. Also, he expressed his struggles for performing these activities, playing games, holding heavy objects, and reading books (Figure 4.5).

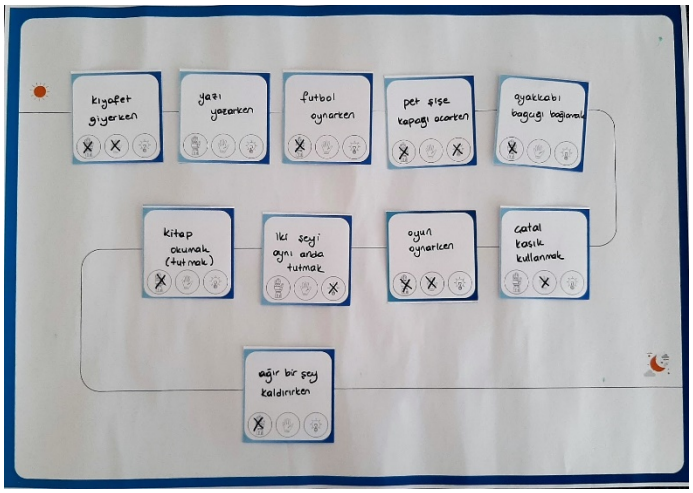


Figure 4.5 Jerry's daily activity journey

He expressed that his left arm's deficiency causes some difficulties while doing daily activities that require two hands.

> *" I need an assistive device while reading a book because I cannot hold the book. Prosthetics can help me while reading a book. I do not have a problem while changing my clothes. It is challenging for me to tie shoes; there are times when I need some help for him. My bag's shoulder straps are a bit narrow, the shoulder straps fall off, and sometimes I cannot hold them. When I hold a teapot, sometimes my hand shakes while doing this, and I cannot support it with my other hand."*

He also spoke of his need of a prosthesis while playing football:

> *"For example, I play football, my arm does not help me to take a throw-in, the ball slips between my arms, and I cannot throw it far. I need a prosthesis for this kind of situations."*

Rachel (Hand deficiency/ Right hand): Rachel expressed that she did not need a prosthesis for her daily activities. Therefore, she preferred mostly to write activities that she could do without prosthesis on given cards. She expressed that she developed strategies for doing almost every activity. To illustrate, she said she did not encounter any problem while eating, writing, and using a touchscreen (Figure 4.6). She showed

her solution for tying shoelaces, opening pet bottles, and holding two objects simultaneously.

> *" I can do anything. For example, when I take a glass and a plate, I can hold the plate like this, and glass, like this. I can use a fork spoon and even I have a way to using a knife while eating can tie my shoelaces with using spaces between my fingers."*

She expressed her dream of playing the violin, and she needs a prosthesis to make her dream come true.

> *“I don't need a prosthesis that much. I just want to use it for violin. "*

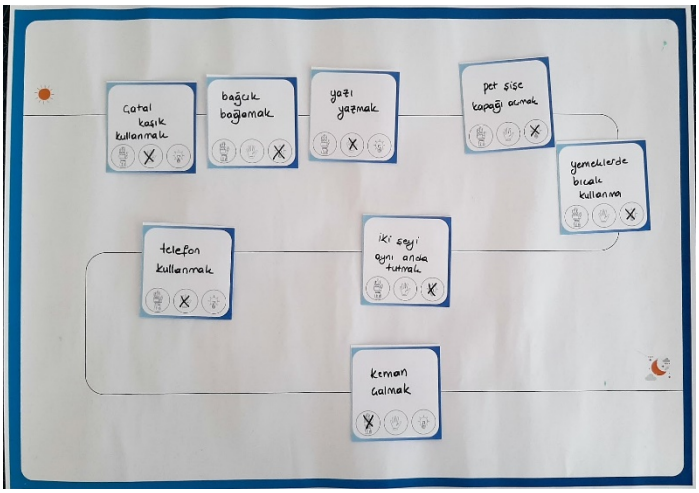


Figure 4.6 Rachel’s daily activity journey

4.3.2 Areas of Satisfaction and Dissatisfaction regarding the 3D Printed Prosthetic Hands

In this section, information about the evaluation of 3D printed prosthetic hands of children that are obtained from 3D Printed Prosthesis Evaluation activity will be explained. The current prosthesis of the children was assessed according to their performance regarding fulfilling the daily needs they mentioned in the previous

activity. The children expressed that 3D printed prosthetic hands provide both satisfaction and dissatisfaction for their daily usages. The evaluations of the children for 3D printed prosthetic devices differ from child to child due to differences in their deficiency level. Therefore, the evaluations will be explained for each of the four children, respectively.

Anne: Anne stated her physical needs for mostly 'daily activities' (i.e., dressing, writing, using a fork, using a touchscreen, opening pet bottle, and tying shoelaces) and needs for mobility (i.e., holding heavy objects, holding objects with one hand, holding two things simultaneously and holding small objects). However, these daily needs are rated with lower satisfaction levels in terms of being answered by 3D printed prosthetic hands. To illustrate, Anne stated that had difficulties holding small objects and making precise movements; however, she stated that her current prosthetic devices do not meet these daily usage needs. She expressed that her prosthetic hand enables her to hold two objects simultaneously and holding objects with one hand however she thinks that her prosthetic hands are not reliable for grasping. For writing and using a touchscreen, she prefers not to use the prosthetic hand due to it cause pain after a while (Figure 4.7).

Activity	😐	😐	😐	😀	😀
dressing	X				
tying shoelaces	X				
using a fork	X				
writing		X			
using touchscreen		X			
breaking something in two	X				
holding heavy objects	X				
holding objects with one hand			X		
holding two things simultaneously				X	
holding small objects	X				

Figure 4.7 Anne's 3D printed prosthetic hand evaluation

Diana: Diana has been using her 3D printed prosthetic hand for two years. She stated that her 3D printed prosthetic hand cannot enable her to make small precise movements to perform complex activities like sewing which is her hobby. Diana said that her prosthetic hand helped her to write. However, she stated that she prefers to write without the prosthetic device due to causing perspiration on her arm. For playing basketball, she thinks that it may help her while throwing a basket; however, she has concerns about the durability of the material for performing such activity. Also, she stated that due to the prosthetic device is not capable of holding heavy objects, it cannot help her for playing tennis. On the other hand, she said the prosthetic hand requires so much effort and it causes pain in her arm while performing activities such as reading a book and holding two objects simultaneously. (Figure 4.8).

Activity					
writing			X		
sewing	X				
reading a book				X	
playing basketball			X		
playing tennis		X			
holding two things simultaneously				X	

Figure 4.8 Diana's 3D printed prosthetic hand evaluation

Jerry: Jerry stated that his prosthesis does not help him for most of the daily activities. He stated that 3D printed prosthetic hand did not provide reliable experience for successfully performing the activities. He said he could not hold heavy objects with his current device and, he could not rely on the durability of the material. He expressed that he did not want to use his device for complex activities which require effort. Also, he said that while changing his clothes, writing, and opening a pet bottle, his prosthetic hand did not help him. He expressed his prosthetic hand could help him read a book and use a fork; however, he said the weight of the device cause pain after a while. He also stated that his prosthetic device could hold a pen; however, he said stabilizing the pencil while writing requires constantly bend his elbow (Figure 4.9).

> *"Thanks really, these prosthetic devices help us psychologically, they made us happy for a while. It is good to have a memory like that. However, technology needs to improve to achieve better solutions. Due to elbow movement cause pain, it would be better if it works with mind power."*

Also, Jerry expressed his love for football as a goalkeeper. However, according to Jerry, his 3D prosthetic device cannot support him while playing football. His prosthetic device could not keep objects without slipping.

Activity					
dressing	X				
tying shoelaces	X				
using a fork			X		
writing		X			
opening pet bottle	X				
reading a book				X	
playing football	X				
holding heavy objects	X				
holding two things simultaneously		X			

Figure 4.9 Jerry's 3D Printed prosthetic hand evaluation

Rachel: Rachel stated that she did not use her 3D printed prosthetic hand anymore. She expressed that her current prosthetic device did not assist her in eating, tying shoelaces, and using a touchscreen. She expressed that the 3D printed prosthetic hand only helps her to hold two objects at the same time however she prefers to ask for help from family members rather than using her prosthetic hand. She stated that she can open a pet bottle while holding it with the help of her prosthetic device (Figure 4.10).

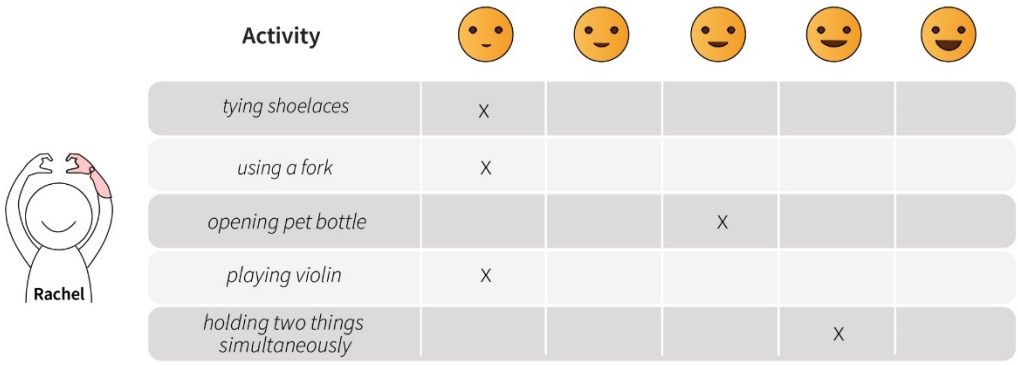


Figure 4.10 Rachel's 3D printed prosthetic hand evaluation

4.3.3 Expectations of Children for the Prosthesis Use

Anne: Anne did not like the futuristic concepts of prosthesis design. She expressed that "They look weird and they are not useful." She said that she liked other prosthesis designs, due to their aesthetic appeal, high functionality, and natural appearance (Figure 4.11).

Figure 4.11 Anne's card sorting sheet

Diana: Diana liked most of the prostheses' visuals except the futuristic concepts. She stated that these prostheses look weird, and she would not wear them. She liked the

hobby-specific prostheses without concerning what the hobby is. She expressed that prostheses for specific functions (i.e., playing basketball, playing the violin, spraying) might help her participate in social activities, events, and competitions. She stated that she liked the prostheses with a natural appearance; however, high functionality was a more important criterion for her when sorting the images (Figure 4.12).

Figure 4.12 Diana's card sorting sheet

Jerry: Jerry expressed that he wanted a prosthesis to be simple in terms of both appearance and function (Figure 4.13). He said he could not rely on the durability of all the prostheses images. The durability of the material was an essential criterion while evaluating the prostheses. On the other hand, he expressed that function-specific prostheses might help him with his hobbies. To illustrate, he stated that he could use the prosthesis with spray for doing graffiti. Also, he stated that he loves prostheses with futuristic concepts and his friends would also love it.

Figure 4.13 Jerry's card sorting sheet

Rachel: While sorting the prosthesis image cards according to her likes and dislikes, Rachel emphasized the prostheses' aesthetic appeal. She expressed that she wanted her prosthesis to draw attention. To illustrate, she stated that she would like to wear a futuristic prosthesis design and her friends would love it also. Having a natural appearance (not showing wires and cables, colour, material) was not enough for Rachel, it should also have high functionality (i.e., the ability to make small precise movements, ability to hold different kinds of objects) (Figure 4.14).

Figure 4.14 Rachel's card sorting sheet

The results of the fieldwork revealed the factors that affect assistive device usage of the children. The commons patterns in overall data which is gathered with the 'Image Cards Sorting' activity, helped to achieve generalizable information related to the prosthesis expectation of the children. As a result of the analysis, these expectations suggested by children divided into two categories: i) pragmatic expectations, which represent the attributes of the prosthesis from children's perspective, and ii) hedonic expectations, which stands for social dimensions affecting their expectations of the prosthesis (Figure 4.15). A detailed explanation of each category will be presented in the next section.

