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Circular Economy Competencies for Design

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TU Delft

Circular Economy Competencies for Design

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To the village that raised me.
Most importantly, to my parents who
ensured I only bent,
but didn't break.

Preface

The reason I started studying Industrial Design Engineering at TU Delft was because I was intrigued by the fact that I could contribute to people's lives by solving problems. I quickly learned that many of my fellow students had the same intrinsic motivation – "to contribute to helping others"; many had had difficulties making a choice between Medicine or Industrial Design Engineering. These two seemingly different professions, have the same underlying idea of contributing to the lives of others; each in its own way. On my student journey, I also realized that some of my peers had started the program with an exact vision of where they wanted to work afterwards - "that large car manufacturer or the large corporate selling Fast Moving Consumer Goods (FMCGs). I, in contrast, became increasingly aware of what I did not want. Prompted by some of my close circle of friends from the United Colors Groups, I learned that there were other options. In my third Bachelor year, I got accepted to participate in the International Entrepreneurship and Development minor at the faculty of Technology, Policy and Management, and I was able to go to Tanzania to work on a project.

In the following years, I have been fortunate to work on projects in both Tanzania and Indonesia. You could say that my upbringing in multiple places in a timespan of about 15 years has ensured that I now know how to adapt to strongly differing contexts. I have gained experience and knowledge from situating myself in new contexts and I have become aware of social and sustainable design and (design) entrepreneurship.

My second turning point came when I started my Master's in Strategic Product Design (SPD), where I started working as a research assistant. This gave me the opportunity to become more familiar with research and it strengthened my confidence in my research skills. In this period, I assisted PhD candidates and attended a defense. So, when I graduated and was given the opportunity to do doctoral research on a sustainability topic, it felt like things had come together.

The subject for this thesis emerged from reflecting on my education background in Industrial Design Engineering. As I had learned that design is one of the enablers in the transition towards a circular economy, I started wondering what made design for sustainability and in particular, the approach of design for circular economy, different from traditional design practice.

Looking back on my own educational development as a designer, I knew a bit about everything and could manoeuvre my way into a conversation with different stakeholders. Specializing as a strategic designer, interested in sustainability, I was able to find my way to creating developing concepts in which I aimed to balance people, planet and profit. Yet, developing concepts in which product integrity is maintained for as long as economically and environmentally sound through the cycling of resources, was something new to both myself and later, as I learned along the way, my peers. Navigating terms like "systems thinking", "use cycles", "life cycles", "access-based models" and applying them in practice reflected the newness of the field. This led to my formulating the main objective of this thesis: to understand what competencies product designers need to successfully develop product and services for a circular economy"

This dissertation binds together a four-year quest into what is by some seen as fuzzy construct "competencies", about which there is lack of consensus and navigates it in the context of design for a circular economy. My intention was to present a coherent set of circular economy design competencies, show how they were derived based on different studies with various designers, and explain what they entail.

Table of content

Summary

The circular economy offers an alternative to the linear economy - the so-called 'take-make-use-waste' society we live in. Its places emphasis on effective resource use, by slowing and closing resource loops. Design is seen as an enabler in a circular economy; design decisions taken now impact the recovery of products in the future. Design for a circular economy differs from other design for sustainability approaches due to the focus on slowing and cycling material loops and offering products and services in circular business models. The transition towards a circular economy requires new competencies to inform the development of circular-economy-based methodologies and curricula. However, little research has been done when it comes to circular economy competencies for design. This led to the main research question of this thesis:

What competencies do designers need to develop products and services for a circular economy?

I applied a mixed-method approach to develop an overview of circular economy competencies for design. The five studies making up this thesis essentially embark from the same main research question, but look at it from different perspectives. The first highlights the role of designers in the transition towards a circular economy; the second connects these design roles with circular economy competencies for design; and the last three focus on iteratively validating and expanding the initial overview of competencies. The overarching aim was to create a coherent, internationally validated overview of key circular economy competencies for design.

I started by exploring the role of designers in transition towards the circular economy (chapter 2). Three roles emerged from the literature review: strategic, coordinating and functional. Strategic roles are about developing future visions, leading projects and determining the scope of design briefs. Coordinating roles are related to building partnerships externally and making internal connections between departments. Thirdly, functional roles have to do with developing products mostly after the design brief has been established.

These roles were then compared to those recognized by designers in practice via a series of eight semi-structured interviews. The participants recognized all three roles. Strategic roles in particular were singled out for being promising when it comes to creating change and working towards a circular economy. However, the designers noted these roles were hardest for them to fulfil. They reported facing barriers such as working in a predetermined solutions space and having a lack of knowledge and skills. This sparked the interest to look into competencies (knowledge, skills and attitudes) that could support designers to fulfil the envisioned roles in a circular economy.

I then conducted a single longitudinal in-depth case to complement the limited empirical evidence on the development of circular economy products and services (chapter 3). The case describes how a design-driven original equipment manufacturer (OEM) piloted a circular business model i.e., a lease and refurbishment plan for strollers. Based on this case, four competencies were derived. Two are categorized as relevant for strategic design roles (1) Concurrently developing the circular business model and the product's design, and (2) Designing a product that must stay relevant, desired, and cost-effective over multiple use cycles. The other two were found to be more relevant for designers fulfilling coordinating and functional roles (3) Facilitating collaboration between stakeholders, and (4) Estimating the environmental impact on a system level over multiple life cycles respectively. Connecting identified competencies to specific design roles was not clear cut, as roles are a fluid concept. A designer fulfilling, for instance, a strategic role can still partake in activities that are normally associated with a coordinating role. Therefore, the focus of the subsequent research shifted to developing a set of key design competencies for a circular economy.

In the final three studies (chapters 4 - 6), I developed a set of circular economy competencies whereby each chapter focuses on validating and expanding the previous overview of competencies using a focus group study, individual face-to-face interviews, and an international survey respectively. This led to my defining the final set of internationally recognized circular economy competencies for design: (1) Circular System Thinking, (2) Design for Recovery, (3) Design for Multiple Use Cycles, (4) Circular Business Propositions, (5) Circular User Engagement, (6) Circular Materials and Manufacturing, (7) Circular Impact Assessment, (8) Circular Economy Collaboration, and (9) Circular Economy Communication (figure i).

This set of nine circular economy competencies lays a foundation for designers to be able to develop products and services for a circular economy. These circular economy competencies for design can be used to create the vocabulary needed to talk in practice about competency development for circular design. Furthermore, the set can be used to develop circular economy-based curricula and methodologies.

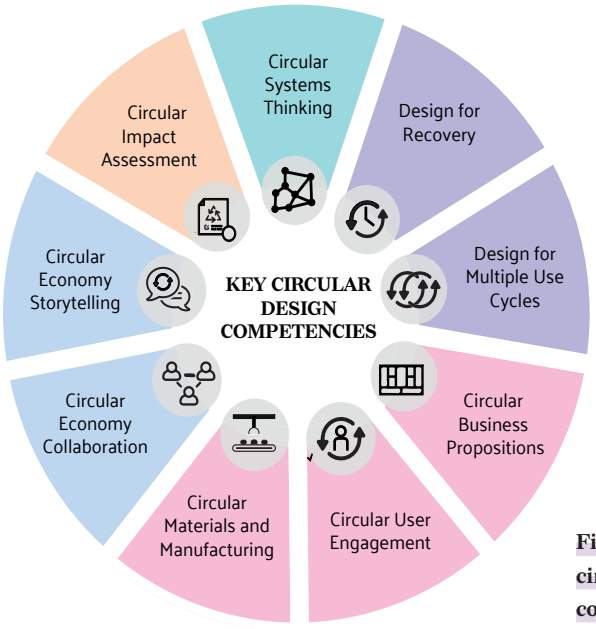

Figure i Nine key circular economy competencies for design

The ability to

Circular Systems Thinking
Adopt an approach to design that regards the circular economy as a complex system, taking into account that circular design interventions will have systemic effects.

Design for Recovery
Develop product service systems that allow for products, components and materials to be recovered and looped back into a circular economy.

Design for Multiple Use Cycles
Create product service systems that are designed to have more than one use cycle while retaining value in a circular economy.

Circular Business Propositions
Develop circular business propositions that aim at fully closing product and material loops and thereby keeping resources in use for as long as possible.

Circular User Engagement
Engage users in all aspects of the circular economy, for instance by enabling users to share and care for (shared or owned) products and stimulate them loop back products at the end of a use cycle.

Circular Materials and Manufacturing
The ability to select and use materials and manufacturing methods for a product to minimize the impact (environment, health, social), while taking into account the full life cycle of the product and its recovery.