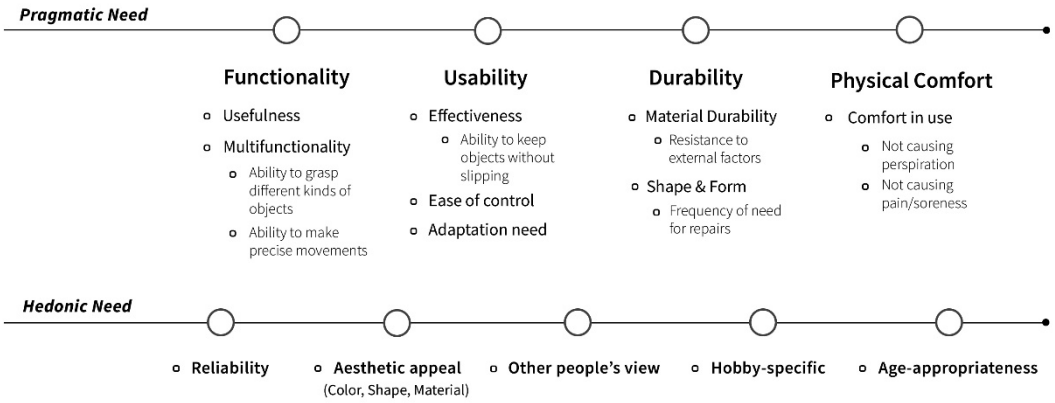


Figure 4.15 Pragmatic and hedonic expectations of children regarding the prosthesis design

4.3.3.1 Pragmatic Expectations Regarding the Design of Hand Prosthesis

According to results of the study the pragmatic expectations of the children are divided into four sub-headings: a) functionality, b) usability, c) durability, and d) physical comfort. Each of them will be explained now in detail.

a. Functionality

'Functionality' heading was constructed on the two subheadings: usefulness and multifunctionality.

‘Usefulness’ is one of the most stated expectation of the functionality. Children expect a prosthesis to being useful for daily activities. Rachel also expressed the importance of functionality of her prosthesis usage in the following statement:

> *“Usefulness is so important, after all, if it is not useful, I would not use the prosthesis.”*

‘Multifunctionality’ which refers to using the prosthesis for different activities certainly increases the prosthesis's daily usage was highlighted by all of the children. The children mentioned two dimensions related to the multifunctionality of the prosthesis; the ability to grasp different objects and the ability to make precise movements. The ability to grasp different kinds of objects (small, soft, heavy) is associated with using the prosthesis for different activities. For instance, Anne explained her expectation regarding doing different activities with her dream prosthesis as:

> *"I want hands that help me for different activities. There will be one hand that enables me to hold everything on and do everything."*

The participants expressed that they face difficulties while making precise movements with their 3D printed prosthetic hands. It is associated with usability in

terms of ease of control and the ability to stabilize objects. For example, Diana commented on a prosthesis visual, which holds an egg (Figure 4.16):

Figure 4.16 Diana's comments on the prosthesis image

Likewise, Jerry stated the difficulty with making precise movements while tying his shoes:

> *"I want to tie shoelaces, but I cannot do it myself. The prosthesis should help me with this, but my current prosthetic hand could not let me make this kind of small and precise movements. Especially in school, I need an assistive device for this".*

b. Usability

Children's expectations in relation to usability can be studied in relation to three aspects; effectiveness, ease of control and adaptation need. Especially, 'effectiveness' is one of the most stated expectations by the children. All of the children expressed their concerns related to the reliability of the prosthesis while stabilizing an object. The ability to keep objects without slipping' is also associated with this expectation. To illustrate, Anne reflects her concerns for her 3D printed prosthetic hand as:

> *""The 3D printed prosthetic device you gave us, slips while holding something, but maybe this one would not slip. If I could hold something tight, I might feel comfortable. While holding something, I want to hold without worrying. For example, my mother bought me something. I was holding it but I was wondering if it would fall or if I could hold it. "*

'Ease for control' was commonly stated in the participants' statements for representing the physical effort needed while performing an activity. According to the results, the current prosthetic devices of the children required constant effort while grasping objects, therefore, it causes pain on muscles after a while. For instance, Diana expressed the difficulty she has encountered during her 3D prosthetic hand as:

> *"I cannot bend my wrist while wearing my prosthesis anymore. Although I have almost never used the prosthetic, these threads became old, and the palm part started to hurt. When I use it a little bit, my arm becomes red because it hurts. "*

Similarly, Rachel stated her expectation about the 'ease for control' while giving an example of her current 3D printed prosthetic arm:

> *"It should be closed with a minimum effort. Normally you have to bend your elbow too much and it cause pain."*

c. Durability

According to the children, 'durability' refers to long-term usage of the prosthesis. And the durability of the prosthesis strongly connected with reliability. In that sense, the durability was constructed on two dimensions, material durability and shape and form. According to the children, shape and form is essential to consider for achieving

a durable prosthesis. To illustrate, Jerry evaluates the durability of the prosthesis image considering its shape and form (Figure 4.17):

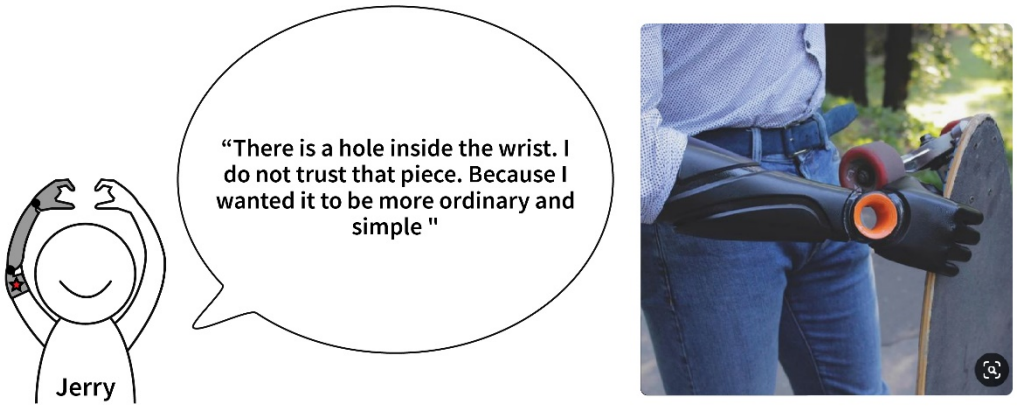


Figure 4.17 Jerry’s comments on the prosthesis image

Material durability is another common stated expectation. While talking about a prosthesis, Diana showed us her old prosthetic hand:

> *"I did not use it much, but these strings were corroded. It was working, but now it is not.”*

On the other hand, external factors cause the need for frequent repairs. The participants' responses indicate the need for frequent repairing cause frustration and negatively affect the motivation of children for prosthesis usage. To illustrate, Jerry stated these are the reasons behind his dissatisfaction regarding his prosthetic device:

> *"The reason why I do not use my 3D printed prosthetic hand is that it breaks down easily and those strings can break off easily. It requires frequent repair, and I am so bored with this. In the end, I will ask permission from you to print the prosthetic hand myself. "*

d. Physical Comfort

Another expectation mentioned by children is 'physical comfort'. In this context, comfort is used for the prosthesis' physical attribute and in contrast to discomfort.

All four children mentioned their current prosthetic hands with feelings of discomfort, which is mainly refers to pain, soreness, and numbness. Diana reflected the expectation ‘comfort in use’ of the prosthesis while explaining her 3D printed prosthetic hand cause pain in her arm:

> *"It hurts my arm when I use it too much. If it does not hurt, I would always wear it."*

The children also expressed the difficulties related to perspiration while wearing a prosthesis hand.

> *"I do not want my arm to sweat inside the prosthesis. It would be better not to sweat. "*

4.3.3.2 Hedonic Expectations of Children Regarding the Design of Hand Prosthesis

Hedonic expectations heading developed from five different aspects of experience from the children's perspective: reliability, aesthetic appeal, other people’s view, hobby-specific, age-appropriateness.

a. Reliability

‘Reliability’ is the most mentioned hedonic expectation of the children. It also has strongly connected with two pragmatic expectations which include usability and durability. Children tend to evaluate the prosthesis with attributes for durability related dimensions which are material durability and durability of shape and form. Also, they mostly put a value on attributes of ease of control, ability to make precise movements and ability to stabilize objects without slipping. To illustrate Jerry stated their concern about relying on the prosthesis (Figure 4.18):

Figure 4.18 Jerry’s comments on the prosthesis image

b. Aesthetic Appeal

All of the children have hedonic expectations, including reliability, aesthetic appeal, other people’s view, hobby-specific, age appropriateness. Prosthesis design attributes that fulfil these hedonic expectations are different from child to child. To illustrate, the ‘aesthetic appeal’ refers to their design preferences regarding their personal taste. In this example, Anne and Rachel expressed their opinions on the same prosthesis visual (Figure 4.19).

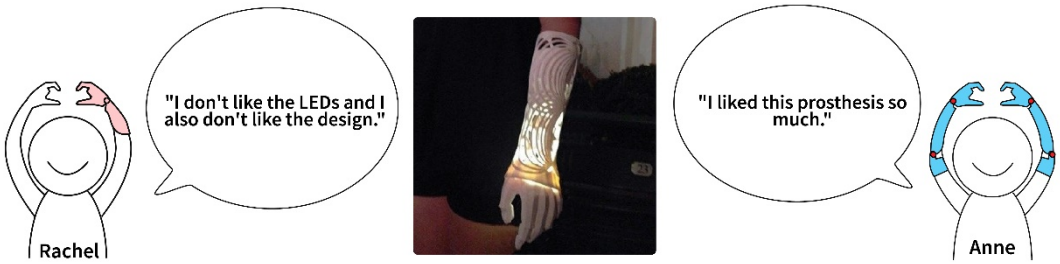


Figure 4.19 Rachel and Anne’s comments on the prosthesis image

For the prosthesis's aesthetic appeal, having a natural appearance is mostly preferred compared to other prosthesis types from children's views. Also, Diana and Anne associated natural appearance with functionality. Also, colour is an important

expectation that affects the children's preferences about the prosthesis. Diana stated that natural-coloured prostheses are more attractive for her (Figure 4.20).

Figure 4.20 Diana's comments on the prosthesis image

On the other hand, different designs attract children's attention as well as life-like prostheses. To illustrate, Rachel explains why she like the prosthesis on the visuals in Figure 4.21.

Figure 4.21 Rachel's comments on the prosthesis image

c. Other People's Views

According to the results, the children's preferences regarding prosthesis design are affected by other people's views. 'The other people' refers to a family member or friends and acquaintance. The children stated different opinions related to drawing attention to their prosthesis, and they all expressed their concerns about other people's opinions for their prosthetic devices.

> *Rachel: "It has to be cool. When I show it to my friends, they should say "wow!".*
>
> *Anne: "When someone looks at my hands or me, I like it very much. Not to my own hands, but my prosthetic hands. I do not like it when they look at my own hands, but when they look at the prosthesis and say, "oh so beautiful", I am pleased."*
>
> *Jerry: "It would bother me that if my prosthesis draws attention."*

d. Hobby-Specific

Prostheses, which are designed for a specific hobby, increase children's motivation for using a prosthesis. The results of this study showed that hobby-specific prostheses, whether it is the child's hobby or not, are considered usable, functional, and attractive by the children. Diana mentioned her view on the possible social

advantages of hobby specific prostheses as illustrated in Figure 4.22.

Figure 4.22 Diana's comments on the prosthesis image

Diana emphasized her hobby-specific expectation while talking about a prosthesis design for playing basketball (Figure 4.23).

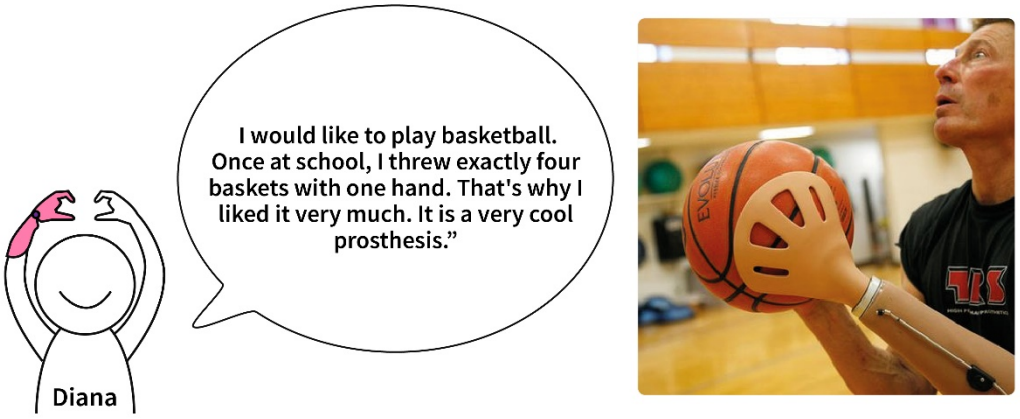


Figure 4.23 Diana's comments on the prosthesis image

Jerry talked about his hobby of e-games, while evaluating a prosthesis design (see Figure 4.24):

Figure 4.24 Jerry's comments on the prosthesis image

Rachel also stated her admiration for the woman who plays a violin with an assistive device, with following words:

> *"Some people are not interested in starting any hobbies due to their physical deficiency. But I think this woman does not limit herself with her physical disability; although she has arm deficiency, she can play an instrument. This is so important. If it enables me to start a new hobby, it would not be important the prosthesis helps me in daily activities or not."*

e. Age-Appropriateness

Some of the children tended to evaluate the prosthesis images according to the prosthesis appropriateness to their age. The 'age-appropriateness' has a strong connection with other people's views and aesthetic appeal. Some children may appreciate the design language for children; however, it also may be viewed as 'for

kids. To illustrate, Rachel expressed her opinion about the activity-specific prosthesis's appropriateness to her age, as shown in Figure 4.25.

Figure 4.25 Rachel's comments on the prosthesis image

4.3.4 Children's Priority Expectation for the Prosthesis

Anne: According to Anne, usability is the most important dimension that a dream prosthesis should have. While evaluating prosthesis images, she mostly emphasizes the expectations for ease of control and holding objects without slipping. Also, she wanted to wear a prosthesis constantly; therefore, it should be useful for performing different activities. Also, durability is one of the most important dimensions that Anne expects from a prosthesis. Her expectation for 'hobby specific' (playing the violin, playing sports, and creating aesthetic appeal placed on the outer circle represent the least important expectations (Figure 4.26).

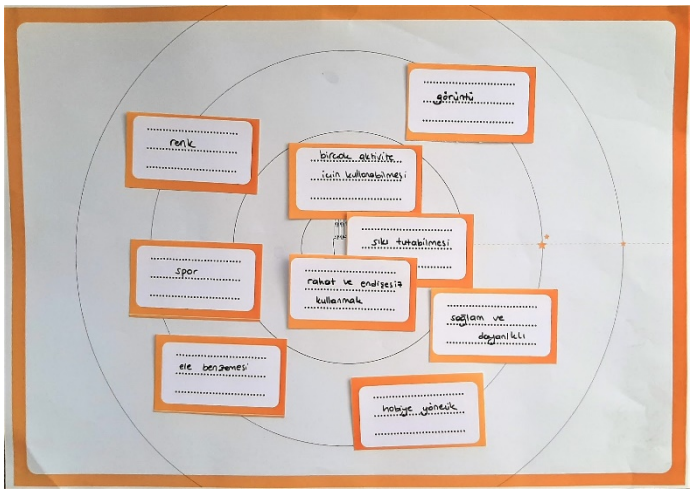


Figure 4.26 Anne's dream prosthesis map

Diana: Diana had difficulty while sorting her expectations. She stated that all of them are so significant for her. Therefore, she placed all of her expectation cards such as ease of control, multifunctionality, hobby-specific, the durability of the material, ability to hold different kinds of objects, aesthetic appeal, not causing perspiration were placed on the inner circle, which represented the most important dimensions that a dream prosthesis should have (Figure 4.27).

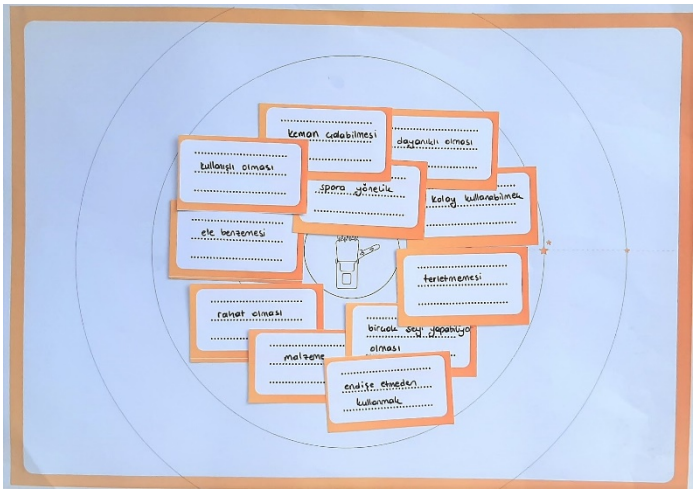


Figure 4.27 Diana's dream prosthesis map

Jerry: According to Jerry, expectations for reliability, aesthetic appeal, hobby specific, resistance to external factors were the most important dimensions for his dream prosthesis. Easy to control, effectiveness and durability of the material were the second priority for Jerry. Using for different activities and natural appearance was placed on the outer circle, representing the least important dimensions for Jerry (Figure 4.28).

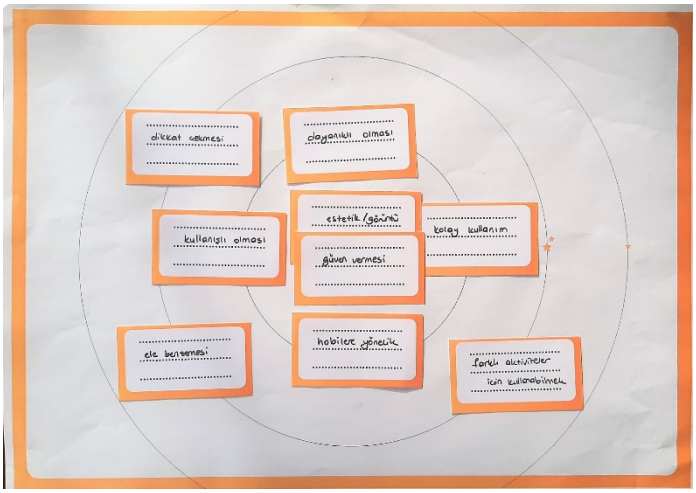


Figure 4.28 Jerry's dream prosthesis map

Rachel: According to Rachel, the aesthetic appeal was the most important expectations that a dream prosthesis should have. She stated that it should be 'cool' and positively draw attention. The expectations for multifunctionality, the ease of control, and the ability to make small precise movements were essential in a dream prosthesis. Material, age appropriateness, hobby specific and colour were the least important dimensions for her (Figure 4.29).

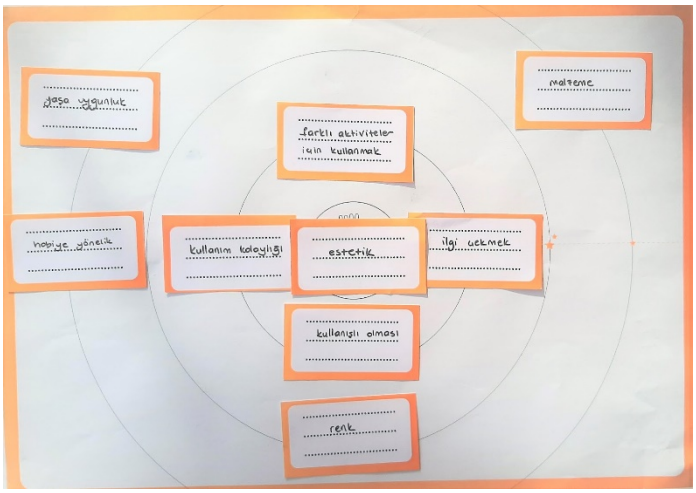


Figure 4.29 Rachel's dream prosthesis map

4.3.5 Relations between Children's Pragmatic and Hedonic Expectations for the Prosthesis

According to Hassenzahl (2008), product experience can be described with pragmatic (goal-oriented) quality and hedonic (self-oriented) quality. This approach underlines the notion that overall experience should be evaluated using both pragmatic and hedonic qualities. In this study, the results of the fieldwork highlight the connection between pragmatic and hedonic expectations mentioned by the children. In other words, some dimensions of the pragmatic expectations including functionality, usability, durability, and physical comfort found to be strongly interconnected with hedonic expectations. The connections between the above-mentioned expectations helped to uncover three essential aspects of prosthesis usage for children: a) positive experience through the reliability of the prosthesis; b) self-improvement through the functionality of the prosthesis; c) social integration through the appearance of the prosthesis (see Figure 4.30).

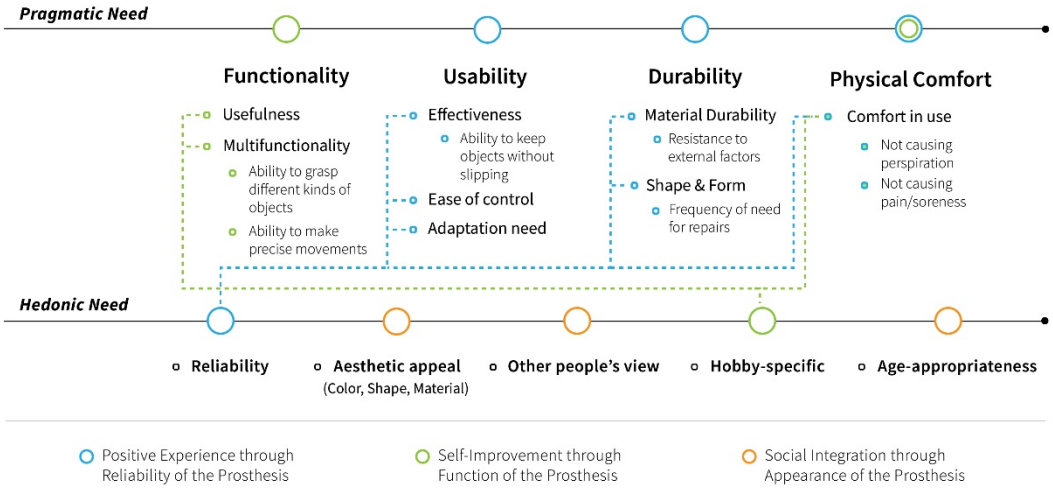


Figure 4.30 Interconnections between pragmatic and hedonic needs of the children

- **Positive Experience through Reliability of the Prosthesis**

Relying on prosthesis while performing an activity is the most highlighted expectation by the children. Reliability also has interrelations with the pragmatic expectations in terms of usability and durability of the prosthesis. The qualities that contribute to the reliable experience of prosthesis usage are the ability to keep objects without slipping, ease of control, material durability, resistance to external factors, and frequency of need for repairs. This relation shows the general concern of the children in terms of the reliability of the prosthesis. If such expectations are fulfilled, the prosthesis can be used with positive emotions rather than worrying about its performance.

- **Self-Improvement through Functionality of the Prosthesis**

The fieldwork study also showed that children's daily needs differ from child to child according to their deficiency level. Therefore, personalized, hobby-specific assistive devices are preferred by children rather than offering them prosthetic devices with limited functions. The functionality-related dimensions; usefulness,

multifunctionality, ability to make precise movements, and ability to grasp different kinds of objects, are highlighted with their strong connection with the expectations for hobby-specific prostheses. According to children's statements, the prosthesis should be able to make precise movements and grasp different kinds of objects in order to be hobby specific. These relations revealed the potential of prosthetic devices for enabling children to improve their skills and engaging social activities. Therefore, fulfilling this expectation may support children to engage in self-actualizing experiences by giving them a chance to achieve their personal hobbies and goals.

- **Social Integration through Appearance of the Prosthesis**

The concern for the other people's views about the prosthesis has a strong connection with the expectation for the aesthetic appeal and the age-appropriateness in supporting the social integration of children with upper limb deficiency. The aesthetics-related dimensions strongly affected by the views of other people. The results revealed that the children have expectations for a prosthesis to represent their self-image and enable them to be socialized with friends or acquaintances through the aesthetic properties. This shows the potential for supporting children's social integration by getting accepted by the community.

4.3.6 Dream Prostheses of the Children

Anne: Anne preferred to make a collage for generating ideas for her dream prosthesis (Figure 4.31). She asked the researcher to cut the selected images. She wanted her prosthesis to have a natural appearance with high functionality. She also expressed that "I dream of a prosthesis that holds every object without slipping."

Figure 4.31 Anne's ideation space

Diana: Diana drew her dream prosthesis with different colours (Figure 4.32). She stated that she wanted her prosthesis, not showing wires and cables and there should be more space between fingers for easy grasping.

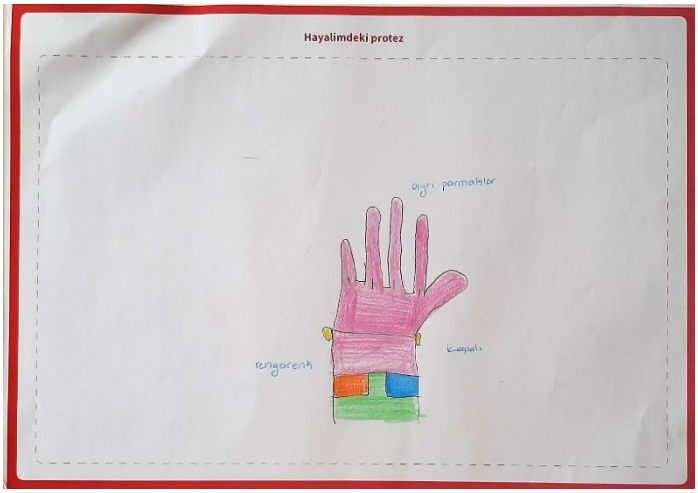


Figure 4.32 Diana's ideation space

Jerry: While generating ideas, Jerry limited himself to the features of 3D printed prosthetic devices (Figure 4.33). When he was asked to think broadly and not restrict himself with his current prosthetic device, he generated the idea of a prosthesis with

resistance to external factors and waterproof for durability and colour-changing and being electronic for drawing attention.