Circular Economy Collaboration
Facilitate multi-stakeholder collaboration across value networks in order to create circular product service systems as well as stimulate the transition towards a circular economy.

Circular Economy Storytelling
Create engaging visions and narratives of the circular economy in order to make the idea understood and to garner support for it amongst various stakeholders.

Circular Impact Assessment
Measure the environmental, economic and social impact of circular design interventions throughout the full product-service life cycle.

Samenvatting

De circulaire economie biedt een alternatief voor de lineaire economie (ook wel de wegwerpmaatschappij genoemd) waarin we leven. Het legt de nadruk op het effectief gebruiken van grondstoffen door de grondstofketen te vertragen en te sluiten. Ontwerpen wordt gezien als een potentiele aanjager in de transitie naar de circulaire economie; ontwerpbeslissingen die nu genomen worden hebben een impact op het terugwinnen van materialen in de toekomst. Het verschilt van andere duurzame ontwerp benaderingen door de focus op het vertragen en sluiten van materiaal kringen en het aanbieden van producten en services in circulaire businessmodellen. Om de transitie naar de circulaire economie te kunnen bewerkstelligen zullen er nieuwe competenties ontwikkeld moeten worden. Een overzicht van benodigde nieuwe competenties kan helpen in ontwikkeling van nieuwe methodologie en curricula. Echter, de kennis aangaande de competenties die benodigd zijn om voor het ontwerpen voor een circulaire economie is gelimiteerd. Vandaar dat de hoofdvraag die gesteld wordt in dit proefschrift is:

Welke ontwerpcompetenties zijn er nodig om producten en services te ontwerpen voor de circulaire economie?

Een 'mixed-method' benadering werd gebruikt om een overzicht van ontwerpcompetenties voor de circulaire economie te ontwikkelen. De vijf studies die zijn uitgevoerd binnen dit onderzoek hebben dezelfde hoofdvraag als uitgangspunt, maar bekijken elk vanuit een ander perspectief het onderzoeksprobleem. De eerste van de vijf studies belicht de rol van ontwerpers in de transitie naar de circulaire economie; de tweede studie koppelt deze ontwerprollen aan ontwerp competenties voor de circulaire economie; de drie laatste studies focussen op het valideren en uitbreiden van het initiële overzicht van competenties. Het uiteindelijke doel van dit proefschrift is het creëren van een samenhangende set van sleutel competenties die van belang zijn bij het ontwerpen voor de circulaire economie.

Het onderzoek begon met het ontwikkelen van de rol van ontwerpers in de transitie naar de circulaire economie (hoofdstuk 2). Uit het literatuuronderzoek kwamen drie rollen bovendrijven: strategisch, coördinerend en operationeel. Strategische rollen hebben te maken met het ontwikkelen van visies voor de toekomst, het leiden van de projecten een

het bepalen van de scope van ontwerpopdrachten, coördinerende rollen hebben te maken met het bouwen van externe samenwerkingsverbanden en het maken van interne connecties tussen afdelingen, en operationele rollen hebben te maken met het ontwikkelen van producten nadat de scope van ontwerpopdracht is vastgelegd. Deze rollen werden tegenover bevindingen uit de praktijk gezet middels 8 semigestructureerd interviews met ontwerpers uit de praktijk. De geïnterviewde ontwerpers herkenden zichzelf al deze rollen. Het vervullen van strategische rollen werd met name gezien als veelbelovend als het gaat om het creëren van verandering en het bijdragen van de transitie naar een circulaire economie. Echter gaven de ontwerpers aan dat deze rollen het moeilijkst te vervullen waren. Ze hadden te maken met barrières zoals werken in een vooraf vastgestelde oplossingsruimte en een gebrek aan kennis aangaande het doen van assessments op het gebied van duurzaamheid. De uitkomsten van deze studie vormden dan ook de aanleiding om te focussen op wat voor competenties (kennis, skills en attitudes) ontwerpers zouden kunnen ondersteunen om de–in de literatuur–voorziene rollen in de transitie naar een circulaire economie te vervullen.

Een diepgaande longitudinale studie werd uitgevoerd om het beperkte empirische onderzoek aangaande de ontwikkeling van circulaire producten en diensten aan te vullen (hoofdstuk 3). De casus beschrijft hoe een ontwerp-georiënteerde fabrikant een pilot rondom een circulair businessmodel (i.e., het leasen en 'refurbishen' van kinderwagens) uitvoert. Uit deze casus worden vier competenties afgeleid. Twee van deze competenties kunnen worden gecategoriseerd als relevant voor ontwerpers die strategische rollen vervullen i.e. (1) het gelijktijdig ontwikkelen van zowel het circulaire businessmodel als het ontwerp van het product om zo coherentie te garanderen en (2) het ontwerpen van producten die relevant, gewild en kosteneffectief blijven gedurende meerdere gebruikscycli. De andere twee geïdentificeerde competenties zijn relevant voor ontwerpen die een operationele en coördineren rol vervullen: respectievelijk: (3) het doen van impact assessments en (4) het faciliteren van de samenwerkingen tussen stakeholders. Uit deze studie blijkt dat het linken van competenties aan de geïdentificeerde rollen geen eenduidige zaak aangezien rollen in de praktijk niet strak afgebakend zijn. Zo kan een designer die bijvoorbeeld een strategische rol vervuld betrokken zijn bij het

uitvoeren van activiteiten die horen bij een coördinerende rol. Vandaar dat het accent van het vervolgonderzoek werd verlegd naar het ontwikkelen van een set van sleutelcompetenties voor circulair ontwerpen.

De laatste drie studies in dit proefschrift (hoofdstuk 4-6) ontwikkelen op iteratieve wijze een set met circulaire ontwerp competenties. Hierbij richt elk hoofdstuk zich op het valideren en uitbreiden van de vorige set met competenties. In de drie onderzoeken worden er respectievelijk een focus groep, individuele face-to-face interviews en een internationale survey uitgevoerd. Tot de uiteindelijke set met internationaal herkende circulaire ontwerp competenties behoren: (1) Circulair Systeemdenken (2) Circulaire Business Modellen, (3) Ontwerpen voor Herwinning (4) Ontwerpen voor Meerdere Gebruikscycli, (5) Circulaire Materialen en Productie (6) Meten van Circulaire Impact, (7) Circulaire Betrokkenheid van Gebruikers, (8) Circulaire Samenwerkingen, (9) Storytelling over de Circulaire Economie, en, zie figuur ii.

Met de ontwikkeling van deze set van negen sleutel competenties voor circulair ontwerpen, draagt dit proefschrift bij aan de ontwikkeling van het veld van circulair ontwerpen. Het overzicht van negen sleutel competenties voor circulair ontwerpen biedt dan ook ondersteuning bij het creëren van een vocabulaire in de praktijk. De uiteindelijke set kan gebruikt worden als basis voor het curricula en methodologie te ontwikkelen.

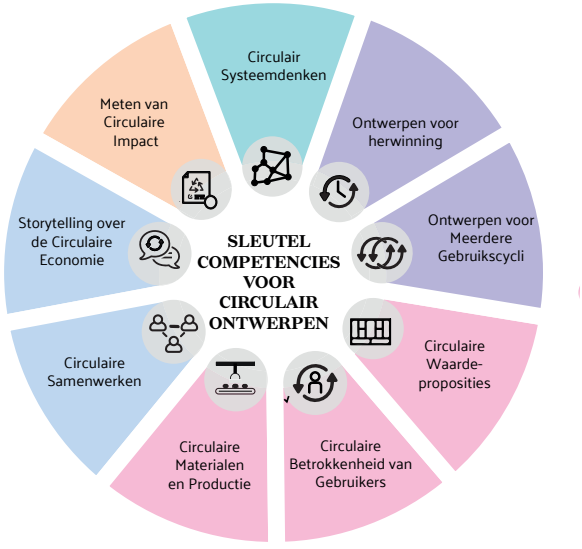

Figure ii Negen Sleutel competenties voor circulair ontwerpen

Het vermogen (om)

Circulair Systeemdenken
Een design aanpak die de circulaire economie als complex systeem ziet te kunnen toe-eigenen, waarbij wordt gehouden met het feit dat circulaire ontwerp interventies een systemisch effect hebben

Ontwerpen voor Herwinning
Product service-systemen ontwikkelen waarbij op voorhand in acht word genoment dat producten, componenten en materialen kunnen worden herwonnen en teruggevoerd kunnen worden in de circulaire economie.

Ontwerpen voor Meerdere Gebruikscycli
Product service-systemen creëren die ontwerpen zijn voor meer dan een gebruikscyclus en waarde behoud in een circulaire economie.

Circulaire Waardeproposities
Circulaire waarde proposities te kunnen ontwikkelen die gericht zijn op het volledig sluiten van product en materiaal stromen en waarbij grondstoffen zo lang mogelijk in gebruik worden genomen

Circulaire Betrokkenheid van Gebruikers
Gebruikers te betrekken in alle aspecten van de circulaire economie door, bijvoorbeeld, ze in staat te stellen voor (deel- en eigen) producten zorg te dragen en ze te stimuleren producten terug te geven aan het eind van de gebruikscyclus.

Circulaire Materialen en Productiemethoden
Materiaal en productiemethodes te kiezen en te gebruiken met zo min mogelijk impact (milieu, gezondheid en sociaal) terwijl tegelijkertijd rekening te houden met de volledige levenscyclus en herwinbaarheid van het product.

Circulaire Samenwerkingen
Samenwerkingen tussen stakeholders die de hele waardeketen doorkruizen te faciliteren om zo zowel circulaire product-service systemen te creëren als de transitie naar een circulaire economie te stimuleren.

Storytelling over de Circulaire Economie
Overtuigende visies en verhalen over de circulaire economie te creëren met als doel het draagvlak onder verschillende stakeholders te vergroten.

Meten van Circulaire Impact
Milieu, financiële en sociale impact op de transitie naar een circulaire economie te meten..

CHAPTER 1

INTRODUCTION

In this thesis, I describe my investigation of design competencies for a circular economy. To achieve this, I conducted a series of studies in which different research methods were applied. This chapter sets the scope for the main thesis topic and places the research in the context of industrial design in the circular economy. To start, I briefly introduce the circular economy. Second, I highlight the role and the meaning of design, and third, I elaborate on how to approach design in a circular economy. Fourth, I describe the perspective this thesis takes on design roles and competencies in more detail, and then, in section 5, I discuss the scope of the studies in this thesis. In section 6, I introduce the main research question and supporting research questions, explain the research design and provide the outline of the thesis. Last, in section 7, I detail the role of the researcher.

1.1 The circular economy

The world we live in has been built on a linear economy leading to growing pressure on the availability and use of the world's resources. We extract these resources to manufacture new 'stuff', which can then be sold to customers who often use it only once. They then discard this (once-only) used 'stuff', which inevitably ends up as landfill. This is known as the so-called take-make-use-waste model. The linear throughput of materials and energy form a challenge for sustainable development (Korhonen et al., 2018); the growing economic system takes resources from the planet, which has its physical boundaries, and gives it back as waste. The environmental impact of resource use has grown considerably since 1970, and currently, it consistently exceeds planetary boundaries (Rockström et al., 2009). The extraction of resources and conversion into materials, products, food and fuels causes "over 90% of biodiversity loss and water stress, and more than half of global climate change impacts" (International Resource Panel, 2019, p. 21). Moreover, the use of these resources can greatly impact conflict regions (United Nations Environment Programme, 2009). By taking measures that deal with this resource extraction and use, we can tackle 45% of the greenhouse gas emissions that come from producing physical products (Ellen MacArthur Foundation, 2019).

The circular economy, propagated by the Ellen MacArthur Foundation (2013) as "restorative and regenerative by design", offers an alternative to the linear economy. It brings together pre-existing concepts and academic field-related schools of thoughts such as Cradle to Cradle (Braungart et al., 2007), Performance Economy (Stahel, 2010), Biomimicry (Benyus, 1997), and Industrial Ecology (Frosch & Gallopoulos, 1989). A plethora of definitions have emerged around this new paradigm (Kirchherr et al., 2017).

In this thesis, the circular economy is viewed as a paradigm that focusses on reducing the pressure on resources by either slowing down (e.g. through repair, refurbishment and remanufacturing) and/or closing resource loops (through recycling), with the overall aim of lowering environmental impact (Bocken et al., 2016). The idea to cycle resources is not new, it was introduced by Boulding (1966) in his book Economics of Spaceship Earth. Boulding advocated that human kind should consider the limitations to what the earth can handle (e.g., planetary boundaries, see Rockström et al., (2009), and suggested that the output from consumption would have to be cycled and used as input for production. However, while Boulding only

advocated recycling material resources, the circular economy additionally focuses on slowing down the use of these resources: in a circular economy the focus on product lifetime extension along with material recycling is crucial. Further, the circular economy emphasizes the use of value recovery strategies (e.g., repair, refurbishment and remanufacturing, recycling) in the context of circular business models. These circular businesses models focus on slowing resource loops by prolonging the use of products and components in consecutive cycles, and closing resource loops by capturing material value left at a product's end of life (Bocken et al., 2019; Nußholz, 2018).

Research suggests that circular economy practices and business models can help the world achieve a number of sustainable development goals (SDGs) such as Clean Water and Sanitation (SDG6), Affordable and Clean Energy (SDG 7), Decent Work and Economic Growth (SDG 8), Responsible Consumption and Production (SDG 12) and Life on Land (SDG 15) (Schroeder et al., 2019). Specifically, circular economy can tackle the effects of greenhouse gas emission by focusing on the way products are made and used, using renewable energy (Ellen MacArthur Foundation, 2019). Schroeder et al. (2019) show that circular economy practices do not contribute to all SDGs, for example, there is a only weak link between circular economy practices and Good Health and Well Being (SDG3) and Gender Equality (SDG 5). However, it is clear that the circular economy can contribute to making the planet more sustainable.

In business circles, the Ellen MacArthur Foundation (EMF) has helped popularize the concept of the circular economy (Bocken et al., 2016). In recent years, thanks to its operational nature, it has been included in policy development (Ghisellini et al., 2016; Kirchherr et al., 2017; Murray et al., 2017). For example, at a national policy level, it has been incorporated in the Dutch program 'Nederland Circulair in 2050' (Ministerie van Infrastructuur en Milieu, 2016). At an international policy level, it has been incorporated in reports such as the European Circular Economy Package (European Commission, 2015) and the European Green Deal (European Commission, 2019). These national and international policy decisions show that the circular economy has become more directly relevant to our futures.

1.2 Role of design in a circular economy

The shift from the current linear economy to the envisioned circular economy requires a transition (Ellen MacArthur Foundation, 2015). Both the grey and academic literature suggest that design can play an important role in this transition (De los Rios & Charnley, 2016; Ellen MacArthur Foundation, 2019; EPEA, 2004). The European Commission emphasizes the role of design in creating a circular economy; the EU action plan for the circular economy states: "better design can make products more durable or easier to repair, upgrade or manufacture" (European Parliamentary Research Services, 2017, p.1).

Many products currently reaching their end of life have been in use for a long period and were manufactured many years ago. Hence, parties responsible for recovery have to deal with design decisions made up to sometimes decades ago (Tam et al., 2019). Moreover, the design decisions currently being made will affect future recovery opportunities (De los Rios & Charnley, 2016). Moreno et al. (2016) state that designers have a responsibility to contribute to the future of how products and services are built. Andrews (2015) even suggests that the role of designers is to facilitate and lead the development of a circular economy.

From an ideological perspective, literature attributes a large role to design due to its direct link with resource use. However, it is unclear precisely what role design will fulfil in practice. Design is never performed in a vacuum, but in a context shaped by society, i.e. design is part of an eco-system that influences the circularity of a system (Konietzko et al., 2020). Taking the perspective of product design being a part of an eco-system as a starting point, the question then becomes: how can design then realize the potential attributed to the profession in the context of a circular economy? Very little research has been conducted specifically on the role of design in a circular economy in practice. Therefore, in this thesis, the focus is on design for a circular economy, placing this work directly at the intersection of product design and the circular economy. To further unpack this, in the next section I define how product design is understood and discuss its potential for a circular economy. Subsequently, I frame design for a circular economy in the context of the domain of design for sustainability.

1.3 Design for a circular economy

This thesis is situated at the intersection of product design and a circular economy; therefore I begin this section with a definition of product design. Literature uses the terms product design and industrial design interchangeably (Heskett,

2002), as they both refer to the creation of objects, services and experiences. I have used the term product design as it is more widespread in design practice and my research is situated in this context. Yet, I acknowledge that most academic definitions use the term industrial design. Literature offers a range of perspectives as to what product design entails (e.g. Roozenburg & Eekels, 1995; van Boeijen et al., 2017). Historically, it was used to characterize a profession concerned with the creation of physical objects. Nowadays product design refers to the process of solving problems in (iterative) innovation cycles (Valtonen, 2005; van Boeijen et al., 2017) where 'end-products' can come in a plethora of forms, ranging from physical objects to intangible experiences, services, systems, or a combination thereof.

To ensure that my use of the term product design covers the full meaning of industrial design, I have based it on the following definition by the Design Organisation (2017).