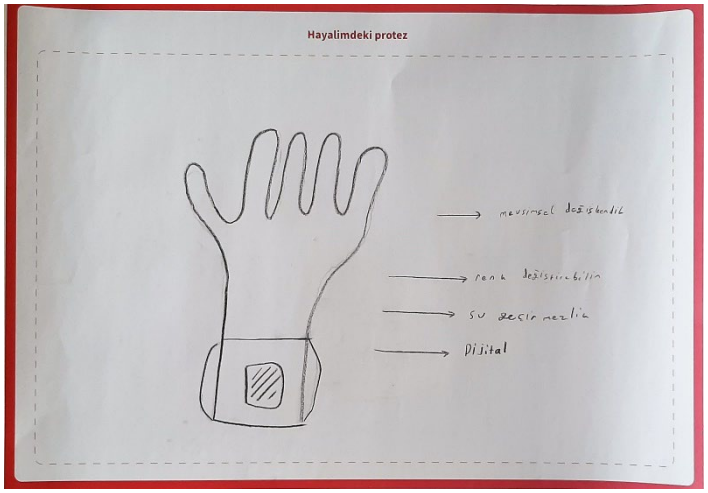


Figure 4.33 Jerry's ideation space

Rachel: Rachel expressed that she did not need a prosthesis for daily usage. The only activity that she needed a prosthesis was playing the violin. She would like to play the violin; however, she could not do it due to her deficiency. Therefore, she wanted to design an assistive device for playing the violin in the ideation space activity. However, she started drawing to generate ideas to present better the concept in 3d form with playdough. Finally, she designed a wrist band that has a place for a bow (Figure 4.34).

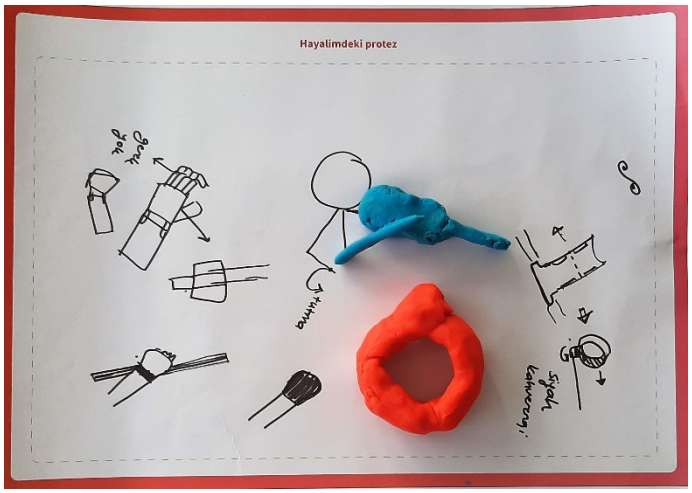


Figure 4.34 Rachel's ideation space

The results of the fieldwork were presented with differences and common patterns of the gathered data from different components of the Child's Prosthesis Co-Design Toolkit. In the next chapter, a guideline for implementing the toolkit will be described.

CHAPTER 5

A GUIDELINE FOR USING THE 'CHILD'S PROSTHESIS CO-DESIGN TOOLKIT'

Based on the results of the fieldwork which are presented in Chapter 6, a guideline for implementing the 'Child Prosthesis Co-Design Toolkit' is devised. In this chapter, the procedure that is followed while performing co-design sessions will be presented. The chapter will focus on important aspects of preparing the toolkit and organizing co-design sessions with the toolkit.

5.1 Aim of Child's Prosthesis Co-design Toolkit

The co-design sessions aim to investigate children's needs and expectations by guiding them to experience generative design activities and letting them express their opinions related to prosthesis usage in order to provide design-relevant data for further developments.

To achieve the aim of the study, the co-design toolkit which consists of five components is designed (Figure 5.1). The toolkit is expected to be utilised by design practitioners, researchers or NGOs who work with children with limb deficiency (see Appendix A). In the following section, organizing the generative design tools in the toolkit will be discussed, and then the guideline for implementing the co-design sessions will be presented.

Figure 5.1 The 'Child's Prosthesis Co-design Toolkit'

5.2 Planning and Organizing the Co-design Toolkit

By considering the sensitivity for expressing physical needs for an assistive device, the toolkit aims to facilitate children's expressions for physical needs, frustrations, expectations, and dreams regarding prosthesis usage. However, the toolkit can be integrated and reinterpreted to understand children's perspective by diving into children's daily lives, hearing their opinions, and giving them a chance to influence the design decisions on products they use. In the next section, aspects that should be taken into consideration for implementing the toolkit in different contexts will be presented with guidelines to organizing the components, preparing the data collection materials, and selecting stationary materials.

5.2.1 Selecting and Organizing Components of the Toolkit

‘Child’s Prosthesis Co-design Toolkit’ has gone a design iteration to achieve intended knowledge from the co-design sessions. It is composed of five components

that are includes generative design tools that are specifically designed for working with children (Figure 5.2).

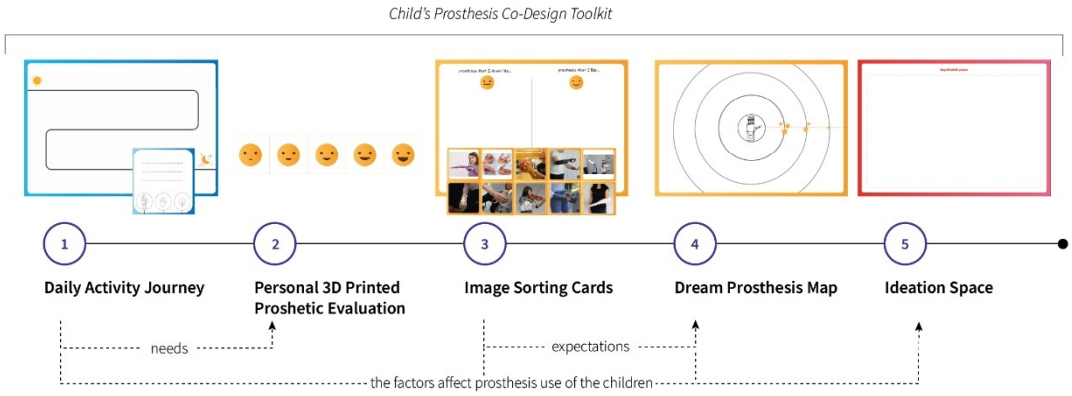


Figure 5.2 The components of the 'Child's Prosthesis Co-design Toolkit'

The components of the toolkit were designed and organized according to an order which was devised from the intended outcomes of the sessions. The outcomes of the first activity 'Daily Activity Journey' are designed to be utilized in the second activity '3D Printed Hand Evaluation'. In the first activity, children's daily needs are aimed to explore and in the second activity, children's current prosthetic hands are investigated whether they answer these daily needs or not. Therefore, these two components should be implemented in that order. Similarly, the third component 'Image Cards Sorting' is designed to provide information about children's expectations related to prosthesis usage and the fourth component 'Dream Prosthesis Map' is designed to explore their priorities these expectations. As a result, these components also should be applied in this sequence. The last activity, 'Ideation Space' is designed to exploring the prosthesis attributes that they want their dream prosthesis to have. While performing this activity, children are expected to reflect their needs and expectations which aimed to gather in the previous activities. Therefore, this component is the last activity of the co-design session.

The aspects should be considered while organizing the components in the co-design toolkit. If the evaluation of the current product experience is out of the scope, the second activity can be excluded from the toolkit. According to the intended knowledge of fieldwork, the other components can also be reinterpreted or removed.

Additional components may be devised in order to facilitate the conceptualizing process of Ideation Space by guiding children to assign the prosthesis to their needs and expectations. Drawing children's attention, encouraging them to participate in the activity and the capabilities of the children should be considered while designing the tools for these additional components.

5.2.2 Preparing the Data Collection Materials

The data collection materials in the toolkit show a great promise for collecting valuable insights from the children with upper limb deficiency while co-designing assistive devices for them. Each component of the toolkit has positive outcomes for achieving the objectives of these components (Table 5.1). Also, there are certain aspects that designers or researchers should consider while integrating these components of the 'Child Prosthesis Co-design Toolkit' into their processes. The toolkit can be used for collecting data from children with other limb deficiencies. Considerations for implementing or reinterpreting each component is presented below.

Tablo 5.1 Positive Outcomes and Considerations of the Tools in the Co-design Toolkit

Tools	Positive Outcomes	Considerations
Daily Activity Journey	• Encouraging children to express physical difficulties and initiating discussions about daily needs	• Openning discussion about activities in a normal day • Starting asking about activities they can do, then asked for are there any activities the participant need a prosthesis • Adding additional tools as trigger and reminder (e.g., daily activity images or word cards)
3D Printed Prosthetic Hand Evaluation	• Giving them chance to express their opinions with sense of empowerment	• Hesitating talking about the difficulties about their 3D printed prosthetic hands due to the researcher's role in the NGO provided these devices
Image Cards Sorting	• Opening discussions about expectations and dreams • Getting opinions and feelings of participants about unknown and unused products	• Selecting proper prosthesis images with the consideration of the context which the prosthesis in
Dream Prosthesis Map	• Opening discussions • The role of research partner • Visualizing dream prosthesis according to children's opinions	• Asking recheck questions to understand better • Making them feel its their space to play and reflect themselves • Age differences in cognitive developments
Ideation Space	• Producing a artefact at the end of the session • Ease to describe their needs and wants • Sense of empowerment	• Limiting themselves with attributes of their current prosthetic hands • Providing children different ways they can express themselves

Daily Activity Journey. The tool composed of a sheet with a timeline and daily activity cards. The component is designed for eliciting children's daily needs regarding prosthesis use. Children are expected to mention their daily activities starting from the morning to the night. While preparing the tools of the activity it is essential to consider it may hard to talk about the physical difficulties of the children face during daily activities. Therefore, giving participants a chance to express their capabilities and achievements is used as a strategy for this activity. As a result, the daily activity cards are designed with three icons which represent i) "the activities I can do", ii)"the activities that I need a prosthesis for" and iii) "the activities I have a solution for doing it". Additional elements may be added to the tool (i.e., daily activity images or word cards) as a reminder of the daily activities of the participant.

3D Printed Prosthetic Hand Evaluation. Five-point Likert Scale is used to elicit children's opinions regarding the 3D printed prosthetic hand usage. Children are asked to rank their current prosthetic devices for performing daily activities mentioned in the previous activity. Hall, Hume, & Tazzyman (2016), states that children tend to give positive rankings rather than negative ones. In order to achieve more distributed ratings, five-point scale from "slightly happy" to "very happy" was preferred. This tool can also be used for understanding importance level of other aspects of assistive devices from children's perspective with this consideration. In order to eliminate hesitations for evaluating the prosthesis, children should be reminded the objectives of the study for improving current assistive devices.

Image Cards Sorting. The component is composed of an image set, expectation cards and a sorting sheet. In this activity, children are asked to sort prosthesis images according to their likes and dislikes. Firstly, the image set is devised from the Internet by examining the 3D printed prosthetic hand options in the market. The options divided into five categories: i) hand-like ii) futuristic iii) electronic iv) hobby-specific v) activity-specific. In order to categorize the options, a mind map (Buzan

and Buzan, 2000) related to the focus of the study be made. While choosing the images, the researcher should consider the context. For each category, it is important to choose two images that one of them shows the context of use and others not directly refer to the context. In that sense, the image set should be consisting of diverse images that show both the usage context and the product itself.

The sorting sheet is designed for providing children with a space for categorizing the prosthesis images according to their 'likes' and 'dislikes'. This activity aims to open discussions related to children's prosthesis expectations. Expectation cards are designed to write the stated expectation and move the information to the next component of the toolkit.

Dream Prosthesis Map. The component includes a sorting sheet which aimed at prioritizing children's expectations regarding prosthesis usage that they expressed in the previous activity. Dream Prosthesis Map included an A2-sized sheet of concentric circles with an illustration of the hand-prosthesis designed at their centre. The closest circle to the centre represented the most critical expectations for the children; the outer circles gradually represented less important ones. The participant is expected to place the expectation cards on the map according to their priority. The sheet is designed as three concentric circles for enabling children to make associations with the closeness of the circles to the dream prosthesis. The number of circles can be increased according to the scope of the research. In this study, three levels were reasonable to understand the priority expectations of the children.