> *"a strategic problem-solving process that drives innovation, builds business success, and leads to a better quality of life through innovative products, systems, services, and experiences. Industrial Design bridges the gap between what is and what's possible It is a transdisciplinary profession that harnesses creativity to resolve problems and co-create solutions with the intent of making a product, system, service, experience or a business, better. At its heart, Industrial Design provides a more optimistic way of looking at the future by reframing problems as opportunities. It links innovation, technology, research, business, and customers to provide new value and competitive advantage across economic, social, and environmental spheres."*

The focus on creating social and environmental value in addition to economic value further reflects the envisioned contribution of the design field to sustainability. Sustainable development became globally recognized as a complex societal problem after publication of the Limits to Growth report (Meadows et al., 1972). The report was published at a time when front runners in design were also starting to vocalize their concerns about the profession and the (lack of) responsibility design showed when it came to creating sustainable futures. Papanek (1971) stated that product design, after advertising design, was the second most harmful profession in the world. Buckminster Fuller (1969)

suggested that designers should start making the most out of less (i.e., resource efficiency). The influence of product design on societal issues such as sustainable development sparked the birth of the field of design for sustainability. Green design and eco-design (Brezet & van Hemel, 1997) were among the first approaches. Eco-design focusses on improving the environmental performance of products during their life cycles (Pigosso & McAloone, 2015). Since its emergence, the field of design for sustainability has expanded, and it now incorporates several movements, approaches and practices (Ceschin & Gaziulusoy, 2016).

This thesis frames design for a circular economy as a field within the domain of design for sustainability. Examples of emerging design for sustainability approaches since the development of eco design are: Nature Inspired Design (de Pauw, 2015), Sustainable Product–service Systems (Vezzoli et al., 2014), Design for Low Resource Settings (also knowns as Design for the Base of the Pyramid) (Crul & Diehl, 2006; Kandachar et al., 2011), Design for Social Innovation (Manzini & Coad, 2015; Meroni, 2007), and Transition Design (Irwin et al., 2015). Similar to other design for sustainability approaches, the main aim of design for a circular economy is to contribute to sustainability. Design for a circular economy specifically emphasizes high value and high quality cycling of materials, it connects sustainable production and consumption by means of sharing and reuse (Korhonen et al., 2018), and places the use of the value recovery strategies in a business context.

The Design for Sustainability research group (Bakker et al., 2014; Balkenende et al., 2017; Bocken et al., 2016; den Hollander, 2018) at the Delft University of Technology (TUD) has greatly contributed to the development of the vocabulary around design for a circular economy; when starting the field had no specific terminology. This vocabulary is rooted in and fed by work by Stahel (2010), McDonough and Braungart (2002), Tukker (2015) and the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2015). Examples of terminology that now form part of this vocabulary are "product integrity" and "resisting, postponing and reversing obsolescence"(Den Hollander et al., 2017). This can be explained as follows: design for a circular economy is an approach that aims to maintain product integrity over multiple use cycles. Following the inertia principle (Stahel, 2010), design approaches should focus on resisting, postponing and reversing obsolescence (Den Hollander et al., 2017). This means that design for long term use whereby the focus is on emotional and/or physical durability (resist) is prioritized over design for extended

use focusing on maintenance and repair (postpone) and design for recovery (reverse). Value recovery strategies such as repair, refurbishment and remanufacturing focused on maintaining integrity at a product level are thus prioritized over recycling, which is done at a material level. This principle is expressed in the value hill (figure 1.1.).

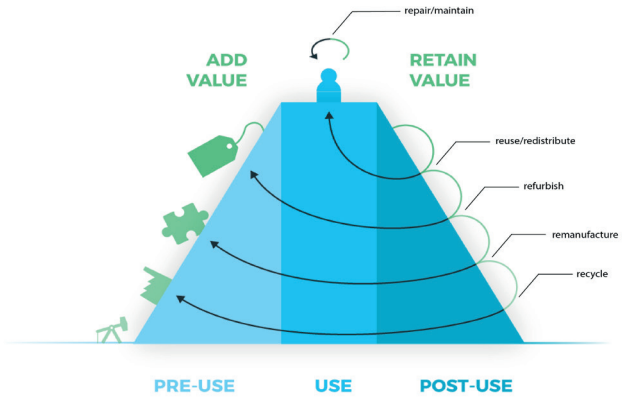

Figure 1.1 Value Hill (Achterberg et al., 2016)

Design for a circular economy also places product design in a business context, i.e., circular business models. Circular business models can help prolong product and parts' lifetimes through successive cycles of reuse, repair, remanufacturing, and closing material loops. A range of circular business archetypes are either product-oriented (Classic-Long Life), use-oriented (Access-based Model) or result-oriented (Performance Model) (Bocken et al., 2016; Tukker, 2015; Wastling et al., 2018). Access-based models and Performance Models are believed to result in more reliable return rates of products, as the ownership of the tangible product then remains with the company, and the customer pays for access to or performance of the product. The shift to using these models can be seen as an enabler for a circular economy. In these circular business models, customers become (temporary) users of products (De los Rios & Charnley, 2016). This changes both their relationship with a company and their expectation of the value propositions offered by that company (Catulli et al., 2014).

Altogether, this demonstrates the link between design and a circular economy. To further understand the practice of design for a circular economy, this thesis looks at design roles and competencies. In the next section, I elaborate on the link between design roles and competencies, the gap within the literature, and I formulate the study's main objective.

1.4 Design roles and competencies

A circular economy requires new competencies (EEA, 2016; Medkova & Fitfield, 2016). To advance circular economy practices and business models, more effort should be put on skills training and capacity-building programs, amongst others (Schroeder et al., 2019). Competencies can be acquired through basic academic education and professional training, and refined through professional practice (Wilcox, 2012); they can then be used to determine what must be taught to students and practitioners to become more 'competent' in a practice (Roe, 2002). Competencies can also be used to inform the development of education discourse (e.g. UNESCO, 2017) as well as methodology (Daalhuizen, 2014; Lindahl, 2005). Once an overview of design competencies for a circular economy is in place, this will, in turn, guide the development of circular economy-based education and methodology.

The wider scientific community, and the educational literature in particular, are not always aligned when it comes to defining competencies. Competencies are often used interchangeably with knowledge, skills, and attitudes (Lambrechts et al., 2013). Roe (2002) suggests that competencies are an overarching construct that build on knowledge, skills and attitudes. In this thesis, I use the definition of competencies which emerged in the context of sustainability literature: "a functionally linked complex of knowledge, skills, and attitudes that enables successful task performance and problem solving" (Wiek et al., 2011, p. 204). Competencies align with what is needed to perform tasks and activities within different roles.

Very little research has been conducted on the circular economy competencies related to design. An overview of circular design competencies by de Los Rios and Charnley (2016) forms the main reference point. This overview lists ten circular economy competencies for design, ranging from "understanding logistics and distribution processes" to "understanding the service experience and designing services". In this thesis, I build on this overview of competencies. Wiek et al. (2011) advocate the need for a "conceptually embedded sets of interlinked competencies" (p. 204). A set of key competencies is needed to support the further development of the field. Therefore, the aim of this thesis is to develop a coherent set of key circular economy competencies for design which will contribute to the development of products and services for a circular economy.

1.5 The Scope

The studies in this thesis were conducted with the aim of gaining a better understanding of circular design in practice, by learning from design practitioners actively involved in developing circular product and services. Roe (2002), in the field of psychology, argues that competencies are acquired in practice through a process of 'learning-by-doing'. As the aim is to generate a complete set of key circular economy competencies for design, this thesis does not zoom in on a specific sector, but includes a wide range of perspectives, experiences and activities from product designers working in different fields.

The focus is on those designers who score high on the ladder of design expertise i.e. expert designers (Dorst & Reymen, 2004). The choice to focus on these experts instead of novices (e.g., design students) was made based on the assumption that a low level of design expertise could interfere with the novelty that designing for a circular economy brings, i.e. learning from expert designers ensures there is a general expertise in design, and that the only 'new' factor is the focus on the circular economy. Therefore the focus is on those designers working in organizations with a proven track record in developing circular products and services; by investigating those designers who are pioneering the field of circular economy provides an indication of where this field is headed.

1.6 Research Questions, Research Design and Thesis Outline

Now the scope of the study has been determined, in this section I detail the main and associated research questions and the research design I used to develop a set of key circular design competencies. The main research question is:

What competencies do designers need in order to develop products and services for a circular economy?

Very little literature is available where empirical cases in which the changing roles and competencies of designers who operate within organizations that prioritize sustainability and circular economy are described (De los Rios & Charnley, 2016). The studies in this thesis investigated design roles and competencies in a circular economy. Table 1.1 gives an overview of the research questions explored and answered in each chapter. The aims of these questions were twofold: to (1) uncover competencies designers need to create circular products and services and (2), connect the identified competencies to the design roles designers can fulfil.

Due to the lack of published literature in this field, it was difficult to start the research by formulating hypotheses that could be tested using a deductive analysis. Therefore, the first studies were exploratory and inquisitive as I needed to gain an understanding of the nuances of the practice of design for a circular economy. The thesis used a problem-oriented research approach, i.e. it was focused on the research problem at hand and employed any method relevant to understanding the problem. The underlying belief is that there is not "one best type" of research method. Specifically, I applied a mixed method research approach, resulting in a rich understanding of the research problem. Additionally, this ensures that any potential bias that might have emerged from applying a single one research method, could be resolved. A series of methods (e.g., longitudinal, single case study, focus groups, and individual face-to-face interviews) were employed to overcome bias.

In this way, I was able to address the research question from different perspectives. The studies followed an inductive approach to contribute to theory building around circular economy competencies for design. Analyzing the activities and tasks of designers resulted in an understanding of what the profession entails and which competencies are needed. The insights gathered in each study were matched with the existing literature. Based on progressing insights and saturation across the studies, I was able to develop a coherent set of circular design competencies.

The structure of the thesis is presented in table 1.1 on p age 30; it shows the chronological order of the thesis, reflecting that the studies build on each other, and that with each study insights progress. Chapter 2 explores the design roles in a circular economy, chapters 3 - 5 iteratively build and validate the circular economy competencies for design. The qualitative studies described in chapters 2 - 5 used a small number ($n<20$) of cases and interviews which were rich in terms of information. Once the theory was built, it was tested in a survey with a large group of respondents (chapter 6) to verify the identified set of competencies. This resulted in a set of competencies that is both grounded within the scientific body of knowledge and empirically tested in practice. The thesis consists of 2 peer reviewed conference papers and 3 peer-reviewed journal publications.

1.7 Role of the researcher

As author of this dissertation and principal researcher, I was involved in each of the studies, setting up the research, collecting data, analyzing data, and reporting the studies. My presence in each study has helped maintain consistency when it comes to the interpreting data gathered within and between the studies. This is especially relevant, as I took an inductive approach. My educational background in industrial design engineering ensured that I could connect with the topic and the participants or respondents in the studies. As principal researcher in the five studies, I was able to overcome potential bias by: triangulating data (Yin, 2014), participating in working and brainstorm sessions with external stakeholders, and increasing intercoder reliability (Kurasaki, 2000) i.e., I shared pieces of transcripts of interviews with members of the supervisory team which were then independently coded (Gioia et al., 2012).

Table 1.1. Overview of the Studies

Chapter	Research Question	Research Methods
2	What is the role of designers in transition towards a circular economy?	Literature review on design roles in sustainability and circular economy Semi-structured Interviews
3	What are the roles and competencies designers need to contribute to the creation of circular business models in practice?	Literature review Longitudinal single case study
4	Which competencies are relevant for product designers working in industry?	Virtual focus groups with designers who are actively exploring circular economy opportunities
5	Which competencies (knowledge, skills, and attitudes) do designers need in order to successfully design products and services for a circular economy?	Individual face to face interviews with design professionals
6	Which circular economy competencies are recognized by an international set of design professionals who are exploring circular economy opportunities?	International Survey

Study	Output	Paper title[1]
1	Conference Paper	The role of product designers in the transition towards the Circular Economy: A Reality Check
2	Journal Paper	The role of product design in creating circular business models: A case study on lease and refurbishment of baby strollers
3	Conference Paper	Design competencies for a circular economy
4	Journal Paper	Circular economy competencies for design
5	Journal Paper	Key Competencies Design for a Circular Economy: exploring gaps in design knowledge and skills for a circular economy

1 The papers are presented in their original form with only a few spelling mistakes corrected and the references all adapted to the APA style. The layout and page numbers of the published papers have also been changed. The pronoun 'we' was used in chapter 2-6 to refer to the authors of the papers: Deborah Sumter, the author of this dissertation, and her supervisory team i.e., prof.dr.ir Conny Bakker, prof.dr. Ruud Balkenende, and in chapters 5 and 6, dr.ir. Jotte de Koning.

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CHAPTER 2

THE ROLE OF PRODUCT DESIGNERS IN THE TRANSITION TOWARDS THE CIRCULAR ECONOMY: A REALITY CHECK

This chapter has been presented at the 2nd Product Lifetimes and the Environment (PLATE) conference in Delft in 2017 and subsequently published in the conference proceedings as: Sumter, D X, Bakker, C. A., & Balkenende, A. R. (2017). The role of product designers in the transition towards the circular economy: a reality check. In C. Bakker & R. Mugge (Eds.), Product Lifetimes and The Environment Conference 2017 (pp. 391–396). https://doi.org/10.3233/978-1-61499-820-4-391.

Abstract

This paper examines the role of product designers in the transition towards the circular economy. Both scientific and grey literature show remarkable optimism when it comes to role strategic and coordinating role designers could play in this transition process. However, there has been little examination of the actual role and influence designers have in practice. In this paper we review the roles that designers play in the transition towards a circular economy according to literature. Through semi-structured interviews, we uncover the views of designers themselves, which we then use to make a comparison. Our main conclusion is that designers experience a lack of knowledge and/or work in predetermined solution spaces, which prevents them from taking on the role that is expected in literature.

Keywords

Designer's role; Product design; Practice; Circular economy; Transition

2.1 Introduction

Within literature statements like "Designers have a significant responsibility to shape the current status on how products and services are built" (Moreno et al., 2016:1) are not uncommon. As one of the first to talk about sustainable design, Buckminster Fuller (1969) envisioned that designers should engage in ephemeralization, a term coined to explain that designers should start "doing more with less", i.e. resource efficiency expanded on this thought Papanek (1971) in his book Design for the Real World, where he took an extreme stance against the role of the designer stating that 'there are professions more harmful than industrial design, but only a few of them'. Andrews (2015) argues that designers helped enable the linear economy and she suggests that they have the potential to facilitate and even lead the development of a circular economy. Finally, in the What Design Can Do manifesto 2017 van Lier (2017) claims 'Designers are pioneers, driving forces, flag bearers for change, active at micro and macro levels', echoing the perception that they fulfil prominent roles. These statements sparked a further investigation into visions that exist about the role of the designer in the transition towards a more sustainable system. Here we focus on the transition to the circular economy. In addition to a literature review we carried out interviews with designers from practice, addressing (1) their current role (2) their vision on the role designers should fulfil in the transition towards the circular economy and (3) the barriers they experience or foresee. We choose this method as a means to be able to make an objective observation of nuances between the visions in literature and practice.

2.2 Method

2.2.1 Literature Review

Using the evidence-focused literature review technique proposed by Hagen-Zanker & Mallett (2013), a literature review has been carried out to uncover the different perspectives regarding the roles and activities of designers in the transition process towards a circular economy. Following the protocol of Hagen-Zanker & Mallett (2013), grey literature was included when deemed relevant and snowballing was done via the reference lists of the selected sources. For retrieval initially the following search terms were used: ("role of" AND "product designer*" OR "role of" AND "industrial designer*") AND ("in transition") AND ("circular economy" OR "sustainability") within the timeframe 1950-2017 during October 2016 to February 2017 in Google Scholar.

Even though there is a slight distinction between product designers and industrial designers both are part of the world of so-called 'object design'. Heskett (2002) describes them as "virtually interchangeable", because there is a focus on making an 'object' in both professions. Therefore, the final search terms include both types of designers.

2.2.2 Semi-structured interviews

Within the research domain of 'organizational role theory' (Biddle, 1986), roles in organizations are seen as "social systems that are pre-planned, task-oriented and hierarchical" (Biddle, 1986:73). As the purpose for doing interviews with designers from practice was to learn more about their current and prospective roles, they were queried about their job descriptions, their place in the work hierarchy, and the activities performed as part of their position. In February 2017, eight semi-structured interviews (Patton, 2002) were conducted. All participants were educated as product designers. Their wide range of positions (from product designer to sustainability manager or CEO of a design agency) ensured different perspectives were included and made it possible to widely reflect on the results from literature.

2.3 Results

The initial search yielded a total of 51 articles. Articles were excluded based on the absence of a vision on the role of designers. This left 12 articles after exclusion, which were used to 'snowball' to 41 articles. Looking at the literature review results; three categories were formulated:

2.3.1 Literature

- The designer's role in general.
- Developments in the role of the designer over time
- Visions on designer's roles in the future

The designer's role in general

The role of designers has been described from varying perspectives. Across different fields, the major roles that could be identified were a (1) strategic role (2) coordinating role and (3) a functional role.