Ideation Space. This component has a sheet for generating ideas on it and 'completing statements' cards as an additional tool for easing the process. Children are guided to complete sentences prepared by the researcher for synthesizing the overall data. The cards consist of sentences such as "I dream of a prosthesis that…", "My dream prosthesis can…", "My dream prosthesis helps me for…". It is aimed to

support children to think about significant aspects of their opinions they indicated in the previous activities. Statements that are given to children can be diversified according to the aim of the study. The researchers should consider that the statements should provide children with an outline of their needs and expectations before generating ideas. After completing sentences, the children were free to express themselves with the different tools in this activity: drawings, maps, models, stories, or collages. The children may find it hard to generate ideas, and they may limit themselves with the attributes of their current prosthetic devices; therefore, the researcher should direct the participant to think outside of the box and should explain that they should focus on what they want from a prosthesis and how can a prosthesis do it for you. When participant still struggles in the ideation phase, different kinds of prostheses images in the collage set (i.e., body-powered, electronic, activity-specific) can be shown and guide them to make collages of their dream prosthesis.

5.2.3 Selecting Stationary Materials

In the context of working with children having limb deficiency, the generative design tools of the toolkit should be designed according to participants' capabilities and expression abilities of their age-group. In some components (i.e., Daily Activity Journey, Dream Prosthesis Map), alternative materials should be provided to the children, such as colour pencils, playdough. Children may want to show their daily needs with drawing or shaping; therefore, it is important to give children a chance to express their opinions by choosing their ways of expression freely. Whilst deciding on the stationary materials, the researcher considered the following criteria: the ability to use with one hand, easy to carry, easy to hold, safety, and child-centredness.

For all toolkit components, it is essential to provide stationery tools such as coloured pencils, scissors, coloured papers, glue, or sticky tacks (in small pieces). Due to children may struggle while opening covers of the tools, the stationary tools with

covers should be opened before the sessions by the researcher to prepare them for children's use. Considering safety and easiness to use, safety scissors should be preferred to prevent puncture accidents and ease children's usage with specifically designed handles to grip and maneuver. As a sticking tool, stick tacks (in small pieces) was found reasonable to use in this research because glues are required squeezing, and it may be hard to perform for children with upper limb deficiency. The researchers should consider these aspects while selecting stationery materials. Additional tools can be added to the toolkit by considering the selected tools and techniques.

5.3 The Procedure of the Child's Prosthesis Co-design Toolkit

The procedure of each components will be described including the introduction of the session, the tools and materials designed for these components and duration of the session. Before explaining the procedure, the role of the children and the researcher in the sessions and preparing the materials will be explained.

The role of the children and the researcher. In this study, children are given an 'informant role' to give information about their needs and expectations (Druin, 2002). Therefore, the toolkit components are designed for giving children a space to express their opinions through generative design activities. The researcher's role in the sessions is 'facilitator'. The researcher guides children to experience the activities, open discussions related to the activities' intended outcomes, and assist them regarding the components in which children may struggle (i.e., writing).

Preparing the materials. The tools of the toolkits and additional materials should be printed and prepared before the session. The card sets (image cards, daily activity cards, expectation cards and completing statement cards should also be printed and cut out to be used. The components' materials should be arranged according to their order between them to save time during the session and avoid distracting children's

attention. The stationary materials should be prepared, and the materials with covers should be opened before the session.

Introduction. Before getting started the session, children should be informed about the study's aim and the roles of both the participant and the research to conduct the session effectively. Also, a detailed explanation of the objectives of the activities and tools should be provided to children before starting the activities. The warm-up activity can be utilized for making children more comfortable about the coming session. The activity may be an introductory activity to provide both children and researcher know each other. The explanation about the co-design session to be introduced to children was as follows:

> "Today, you and I, as a team, are exploring how your dream prosthesis should be. In our team, we have different roles; you are the informant of the research who gives important information about the topic, and I am the facilitator who will guide and assist you in the session. For this session, I have designed a toolkit with five creative activities. Each component has different tools that guide you to experience different toolkit steps and finally direct you to design your dream prosthesis. As a team, first, we need to understand your daily life. After that, we will try to explore both the negative and positive aspects of your current prosthesis. Then, we will talk about some prosthesis images, and lastly, you will design your dream prosthesis at the end of the session. We have colour pencils, coloured papers, glues, scissors, and image sets to use whenever you want."

After completing the introduction, the children should be asked whether they have questions about the session. If they do not have questions, the session can be started with the first activity.

Daily Prosthesis Journey. Before the activity starts, the objectives of the activity should be explained to the participant. Also, in order to not cause any struggle for the children while performing the activity, the researcher should mention her own role for 'writing' in the activity. After that, the participant is asked to mention their

daily activities on a normal day. The mentioned daily activity is written on a daily activity card by the researcher. If participant states that he/she needs a prosthesis to perform the daily activity, the further question, "Do you have a solution to performing it with your hands" should be asked in order to direct the children to talk about his/her solutions for eliminating the difficulty of expressing the physical difficulties they face.

3D Printed Prosthesis Evaluation. After completing the first activity, the participant should be informed about the objectives of the activity. Also, the Likert Scale should be described to the participant. The prepared daily activity cards are used as transition elements between the first and second activity. Children are asked to rank their current prosthetic devices in terms of their satisfaction for answering their daily activities by sorting daily activity cards on the Likert Scale.

Image Cards Sorting. After completing the second component, children should be given information like following statement:

> "We have completed the first two activities and explore your daily needs and areas of satisfaction and dissatisfaction regarding your current prosthetic device. Now we will continue with exploring your expectations from a prosthesis."

Then, sorting sheet and image set are shown to the participant. The researcher should explain the activity to the participant.

> "There are ten prosthesis images that I want to show you. I want you to sort these prostheses according to your 'like' and 'dislike'. After you complete sorting, we will talk about your opinions on each of them."

When children complete the sorting activity, the researcher starts asking questions to elicit the participant's expectations. In this activity, five why technique may be applied to reach a deeper understanding and insightful information about the

expectations (Pojasek, 2000). After completing talking about prosthesis images, children are directed to experience the next activity.

Dream Prosthesis Map. The participant is informed about the objectives of the activity. The researcher describes the activity and the sorting sheet to the participant.

> "In this activity, we will create your dream prosthesis map by sorting the expectation cards that we filled in the previous activity according to their importance level. Dream Prosthesis Map has concentric circles with an illustration of the hand-prosthesis designed at their centre. The closest circle to the centre represents the most important expectations; the outer circles gradually represent the less important ones. You are expected to place the expectation cards on the map according to their priority for you."

The researcher should explain that the dream prosthesis will cover all the expectations on the map; however, it is important to highlight the objective of the activity for exploring the differences of their importance level.

Ideation Space. Before starting the design phase, the participant is given completing statement cards. The researcher read the statements to the participant and asked to fill the complete them:

> "I dream of a prosthesis that…"
>
> "My dream prosthesis can…"
>
> "My dream prosthesis helps me for…"

After completing the statements, the participant is guided to reflect the outcomes of the previous activities on idea generation for the dream prosthesis. The participant is provided with different materials for generating design ideas. In this activity, additional tools such as image sets, or prototyping toolsets may be added for children having extreme upper limb deficiency due to these children may struggle while using pencil, scissors etc. This activity can be collaboratively conducted with the researcher if the participant asks so; however, the researcher should not contribute

to the design decisions of the participant. When the activity completed, the researcher thanks the participant to contribute the research:

> "We have completed our toolkit. We explored how your dream prosthesis should be. Now, your contributions will help people to achieve further improvements in prosthesis design. Thank you for guiding me with your valuable opinions. You are a great teammate."

5.4 Recording the Co-design Session

All the session should be recorded. In order to create a comfortable environment for the children, an audio recording was preferred in this research. If the session will audio recorded, the researcher should take notes accurately and simultaneously when the participant points at the images or explaining some activities to the researcher with enacting or showing. If the session will video recorded, the consent of the child should be taken, and the researcher should explain how to use the video recordings for the objectives of the study.

5.5 Analysing the Outcomes

This research aims to reveal both similar and different patterns of children's needs expectations. The results of the fieldwork showed that expectations of these children have similar patterns, and the needs of the children have differences from child to child according to different limb deficiency levels. Therefore, the overall data is analysed considering the similar patterns and differences in the responses of the children. The objectives of the study should be considered while analysing the outcomes of the toolkit.

The outcomes of the co-design sessions should be separately documented for each child under categories of five components. Daily Activity Journey and 3D Printed

Prosthesis Hand Evaluation is designed to provide knowledge about children's physical difficulties in daily activities (needs). Image Cards Sorting and Dream Prosthesis Map are designed to obtain information about children's expectations for a dream prosthesis. The overall outcomes of the study are approached like interview data. Analysis of the collected data divided into relevant paragraphs, and meaningful phrasal are coded. The transcribed data are interpreted, and all statements are divided under these two heading, and the codes are reconsidered and rearranged while new headings emerged during the analysis process.

CHAPTER 6

CONCLUSIONS

6.1 Overview of the Research

The present research aimed to provide suggestions for the future development of child hand prostheses from children's perspectives by considering their past experiences and future dreams related to prosthesis usage. The research is carried out with three children, aged between 8-12 years old, with upper limb deficiencies.

The proposed methods of this research sought to explore: i) daily prosthesis needs of children, ii) prosthesis design expectations by children and (iii) children's priorities for the expectations related to prosthesis usage will be investigated with the following research questions in mind.

In order to achieve this aim, the literature review was carried out in the areas of limb deficiency, design for and with children, and design for wellbeing to explore existing tools and methods to understand the children with upper limb deficiency better and explore ways to collect design-relevant data from children's point of view (see Chapters 2 and 3). The literature review on limb deficiency provided a solid ground for understanding the participants' background. The literature on design for and with children provided significant knowledge about the participatory design approach and its effect on design research. In addition, the literature review on generative design tools provided exploring existing tools and methods for designing with children. The literature review on design for well-being provided investigating how the aspects of both hedonic and eudaimonic well-being can enhance the users' experience. In

addition, fieldwork (Chapter 4) was designed according to the information provided by the literature review. The co-design toolkit was developed to conduct individual co-design sessions with children. The fieldwork provided knowledge about children's needs and preferences related to prosthesis usage. As a result, this combination of findings and the literature helped to bring suggestions for achieving improved assistive devices that support children's physical, emotional, and social wellbeing (Chapter 5).

This chapter will present both the insights of the literature review and the findings of the fieldwork of the study. In addition, the reflections on the research questions will be explained by pointing out how this study utilized the literature findings, how this study defined the prosthesis experience of the children, and how it investigated the factors affecting their prosthesis experience. The chapter will also present suggestions for supporting children's wellbeing through the prosthesis experience. The chapter will conclude by discussing the limitations of the study and suggestions for further research.

6.2 Revisiting Research Questions

This section presents direct answers to two main research questions, together with their sub-questions, posed at the start of the research. For some additional information, relevant Chapters will also be pointed out.

Q1. In what ways children can be encouraged to express their feelings about the physical deficiencies they experienced during daily activities?

- Q.1.1. Which existing design approaches, methods and tools have been implementing for obtaining knowledge from children with upper limb deficiency?

- Q.1.2. How can the existing design methods and tools be reinterpreted for encouraging children to express their intangible needs related prosthesis usage?

Q.2. How can child prostheses be enhanced to influence the wellbeing of children with upper limb deficiency positively?

- Q.2.1. What are the needs and expectations of the children related to prosthesis usage?
- Q.2.2. To what extent the 3D printed prosthesis hands fulfil the children's needs and expectations? What are the areas of satisfaction and dissatisfaction regarding the hand/arm prosthesis use of the children?
- Q.2.3. Which design considerations should be implemented while designing hand prosthesis from the children's perspective?

The answers to the question: ***In what ways children can be encouraged to express their feelings about the physical deficiencies they experienced during daily activities?*** were sought through the following supportive questions.

Q1.1: Which existing design approaches, methods and tools have been implementing for obtaining knowledge from children with upper limb deficiencies?

In order to answer this question literature on designing for and with children was reviewed. Recently, there has been a growing interest in tools and methods developed for designing for and with children in the literature. There are few examples of including children with limb deficiency in the process of the prosthesis design and presenting the ways for utilizing this process for supporting children's well-being. Hussain (2011) used a philosophical hermeneutics research approach

through innovative research methods for conducting her research with three children with lower limb deficiency in Cambodia. According to the findings of that study, Hussain and Sanders required a new approach for understanding what children want and need. They implemented a participatory design process with three children (Hussain & Sanders, 2012). They define participatory design as a design practice that involves non-designers in various co-design activities throughout the design process (Sanders, Brandt & Binder, 2010). Their study stands for representing a good example for demonstrating the advantages of the generative design approach regarding eliciting children's perceptions regarding leg prosthesis usage.