Strategic role

Designers operating in a 'strategic role' are, are involved in the development and execution of (company and/or product) policy/strategy, and are responsible for formulating an overall, integrated vision for future solutions (Joore, 2010; Papanek, 1971).

Table 2.1.Future visions on designer's roles

	FUTURE VISIONS OF DESIGNER'S ROLE			
	Field	**Role Designer**	**Quote**	**Citation**
1	Design for Sustainability	Facilitators	From thinking of ourselves as the authors of a finished work, we had better evolve toward thinking of ourselves as facilitators whose job is to help people act more intelligently, in a more design-minded way, in the systems we all live in. (Thackara, 2006, p. 214)	Thackara (2006)
2	Transition Design - Critical Design	Social Visionaries Intermediary,	[...] Social Practice Theory demands that designers acknowledge their responsibility for determining how our societies are made durable (to paraphrase Bruno Latour). Tonkinwise (2015).	Tonkinwise (2015)
3	Design for Sustainability	Solution provider, Coordinator	And agreed, the designer can play a significant intermediary role between a diversity of actors in and around the company. [....] Joore (2010, p. 44;). [...] the role of the designer could be broadened to more of a coordinating role between or above the parties. (Joore 2010, p. 199)	Joore (2010)
4	Design for Sustainability	Social and environmental responsible	Victor Papanek (1971) called for designers to integrate more social and environmental responsibility in their work in his manifesto Design for the Real World: Human Ecology and Social Change. (Tan 2012, p. 113)	Tan (2012); Papanek (1971)
5	Design for Sustainability	Social and moral responsible	Thirty years ago, Buckminster Fuller (1969) [...] called for designers to adopt more social and moral responsibility in their work. (Tan 2012, p. 2).	Tan (2012); Buckminster Fuller (1969)

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6	Design for Social Innovation	Connectors, Facilitator, Quality Producers, Visualisers, Visionaries, Future Builders, Promotors of new business Models, Catalysers of Change	Understanding the new designer role: designers as connectors and facilitators, as quality producers, as visualizers and visionaries, as future builders (or co-producers). Designers as promoters of new business models. Designers as catalyzers of change. (Manzini 2009, p. 11)	Manzini (2009)
7	Social Innovation	Facilitator	Both companies and designers will no longer be proponents of a set of products and services to passive users, but rather the facilitators of a system of value co-production. Therefore, they will lose the central role they had in the previous contextual condition, and become catalyzers in a networked system. This requires [...] designers learn new methods and languages to operate in the new context. Morelli (2007, p. 18)	Morelli (2007)
8	Social Design - Participatory Design	Questioner, Maker	(1) For some of the participants its role should be 'the questioner', which means that designers should support the stakeholders involved in a process by highlighting issues and key aspects. [...] (2) Other participants stated that the context analysis is not the core competence of design in social innovation, instead they were suggesting 'making': visualizing, prototyping and showing as the ability of designers to bring to life participants' ideas and imagination and support them in prototyping processes for finding opportunities and possibilities. (Emilson et al, 2011, p. 26)	Emilson et al. (2011)

9	Design for Sustainability	Strategic Role	"Change actors like designers play a strategic role in innovation and transition processes towards a sustainable society." Joore & Brezet (2015, p. 92)	Joore and Brezet (2015)
10	Design Methodology	(Knowledge) Brokers	Jin (2015, p. 44) refers to Daalhuizen (2014), who suggests designers can act as brokers to bridge different stakeholders and democratize collaboration processes.	Jin (2015); Daalhuizen (2014)
11	Design Methodology	Teamwork leaders	Jin (2015, p. 44) cites Smulders and Subrahmanian (2010): As coordinators and managers, designers can act as agents to lead teamwork and incite change in stakeholders who aren't necessarily educated in design..	Jin (2015); Smulders and Subrahmanian (2010)
12	Design for Sustainability (Eco-design)	Strategic	Designers have the potential to create innovative solutions for less environmentally damaging products and product systems. [...] The more a designer is involved in strategic planning issues (i.e. determining what product the company will be developing), the more influence he or she will have on the potential environmental impact of the product. (Bakker, 1995, p. 8)	Bakker (1995)

This also entails being involved in the product development process early on (Bakker, 1995; Behrisch, 2013), developing the framework within which functional products will be developed (C. A. Bakker, 1995), initiating projects and leading the design in the intended direction (Seidel, 2000; Perks et al., 2005).

Coordinating role

Designers in a 'coordinator role' are focused on balancing different interest and ideas among a group of stakeholder (Behrisch, 2013; Battiston, 2015; Manzini & Coad, 2015; Ortiz, 2012; Tan, 2012; Julier, 2007). They facilitated, support and enable the conversations between these actors (Tan, 2012) and form a bridge through which this knowledge transfers and is translated to the design discourse (Battiston, 2015; Verganti, 2008).

Functional role

Within the 'functional role', the "designer's task is to translate a product idea into a concrete product" (Bakker, 1995:43; Behrisch, 2013). Designers carrying out this role are involved from product idea to an implementable solution (C. A. Bakker, 1995) and focus on the materialization of the product rather than the development of the higher level product policy. Note however, that the roles are not mutually exclusive; one person can fulfill multiple roles.

Developments in the role of the designer over time

Valtonen (2005) is one of the few authors who gives an overview of how the role of the industrial designer has broadened since the emergence of the field in the 1950s. She describes how designers have evolved from creators of objects (functional role) to innovation leaders (strategic role) in the 2000s (Maciver, 2011; Valtonen, 2005). While Valtonen's (2005) research is limited to the Finnish designer, a similar widening in the role is being echoed in other fields (Joore & Brezet, 2015; Meroni, 2007; Thackara, 2006; Gaziulusoy, 2015; Bakker, 1995; Banerjee, 2008; Maciver, 2012; Roth, 1998). Jin (2015) in additional mentions a broader role as coordinator. The evolution to a wider role, seems to be connected to designers having to work on progressively complex problems (Gaziulusoy, 2015; Roth, 1999).

Visions on designer's roles in the future

In the table 2.1: Future visions of designer's roles we see parallels with the former categorization of roles. Although most authors do not explicitly place the envisioned roles in the context of a transition, the fact that the visions stem from authors within a field that differs from the status quo reflect which roles are assumed in the transition process towards

more sustainability/circularity. While authors call on designers to adopt more social and moral responsibility in their work in general (Buckminster Fuller, 1969; Papanek, 1971; Tonkinwise, 2015) some assign specific roles. First of all, the role of coordinator (Thackara, 2006; Morelli, 2007; Jin, 2015; Daalhuizen, 2014). Manzini (2009) and Joore (2010) envision a strategic role in addition to this. In contrast, Emilson et al. (2011) conceptualize that designers should fulfill a functional role in addition. Lastly, there are also authors, who rather only foresee a single strategic role (Joore & Brezet, 2015; Jin, 2015; Bakker, 1995; Smulders & Subrahmanian, 2010). In short, the overview reflects that there is an overlap in the visions across the three main roles and that these visions stem from a sense of responsibility.

2.3.2 Practice

Background Interviewed Designers

The categorization of owners (participant 1-4, all owning a small consultancy) versus non-owner (participant 5-8, all employed in a large organization) determined whether or not the designer was involved in strategic decision making (table 2.2: Background Interviewed Designers). Even though the non-owners in some cases mentioned that they were involved in more strategic roles (e.g. building and managing of teams, and leading projects), they are not in the position to determine the overall company strategy regarding sustainable design. Interviewee number 5 and 6 mentioned that depending on the project they alternated between a more strategic role and a functional role.

Four interviewees out of eight said that they see it as their responsibility to actively acquire knowledge regarding sustainability (or circularity), while one interviewee mentioned that acquiring and implementing knowledge on sustainability was part of an actual company assignment. This company strategy was employed to create more buy-in within the company the designers were working in. The interviewees, who mentioned that they acquired knowledge based on their intrinsic motivation, did this inter alia to be able to convince clients about their capabilities.

Barriers recognized by designers

The interviewees were also asked to describe an ideal sustainable project that was meant to stimulate the transition towards sustainability and the role that they would envision themselves in. They were then asked which barriers they would realistically foresee regarding this project, based on everyday experiences. This resulted in the overview in table 2.3: Barriers recognized by designers. Seven out of eight designers

Table 2.2. Background Interviewed Designer

	1	2	3
Company Type	Design Consultancy	Circular Business Developer	Design Consultancy
Owner	Yes	Yes	Yes
Position	CEO/ Product Designer	CEO/ Innovation director/ Product Designer	CEO/ Product Designer
Company Size	< 10	< 10	< 10
Higher level project activities			
• Acquisition of projects	x	x	x
• Leading (Design) Projects	x	x	x
• (Actively) Managing Teams		x	
• Making links between projects		x	
• Finding Partners	x	x	x
• Guiding clients and guarding design process			x
Internal Activities			
• Strategic Decision Making	x	x	x
• Building Team			
• Transferring knowledge on sustainability and CE (external workshops)	x		
Design Activities			
• Designing Products	x	x	x
• Designing Strategies			
External Activities			
• Acquiring knowledge on sustainability and CE	x		

4	5	6	7	8
Strategy Consultancy	Design Consultancy	Design Company	OEM	OEM
Yes	No	No	No	No
CEO/ Strategic Designer	Product Designer/ Project Leader	Senior Designer	Sustainability Manager	Design Lead
< 10	> 500	> 500	> 500	> 500
x				
x	x			x
x	x		x	x
x				
x				
		x	x	
	x	x	x	
	x			
x	x			x
x	x	x	x	

envisioned a strategic role for themselves rather than a functional or coordinating role. Within a strategic role, they especially recognized the ability to be a visionary and/or the need to be a role model for other designers. However, two designers mentioned a fear of becoming a 'preacher' (e.g. someone who constantly talks to others inside and outside the company about the absolute and correct way to reach more sustainability/circular).

In terms of barriers, all eight designers foresee problems with the long-term commitment and ability of clients to deal with setbacks during the transition to a circular economy. Overall it is apparent that while the owners of the agencies (participants 1-4) already are fulfilling a role that could be qualified as more strategic, they also foresee more barriers for designers to make the transition to a circular economy.

2.4 Discussion

Our results indicate that theory and empirical data only partially overlap. Firstly, literature shows three major roles: strategic, coordinator and functional. While the interviewed designers agree with a vision in which they fulfill a strategic role in the transition, they also foresee barriers within this regard. Some of them being the lack of know-how to find or create the right business case, not knowing how to assess the sustainability/circularity of an idea and not knowing how to apply systems thinking to come to a solution. Additionally, five designers imagined that working in a pre-determined solution space as a result of the functional role (as recognized by Koo (2016)) that they were carrying out, would be a barrier in the transition to carry out the envisioned strategic role. With respect to this, one designer working in a predetermined solution space in a design consultancy mentioned company culture, client interest and lack of government policy as additional barriers (in literature also recognized by Behrisch (2013)).

Secondly, the group of designers from practice mentioned the coordinating role only once when talking about the envisioned role. Instead, in practice it seems that designers foresee themselves fulfilling a strategic role. However, they foresee quite some limitations and boundary conditions that limits their possibilities. This might be connected to the fact that four of the interviewed designers actually already work in the positions in which they fulfil activities that overlap with those fulfilled in a strategic role. Through this they might have already experienced successes in executing sustainable projects. This in

turn could have led them to extrapolate the vision in which they fulfill a strategic role. However, they also seem to be the ones foreseeing more barriers. This can be attributed to the fact that they do indeed have more opportunities to experiment more freely, hence they get confronted with more barriers.

Lastly, the interviewed designers showcased an intrinsic motivation to diminish the negative impact of products they design on the environment and society. They added that designers, apart from the role they already play, should always be critical 'questioners'. Yet, they express concerns of becoming a 'preacher'. This means that the impact of their efforts might be smaller than they would like it to be as they adjust their communication. Instead they might propose incremental sustainable solutions. In comparison, we see that the visions from practice provide more nuance towards the strategic role of designers and instead add insights regarding the foreseen barriers.

2.5 Further Research

The research described here shows that there are promising paths for further research into the role of the designer in the transition towards the circular economy. Future research should deal with the limitations of this investigation. First of all, the small sample size of only eight participants hampers generalization of the results. In addition, the interviewed group did not cover designers working in middle-sized companies, while this could have led to different observations. Further research should therefore focus on selecting a larger and more heterogeneous sample in terms of designers working in a specific position. Moreover, the external barriers mentioned need to be validated in further research.

Further exploring the designer's role will be particularly relevant for insight in the development of skills, competences and capabilities, required to enable designers to optimally fulfill the various roles that are requested when working in different positions. Lastly, the scope of this research was limited to visions within the design field when it comes to the role of the designer. Future research should show whether other fields also mention that designers should play a specific role.

Table 2.3: Barriers Recognized by designers

	1	2	3	4	5	6	7	8	Total
INTERNAL (COMPANY)									
Knowledge/Training -CE Related									
• Not knowing how to assess circularity of an idea	x	x		x	x	x			5
• Not having the know-how to find or create the right business case	x				x	x	x	x	5
• Not knowing how to use systems thinking to come to a solution		x				x	x	x	4
• Not having access to courses about CE			x		x				2
• Not having access to the (right) methods fitting the CE rhetoric	x						x		2
Self Criticism									
• Fear of becoming a preacher	x					x			2
Position									
• Not being involved in decision making (as a designer)		x	x	x	x			x	5
• Having to work in a predetermined solution space	x	x	x		x			x	5
• Not getting the opportunity to acquire and knowledge					x			x	2
• Not being involved in the development of company policy					x				1
• Having to create your own space as a (CE) designer		x							1
Recruitment									
• Finding the right people to work with	x	x		x		x			4
Strategy									
• No strategy/scope for CE	x				x			x	2
Long Term									
• Having the patience to deal with setbacks, when committing to CE/sustainability	x	x			x			x	4
EXTERNAL (COMPANY)									
Knowledge/Training									
• Not getting the opportunity to transfer knowledge to clients			x						1

	1	2	3	4	5	6	7	8	Total
Recruitment									
• Not finding the right partners to work with			x					x	2
Projects/Clients									
• Clients not being interested in (real) CE		x		x	x		x		4
• Clients' priorities within sustainability projects		x	x	x					3
• Lack of projects with a sustainable focus				x					1
Circular Buy-In									
• Ability to bring together a network of partners to develop a CE solution		x	x	x	x	x	x		6
Long Term									
• Not having the patience to deal with setbacks, when committing to CE/sustainability	x	x	x	x	x	x	x	x	8
• Not having enough financial resources	x	x			x				3
• Clients not being ready to accept (big) change	x	x							2
Examples									
• Lack of successful scalable examples to learn from				x					1
CUSTOMER									
• Consumers not caring enough about sustainability				x		x		x	3
GOVERNMENT									
Policy									
• No policy in place		x							1
• Designers not being involved in policy development					x				1
• No conditions/incentives created to invest/support CE					x				1
Exciting conditions									
• Virgin/low-quality resources being cheaper					x	x			2

2.6 Conclusion

This paper explored the current role of the designer, visions in literature about the desired role of designers in the transition towards the circular economy and the barriers perceived in practice. Within literature the main visions are that the designer should assume a strategic or a coordinating role. Designers/owners working in small sized agencies agree with the first role, which covers activities that they currently already perform. However, they experience and foresee barriers to be able to fulfill this role, such as having to work in a predetermined solution space and lack of knowledge about assessment. There seems to be less agreement on the role as a coordinator, which is frequently mentioned in literature, but not by the interviewed designers working in practice. This study paves the way to explore the type of skills, competences and capabilities designers need to develop in order to play the most effective role in the transition towards the circular economy.

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CHAPTER 3

THE ROLE OF PRODUCT DESIGN IN CREATING CIRCULAR BUSINESS MODELS: A CASE STUDY ON LEASE AND REFURBISHMENT OF BABY STROLLERS

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Abstract

In the transition to a circular economy companies are exploring new business models, implying a shift from selling products to offering products in circular business models, such as leasing. Product design is thought to play a crucial role in enabling this. Having a robust overview of relevant design roles and competencies is of foundational importance for the development of circular design tools and methods, and for the development of circular economy-based design curricula in higher education. However, how the role of design and the competencies required by designers need to change has hardly been investigated. Building on insights from literature regarding competencies of designers required to consider sustainability, sustainable design, and circular design, we developed a framework in which these competencies are related to the functional, coordinating, and strategic roles that have been recognized within the literature for designers. To complement the results from the literature with insights from practice, a single longitudinal in-depth case study was carried out describing a lease and refurbishment pilot conducted by a Dutch design-driven manufacturer of baby strollers. This case study allowed verification of the literature regarding the functional and coordinating roles of the designer. In addition, we were able to fill the gap observed in the literature regarding the strategic role product designers can assume when designing offers for circular business models. The competencies that we found are (1) the ability to concurrently develop the circular business model and the product's design and (2) the ability to anticipate how the circular offering will evolve over multiple lifecycles. These findings have been used to expand the framework.