Q1.2: How can generative methods and tools be reinterpreted for encouraging children to express their intangible needs related prosthesis usage?

To answer this question, literature review and methodology chapters should be examined. However, integrating children with upper limb deficiency into a process and encouraging them to express their opinions about intangible needs requires adopting certain techniques. Therefore, reviewing the literature on existing approaches for co-designing with children enabled the researcher to find essential questions about the effects of co-design with children with disabilities (Frauenberger, Good & Alcorn, 2012; Hussain & Sanders, 2012).

The literature review provided combining tools for developing a toolkit that is used to serve the objectives of the study. In addition, the literature review provided insights about various methods, tools and techniques and their implications for studying with children. However, there has been little research directly investigating the considerations for developing tools or methods for designing for and with children with disabilities. To organize what design approach and accompanying methods, tools and techniques to use for engaging children in the design process, Sanders (2010)'s framework include three dimensions: form, purpose and context were utilized. Sanders categorized tools and techniques being used by 'form' in three

headings; making (2D collages, 2D mappings, 3D mock-ups), telling (diaries, cards), enacting (game boards, props, participatory envisioning, improvisation, acting out) described them by ‘purpose’ (probe, prime, understand, generate) and ‘context’ (individual, group, face to face, online). As stated by Sanders (2010), it is essential to understand the objectives of the study and then customize these dimensions accordingly. Considering this framework, 'Child's Prosthesis Co-design Toolkit' was developed, and the process of development and implementation stages are explained in Chapter 5.

Q1. To what ways children can be encouraged to express their feelings about the physical deficiencies they experienced during daily activities?

In the literature on designing with children, generative design tools are commonly used for encouraging children in the design process. Several studies confirm its benefits to facilitate the expression of sensitive issues and overcome barriers of communication (Sanders, 2000; Baek & Lee, 2008; Hussain, 2010; Druin., 2002). Instead of relying solely on verbal communication, the generative tools enable children to express themselves through mediums.

In this research, co-design sessions were carried out through 'Child's Prosthesis Co-design Toolkit', which is comprised of generative design tools. These tools were developed in light of the literature review on participatory design. In the co-design sessions, these tools are served as initiating discussions and encouraging children to express their opinions.

Also, to engage children more in the process, showing the evidence of respect, openness, and genuine intent to listen is essential to make children feel more comfortable sharing their experiences, frustrations, and dreams. In this way, the sense of empowerment may be provided to children rather than disempower them expecting to answer questions on difficult issues.

The answers to research question: ***How can child prostheses be enhanced in order to positively influence wellbeing of children with* upper *limb deficiency?*** were sought through the following sub-questions.

Q.2.1: What are the needs and expectations of the children related to prosthesis usage?

This question was answered by the results chapter (Section 4.3) with presenting the prosthesis need of children as the factors affect the prosthesis usage for children. According to results, the daily needs of the prosthesis for children differ according to the child's deficiency level. The expectations of the children can be categorized as 'pragmatic' and 'hedonic' expectations. Pragmatic expectations include functionality, usability, durability, and physical comfort, while hedonic expectations stand for aesthetic appeal, age appropriateness, other people's view, hobby-specific and reliability. A detailed explanation of these dimensions is presented in Chapter 4.

Q.2.2: To what extent the 3D printed prosthesis hands fulfil the children's needs and expectations? What are the areas of satisfaction and dissatisfaction regarding the hand/arm prosthesis use of the children?

The answer to this question was found in the results of the fieldwork (Section 4.3.2). There are both satisfactory and dissatisfactory areas of 3D printed prosthetic hand usage for children. First, the areas of satisfaction can be listed as; customization and age-appropriateness, which carries the potential to fulfil children hedonic expectations, which are the aesthetic appeal, other people's views. However, children stated that their prosthetic hands give them pleasure for a while, then they started to not wear the prosthetic hands due to their inefficiency.

The areas of dissatisfaction include functionality, usability, durability, and physical comfort, which are the dimensions that 3D printed prosthetic hands should be

improved for. The current 3D printed prosthetic hands models provide children with limited hand function (e.g., grasping). According to the children's responses, these devices do not enough to perform daily activities. Due to deficiency in the development of elbow or wrist muscles, children struggle while controlling the device with bending the elbow or wrist. Children needed to put too much effort into using the device; this led to pain and soreness on their wrist/elbows. In addition, the durability of the material is emphasized while children were expressing the problems, they faced during prosthesis usage. All children expressed their concerns regarding the durability of both material and design. Therefore, they were not able to use their prosthetic hands in different contexts (e.g., school, outdoor). All these difficulties caused dissatisfaction regarding the reliability of the device.

Therefore, dissatisfaction regarding 3D printed prosthetic device use should be considered while developing new assistive devices.

Q.2.3: Which design considerations should be implemented while designing hand prosthesis for the children?

The results of the fieldwork revealed the needs and expectations of the children regarding the prosthesis use (Section 4.3). Design considerations for developing hand prosthesis according to these needs and expectations of the children are presented as functionality, usability, durability, comfort, multifunctionality, usefulness, aesthetic appeal and age-appropriateness discussed in the following section.

Q.2. How can child prostheses be enhanced to influence the wellbeing of children with upper limb deficiency positively?

The results of the fieldwork elicited children's daily needs and expectations regarding prosthesis usage, which should be considered while designing prosthesis

that supports the wellbeing of the children. The results of the analysis showed that daily needs differ according to the deficiency. However, similar daily needs were analysed and categorized under four headings: daily activities, sports, hobbies, and mobility-related needs. According to the results, the expectations suggested by children can be generalized for each child and divided into two categories: i) pragmatic expectations, which represent the attributes of the prosthesis from children's perspective, and ii) hedonic expectations, which stands for social dimensions affecting their expectations of the prosthesis. The children's pragmatic expectations include four dimensions, functionality, usability, durability, and physical comfort. Hedonic expectations comprise five different aspects of experience from the children's perspective: reliability, aesthetic appeal, other people's view, hobby-specific, age-appropriateness.

In the context of prosthesis design, three aspects which emerged from the relation between the hedonic and pragmatic expectations suggested by the children: (i) positive emotional state through reliable prosthesis experience, (ii) improving skills through the functionality of the prosthesis and (iii) social integrations through the appearance of the prosthesis, should be considered while applying design decisions with aiming the positive outcomes. In that way, increased usage strengthened personal wellbeing, and psychological empowerment can be achieved through the prosthesis experience. To develop various design proposals that aim at a positive experience, designers should consider children's varying needs regarding hand/arm prosthesis use instead of taking a one-fits-for-all approach. The detailed answer to this question can be found in the next section.

6.3 Implications for Prosthesis Design: Strengthening Personal Well-being of the Children through Prosthesis Experience

In this section, a discussion of design implications for strengthening the wellbeing of children with an upper limb deficiency will be presented.

The literature review on positive psychology (see Section 2.5.1) has clearly shown that it is possible to positively affect the quality of experience to increase the well-being of individuals. In order to increase wellbeing, positive psychology suggests a holistic exploration of both positive and negative conditions of an individual's life (Desmet and Pohlmeyer, 2013). In order to question the contribution of the design practice on the subjective wellbeing of the individuals, a positive design approach emerged. The approach aims to increase positive emotions by focusing on possibilities rather than designing to reduce negative (Roozenburg and Eekels, 1995). In this respect, this approach enables designers to reach a "desired" state of being rather than reaching a "not bad" state of being (Desmet and Pohlmeyer, 2013). In this context, the findings of this study are discussed in order to achieve children's desired state of being from the actual state of being while improving the overall wellbeing. Therefore, the actual state of being of children with upper limb deficiency was investigated with the help of 'Daily Activity Journey' and '3D Printed Prosthetic Hand Evaluation' activities. With the results of these activities, the needs and expectations on their current prosthetic devices were presented (see section 4.3). Besides, the needs and preferences of the children revealed with the help of the Image Cards Sorting and Dream Prosthesis Map activity for exploring the expectations and factors which affect prosthesis usage positively. The desired state of being may be achieved by fulfilling these aspects with a possibility driven approach. Hence, in the context of prosthesis design, concerns of the children that can be framed as their needs, expectations and the prosthesis experience are essential to achieve the

children's positive emotional state. The desired state of being that positive psychology aims can be achieved with this approach (Figure 6.1).

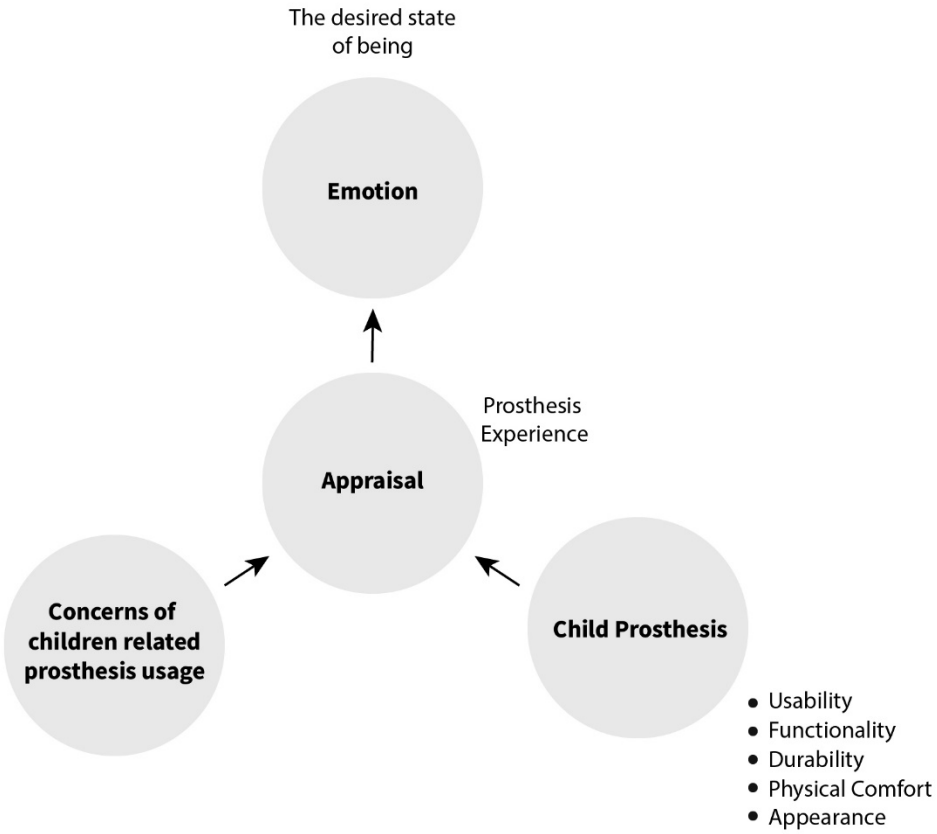


Figure 6.1 Basic model of product emotions in the context of this study (adapted from Desmet, 2002)

In the context of prosthesis design, three aspects which emerged from the relation between the hedonic and pragmatic expectations suggested by the children: (i) positive emotional state through reliable prosthesis experience, (ii) improving skills through the functionality of the prosthesis and (iii) social integrations through the appearance of the prosthesis, should be considered while applying design decisions with aiming the positive outcomes. In that way, positive implications of appraisal, such as increased usage, strengthened personal wellbeing, and psychological

empowerment, can be achieved through the prosthesis experience. In that sense, design considerations for a child hand prosthesis that increase positive effect of prosthesis usage on children's well-being are presented in Figure 6.2.

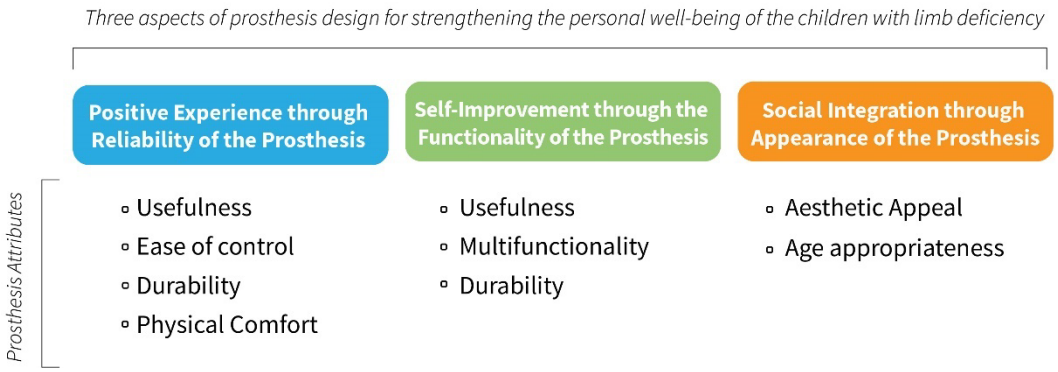


Figure 6.2 Design considerations for child hand prosthesis

- To develop various design proposals that aim at a positive experience, designers should consider children's varying needs regarding (hand) prosthesis use, instead of taking one-fits-for-all approach. However, it is possible to interrelate design considerations for three aspects of the prosthesis usage which are positive experience through the reliability of the prosthesis, self-improvement through the functionality of the prosthesis and social integration through the appearance of the prosthesis, with prosthesis attributes that reflect the expectations of the children. In order to design assistive devices that help to strengthen children's wellbeing, the following points can be listed as generalizable inferences:

- Due to a lack of muscle development, children experience difficulty while controlling the body-powered prosthesis. This cause concerns in children related to the reliability of the prostheses for performing certain activities

(e.g., holding or carrying objects). Therefore, the effort needed to use the prosthesis while performing such activities should be at a minimum. Also, it should be designed with the child's age and deficiency level in mind. A positive emotional state can only be achieved whilst carrying out activities without a struggle. The ideal prosthesis design should be easy to control, easy to use, durable and comfortable.

- Children with upper limb deficiencies face barriers in participation in many activities and events. Therefore, supporting children in improving their skills through an assistive device is essential for children's both physical and social well-being. The design of the prosthesis should allow children to perform a wide range of activities, multifunctionality should be taken into consideration. The durability of the materials, design contribute to enabling children to accomplish different activities in different contexts, as well as supporting long-term usage. Portability is another criterion that needs to be considered by designers as it will help children to carry it themselves and use it in various contexts. With fulfilling all related expectations, the findings show that children tend to like hobby-specific prosthesis regardless of what the hobby is.

- For children, a prosthetic hand is not only a physical tool that helps them in daily activities, but it is also a social instrument that represents the child's identity. Therefore, visual aesthetics should be considered as a tool for the social integration of children. The study results revealed that aesthetics-related expectations are strongly associated with the views of friends, as well as their acquaintances and family members. Aesthetic appeal, age appropriateness, novelty and customizability should be considered to help children to be more confident to get involved in society without hesitating about their deficiency.

6.4 Implications for 3D Printed Prosthesis Design

In light of the insights from the results, the suggestions for 3D-printed prosthesis design will be presented in this section. Due to differences in children's deficiencies, their needs for daily prosthesis usage can also differ. Therefore, meeting the varied needs of each child cannot be possible with a limited functionality offered by a prosthesis, such as grasping. In that sense, the children's deficiency level and expectations should be considered while designing 3D- printed assistive devices.

The results of the study revealed three important aspects of children's prosthesis usage. I) positive experience through the reliability of the prosthesis, ii) self-improvement through the functionality of the prosthesis, and iii) social integration through the appearance of the prosthesis. 3D-printed prosthetic devices have great potential for fulfilling these aspects of prosthesis usage. With the advancements in technology, a reliable prosthesis experience can be achieved, and a positive emotional state can be reached through this experience. The study also shows that current 3D printed prosthetic devices do not meet the children's needs with their limited functionalities. Therefore, designers should also consider the potential of these prosthetic to achieve improved 3D printed prosthetic devices. In addition, the designer should also focus on developing hobby-specific assistive devices rather than concentrating their efforts solely on creating life-like (hand) appearance and usual hand functions (e.g., grasping, gripping). In this way, children can be supported for self-improvement with a positive prosthesis experience. Besides, 3D-printed technology has great promise to meet aesthetics related expectations by generating customizable designs for each child. Nowadays, different materials with varied colours, flexibility/rigidity, softness/hardness options, and even interwoven complicated structures can be 3D-printed. This area should also be explored further. In this way, children's social integration can be supported with the customization of the prosthetic hands.

These three aspects of prosthesis usage can be accepted for children with lower limb deficiencies (e.g., leg, thigh, pelvis). Designers should consider the needs for reliable experience, functionality, and appearance in terms of improving the overall well-being of these children.

6.5 Implications for the 'Child Prosthesis Co-design Toolkit'

The fieldwork presented in Chapter 5 investigation the potential of methodology that aims to elicit children's needs and expectations for hand prostheses. In this context, the 'Child's Prosthesis Co-Design Toolkit' has demonstrated an auspicious direction to encourage children to express themselves concerning physical difficulties they encounter while at the same time uncovering their needs, expectations, and priorities for the prosthesis usage.

The toolkit has also been beneficial for uncovering the children's reflections by considering aspects such as age-appropriate levels of cognitive ability, language skills, and motor-sensory capabilities. In this way, it enabled the researcher to initiate a conversation with children, allow children to participate and overcome their passive attitudes, and talk about their physical deficiencies that are sensitive for the children. In this way, the outcomes of the toolkit make it possible to identify new technological possibilities that might not otherwise have been considered.

Although hedonic expectations are more challenging to elicit than pragmatic expectations, the generative toolkit facilitated the process of collecting knowledge of children's cognitive characteristics. The toolkit provided children with a new language by using verbal and visual communication forms for expressing their hedonic needs in a more tangible form. In addition, the toolkit enabled children to reflect their opinions, needs and dreams on visual means. The artefacts that children prepared in the sessions were beneficial to initiate conversations about important and meaningful things to them.

Although the psychological impact of gathering information from children by the proposed toolkit was outside the scope of this study, it is worth mentioning that the children expressed their pleasure in participating in the fieldwork. The narrations of the children revealed that giving them a voice to express their opinions about design solutions that affect their lives has significant potential as an empowering process both physically and psychologically. This approach is not only beneficial to develop various design solutions but also to provide children with psychological empowerment by giving them a sense of ownership. Therefore, it is evident that the 'desired state of being', which is aimed to achieve with prosthesis design, should start with involving children in the design process.

6.6 Suggestions for NGOs Who Work with Children with Limb Deficiency

The results of the study reveal some strategies which may be beneficial for NGOs who work with children. In that sense, the following suggestions can be given.

- In order to strengthen children's overall wellbeing, NGOs who work with children should integrate the co-design process into their processes. By consulting children to design their services or products, the products or services which may improve children's psychological, social and emotional wellbeing can be achieved. Involving them into a design process and giving them a chance to express themselves among adults has the potential to empower these children.
- In order to achieve further improvements, children's opinions related to provided service should be taken into consideration. Therefore, it is essential to give children a chance to evaluate the service to help NGOs better understand children's needs and provide NGOs to improve themselves to better services.

- Rather than embracing a one-fits-for-all approach to providing the same service to each child, it is essential to focus on the personal needs and expectations of the children with physical disabilities. In that way, improved products or services that meet each child's needs and expectations can be provided.

6.7 Further Reflections on the Study

The 'Child's Prosthesis Co-design Toolkit' proved to be useful for gathering insights to support the design process of hand prostheses. The outcomes of the study believed to help guiding designers who work on child prostheses. As a final remark, reflection for co-designing with children with upper limb deficiency are presented:

The concept of understanding the views of children requires time and effort. Asking children about their opinions and getting a reply is not that easy. Gaining their trust is essential in terms of getting insightful information. To establish a trust-based relationship, being patient and giving persistent time is required. Once the researcher gains children's trust, enlightening knowledge is given by the children. In this study, such a relationship was established with the children with the help of the researcher's past experiences in the Robotel (see Section 1.1). Therefore, this relationship of trust provided children to express their needs, expectations, and dreams comfortably.

Gaining the trust of the parents also essential. Some of the parents may insist on being present during the co-design sessions in order to be sure about their children's helpfulness to the study. In that kind of situations, preserving children's confidentiality should be provided. In the fieldwork, some of the parents wanted to participate in the sessions for being sure about whether their child's responses reflect realities or not. The researcher kindly rejected this request and explained to them the

objectives of the study regarding obtaining children's real opinions and the value of their children's contribution.

Children tend to say what adults want to hear. Children tended to hesitate to talk about difficulties related to 3D printed prosthetic hands usage due to the first author's role in the NGO that gave them these prosthetic hands. Therefore, explaining the study's aim and the value of children's participation should be explained while researching with children.

Children can give abstract and ironic expressions. Some children gave conflicting expressions while sharing their opinions related to prosthesis images. For a better understanding, the actual construct behind the words, more in-depth questions can be asked for these kinds of situations.

Giving children free space to express themselves is necessary. It is important to inform children about their role in the co-design session. In the co-design sessions, children were asked to participate in activities as an informant design partner and were informed about their participation's importance for the study.

Some task-based activities may be hard to carry out for children with upper limb deficiency. While working with children with an upper limb deficiency, it is essential to design tools that are proper for their physical capabilities considering their deficiency type. In the co-design, some children had difficulties while writing. The researcher offered help for writing-based tasks.

Generative design tools have the potential to broaden children's horizon. These children are not usually given a voice for expressing their opinions, feelings, and dreams about their deficiencies. Some of the children expressed their happiness for

participating in the research study. Also, some of them stated they had never thought about prostheses of their dreams.

6.8 Limitations of the Research

The scope of this research was to explore the needs and expectations of the children with upper limb deficiency in individual sessions. For sampling, five children (one of them included in the pilot study) were chosen to consider age group, 3D printed prosthetic hand experience and consent criteria in the NGOs database. Ideally, we would have like to work with a larger number of children; however, due to the pandemic, the researcher could not conduct one to one session, and the fieldwork could not be completed. Research conducted with a greater number of participants may provide more significant results for prosthesis design considerations. Even though the small size of the sampling, the study illustrates that generative design tools enable the researchers to elicit children's needs and expectations by including them in co-design sessions.

When working with children, both parents and children's schedule should be taken into account. It was challenging to find a common time with parents and children. Therefore, the fieldwork took more time than expected. Thus, providing parents with a wide range of time options on a digital tool or conducting the study in children's home environment would facilitate the time arrangement processes.

Due to the researcher's background related to the study topic, avoiding subjective interpretations was essential; therefore, the data analysis was reconducted many times for ensuring not affect the results with the researcher's bias and interpretations. For researchers who have a background in the topic of study, it is critical to ensure the objectiveness of the final interpreted results of the study and concentrating on bringing forth the voices of the children.

6.9 Future Research Possibilities

This research investigated the needs and expectations of the children with upper limb deficiency, which may contribute to prosthesis design that strengthens the children's wellbeing. Also, the co-design toolkit was suggested for eliciting these needs and expectations of the children. The exploration can be furthered by broadening the research to include later design phases rather than focusing on early design phases. This will require the development of new methods and tools.

Also, the research revealed the potential of the co-design process for supporting the psychological empowerment of the children. Therefore, the scope of the research can be extended by integrating the co-design session into the service of the NGOs who work with children with limb deficiency and exploring the analysis of the perceived psychological empowerment to inspire long-term effects of the studies and services.

In that sense, the research can further investigate the relationship between psychological empowerment and co-designing with children, which will help both design practitioners and organizations working with special children to have a comprehensive understanding of their impact on children’s wellbeing.

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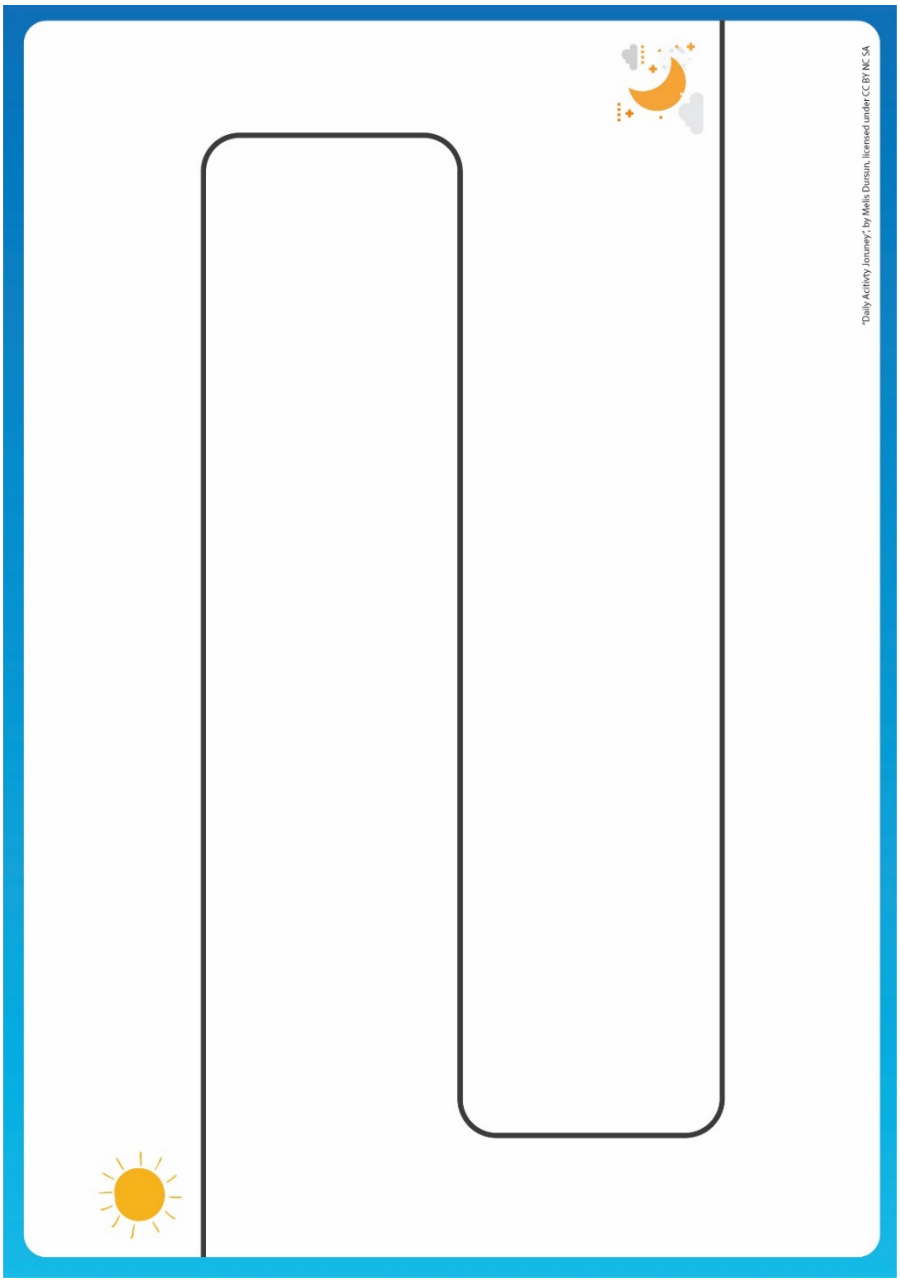
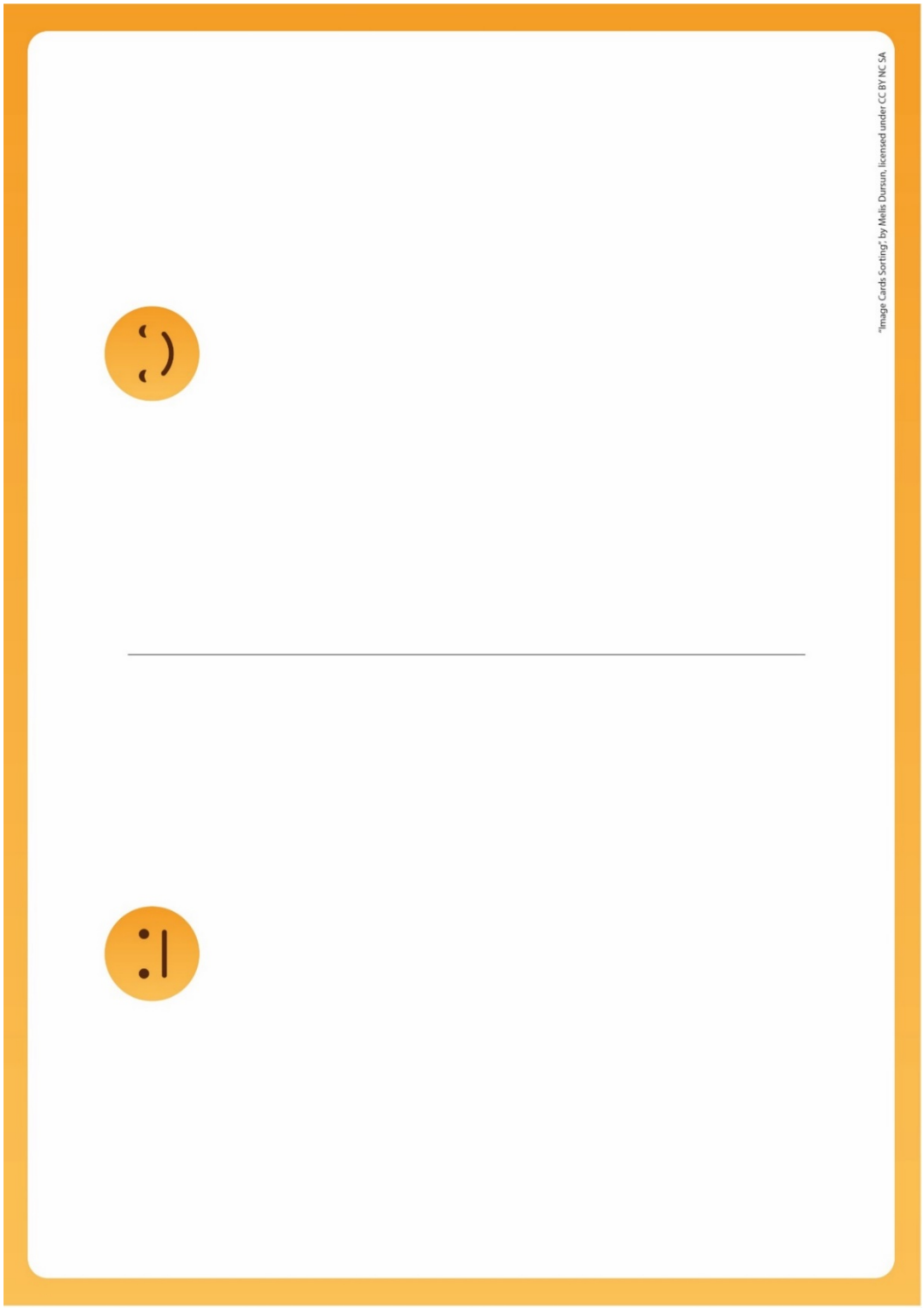
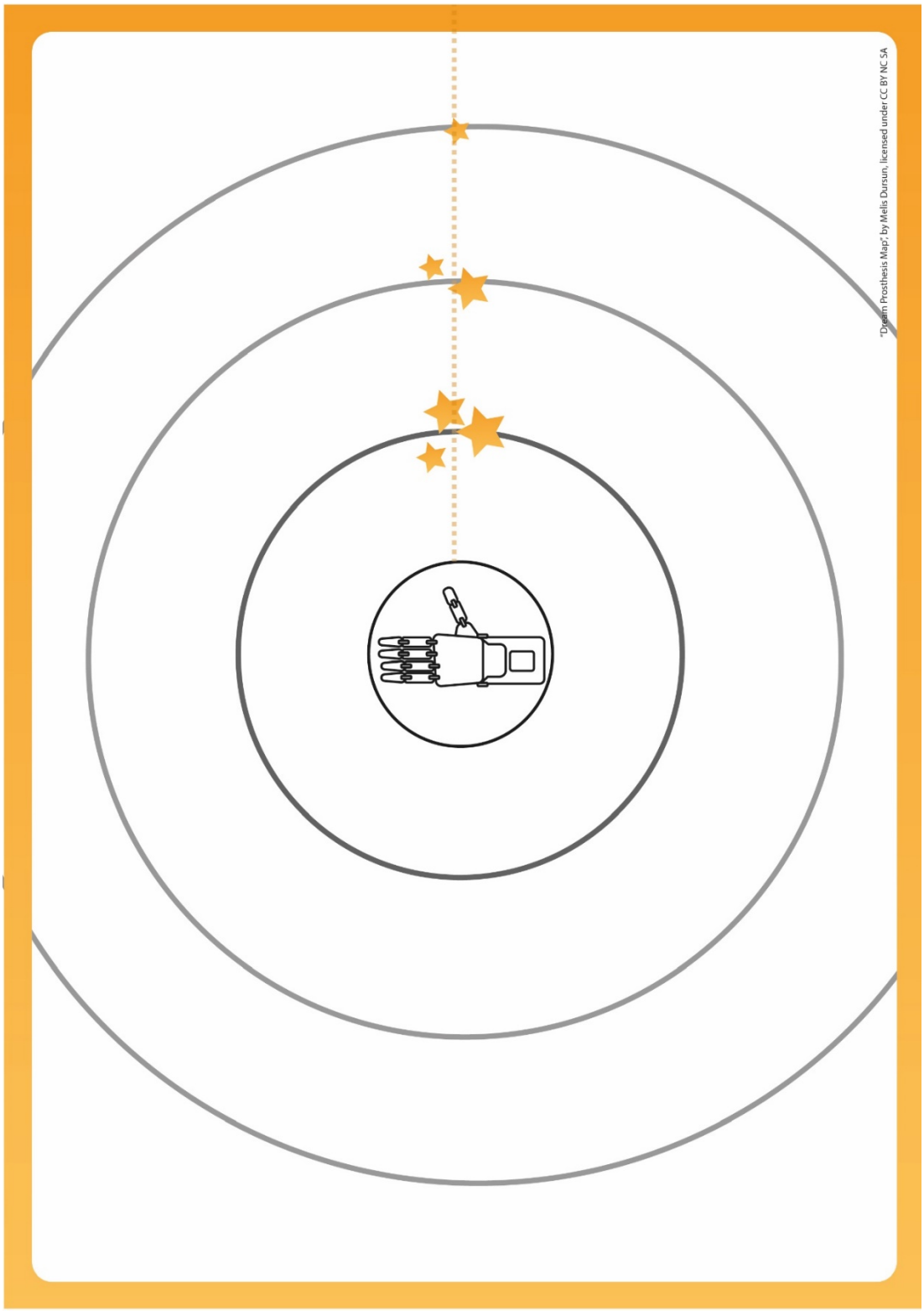
APPENDICES

A. ACTIVITY MATERIALS PREPARED FOR THE TOOLKIT




"Image Cards Sorting" by Melis Dursun, licensed under CC BY NC SA


"Dream Prosthesis Map" by Melis Dursun, licensed under CC BY NC SA

B. INFORMED CONSENT FORM (TURKISH)

Veli Onay Formu

Bu araştırma, ODTÜ Endüstri Ürünleri Tasarımı Bölümü Yüksek Lisans öğrencisi Melis Dursun tarafından yüksek lisans araştırması olarak yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Bu çalışmanın amacı nedir? Çalışmanın amacı 3 boyutlu yazıcılardan çocuk protezin teknolojik gelişimi ve çocuklar için (günlük hayatlarında) ne ifade ettiği ve aileleri olarak sizlerin bu kapsamda nasıl bir rol aldığınızı araştırmaktır.

Çocuğunuzun katılımcı olarak ne yapmasını istiyoruz? Bu amaç doğrultusunda, çocuğunuzdan tasarım yöntemleriyle hazırlanan görseller, çizimler ve alanları kullanarak kendini ifade etmesini istiyoruz. Süreç boyunca cevaplar ses kaydına alınacak olup çalışmaya başlamadan çocuğunuzdan da sözlü katılımıyla ilgili rızası mutlaka alınacaktır.

Çocuğunuzdan alınan bilgiler ne amaçla ve nasıl kullanılacak? Çocuğunuzdan alacağımız cevaplar tamamen gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir. Elde edilecek bilgiler sadece bilimsel amaçla kullanılacak, çocuğunuzun ya da sizin ismi ve kimlik bilgileriniz, hiçbir şekilde kimseyle paylaşılmayacaktır.

Çocuğunuz ya da siz çalışmayı yarıda kesmek isterseniz ne yapmalısınız? Katılım sırasında çocuğunuz çalışmayı bitirmekte serbesttir. Sizler de böyle bir durumda çalışmadan sorumlu kişiye çocuğunuzun çalışmadan ayrılmasını istediğinizi söylemeniz yeterli olacaktır.

Bu çalışmayla ilgili daha fazla bilgi almak isterseniz: Çalışmaya katılımınızın sonrasında, bu çalışmayla ilgili sorularınız yazılı biçimde cevaplandırılacaktır. Çalışma hakkında daha fazla bilgi almak için Melis Dursun ile (e-posta: melisdursun1@gmail.com) ile iletişim kurabilirsiniz. Bu çalışmaya katılımınız için şimdiden teşekkür ederiz.

Yukarıdaki bilgileri okudum ve çocuğumun bu çalışmada yer almasını onaylıyorum (Lütfen alttaki iki seçenekten birini işaretleyiniz.)

Evet onaylıyorum___ Hayır, onaylamıyorum___

Velisinin adı-soyadı: _____ Tarih:_____

Çocuğun adı soyadı ve doğum tarihi:_____