Keywords

circular economy; product design; refurbishment; alternative ownership model; lease model; design competencies

"A new role for design is to lead clients on the circular economy." (Sherwin, n.d.)

3.1 Introduction

This paper addresses the role of product design in the creation of circular business models. A circular business model describes how an organization creates and captures value in a circular economy; it distinguishes itself from traditional ('linear') models by its focus on high value and high-quality material cycles (Korhonen et al., 2018, p. 45). In the words of Den Hollander, circular business models aim to preserve product integrity to a maximum extent and achieve the most complete cycling of materials possible (den Hollander, 2018, p. 84). It is likely that this requires product designers to work more closely with strategic business functions, such as marketing, and, as such, this would recast the role of product design as a co-shaper of business strategy (den Hollander, 2018).

An example of a circular business model is a combination of an access-based payment model, such as a product lease, with a value recovery strategy, such as refurbishment. Leasing models are thought to give manufacturers control over their products over the life cycle and result in reliable product return rates. This would facilitate the recovery of the value embedded in products (Ellen MacArthur Foundation, 2015). Hence, the shift from selling products to providing access-based payment models is considered an important business model for a circular economy. Product design then also includes the design of the associated service.

Product design's role in shaping a circular economy is often described as pivotal. The Ellen MacArthur Foundation, for instance, states: "At its core, a circular economy aims to 'design out' waste. Waste does not exist–products are designed and optimized for a cycle of disassembly and reuse" (Ellen MacArthur Foundation, 2015, p. 7). In a similar vein, Thomas (2013) argues "Design will play a key role in the transition to a circular economy." This sentiment is echoed by the European Commission, for instance, in their recent European Strategy for Plastics in a Circular Economy: "...where the design and production of plastics and plastic products fully respect reuse, repair and recycling needs and more sustainable materials are developed and promoted" (European Comission, 2015, p. 5).

In spite of the widespread recognition of the importance of design in a circular economy, there is very little empirical research into the role of design during the development of a circular business model. De Los Rios and Charnley (2016), for instance, argue that the current literature lacks case-based

evidence of changing skill sets of designers, who increasingly need to operate in businesses that prioritize sustainability and circular economy. Having a better understanding of this role and the associated design skills would be of great value for design practitioners and for the education of design students.

This paper aims to identify, map, and complement designers' roles and design competencies for the creation of circular business models in practice with insights from the literature. The term 'competency' is defined as 'a functionally linked complex of knowledge, skills, and attitudes that enable successful task performance and problem solving' (Wiek et al., 2011, p. 204). A detailed insight in design roles and associated competencies forms the foundation for the development of circular design methods and tools, and the development of circular design curricula. The methods used in this study are a literature review and an in-depth analysis of a longitudinal case study of a lease and refurbishment pilot conducted by a Dutch manufacturer of baby strollers. The literature is reviewed in order to develop a framework that organizes different sustainability and circularity-related competencies against three different design roles. The case study is used to verify and (possibly) expand the framework.

The paper is structured as follows: First, the results of the literature review are presented and summarized in a framework. Next, the case study is described and the results are elaborated. Finally, these findings are discussed in order to arrive at an adapted framework.

3.2 Background

In this section we develop a framework in which different roles and competencies of designers are mapped, based on the literature on sustainable and circular design. Design for sustainability aims at minimizing environmental impact. Circular design strongly focuses on resource efficiency, striving for closed-loop systems. The simultaneous need of economic viability leads to the ambition to maintain product functionality over multiple lifecycles. This makes product lifetime a key concept in a circular economy. Circular design can be considered as a part of design for sustainability with a number of more specific aims.

3.2.1 The Changing Role of Design

Ceschin and Gaziulusoy (2016) describe how the role of design for sustainability has been expanding over the past decades, from the development of single products to complex systems, reflecting a shift from relatively isolated design

solutions (i.e., improving a product's energy efficiency) to systemic design innovations (i.e., developing a sustainable product-service system). Within this expanding field of influence, three distinct roles for designers can be identified (Sumter et al., 2017). First, the traditional role of product designers will be referred to as 'functional'. This is a role in which designers are mainly tasked with developing industrially-produced products based on a design brief (Julier, 2007; Manzini & Coad, 2015) , meaning that they are involved after the product brief is developed. Second, the coordinating role: a role in which designers build new partnerships, set up stakeholder interactions (Tan, 2012), and balance the interest of these stakeholders (Manzini & Coad, 2015; Sumter et al., 2017; Vezzoli et al., 2014). It also entails making internal (personal) connections between departments in order to enhance the understanding and increase team-working (Perks et al., 2005). The third role identified in the literature is the strategic role. Designers fulfilling this role are involved in the design process early on (Behrisch, 2013), determine the scope in which a product or service will be created, develop future visions (Joore, 2010), and initiate and lead projects (Perks et al., 2005; Seidel, 2000).

Design Roles and Competencies

Different roles require different competencies. On a generic sustainability level, not specifically related to product design, Wiek et al., (2011) list five competencies that are considered essential to sustainable development: (1) the ability to determine sustainability values and act upon these, which requires the use of sustainability assessment methods such as life cycle assessment (i.e., normative competency); (2) the ability to organize and facilitate collaboration between stakeholders (i.e., interpersonal competency); (3) the ability to design and implement transition strategies aimed at increasing sustainability (i.e., strategic competency); (4) the ability to analyze systems on different levels (i.e., systems-thinking competency); and (5) the ability to create future visions geared towards increasing sustainability (i.e., anticipatory competency). These competencies are also identified by de Haan (2006) and (Rieckmann, 2012). Related to product designers, the first one can be considered part of a functional design role, the second one belongs to a coordinating role, while the latter three are related to a strategic role.

Ceschin and Gaziulusoy (2016), list the following competencies needed to fulfil strategic and coordinating roles when designing sustainable product-service systems: (1) the ability to address sustainability at an integrated level; (2) the

ability to create shared visions to orient innovations; (3) the ability to create relations between different stakeholders; and (4) the ability to facilitate co-design processes. Vezzoli et al. (2014) write that designing sustainable product-service systems requires the following strategic competencies: (1) the ability to design an integrated product-service combination that meets a single user demand; (2) the ability to design the stakeholder interactions needed to operationalize a product-service system; and (3) the ability to design locally-based, cohesive offers with the aim to increase eco-efficiency and social equity.

De los Rios and Charnley (2016) are the only authors who focused on design competencies specifically for creating closed loop products (i.e., circular business models). Using case study research, they identified ten design competencies necessary to create products for closed loops, based on cases with Nokia, Philips, IKEA, Audi, and others, who developed circular business models. All of the competencies identified relate to functional roles of designers, such as "understand logistics and distribution processes", and "understand the service experience and how to design services" (De los Rios & Charnley, 2016, p. 118). All ten competencies are listed in Table 3.1. In their discussion of the results of their study, de los Rios and Charnley conclude that "some industrial transformations involve a barely noticeable change in the role of design,…, while others represent increasing technical challenges for designers or extended responsibilities" (De los Rios & Charnley, 2016, pp. 116–117).

Framework: Competencies Related to the Design for Sustainability and Circularity

Based on the review of the literature above, it is now possible to map the different design roles and competencies described in the literature. The framework in Table 3.1 lists the different roles product designers can assume (i.e., functional, coordinating, and strategic), and the competencies described in literature within the context of sustainability (De Haan, 2006; Rieckmann, 2012; Wiek et al., 2011), sustainable design (Ceschin & Gaziulusoy, 2016; Vezzoli et al., 2014) and circular design (De los Rios & Charnley, 2016). The competencies are listed from left to right from high-level sustainability to circular-economy specific. Further, similar competencies listed by different authors are categorized in the same row. For instance, Wiek et al. (2011), Ceschin and Gaziulusoy (2016) and Vezzoli et al. (2014) all describe competencies related to organizing and facilitating stakeholder interaction, which are all listed under the coordinating role.

Table 3.1. Roles and competencies for sustainable and circular design.

Role of Designer	**General Sustainability Competencies**	**Design for Sustainability Competencies**	**Design for Circular Economy Competencies**
	Wiek et al. (2011), de Haan (2006) and (Rieckmann, 2012)	Ceschin and Gaziulusoy (2016) and Vezzoli et al. (2014)	De los Rios and Charnley (2016, p. 118)
Functional	Normative: "Collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets" (Wiek et al., 2011, p. 209)		
		"Design ... the satisfaction of a particular demand ... and all its related products and services" (Vezzoli et al., 2014, p. 51)	"Understand the service experience and how to design services" "Understand user expectations and perception of value" "Understand factors of the use experience" "Understand processes for reverse and re-manufacturing" "Assess material physical and chemical properties "Understand product wear by use" "Understand engineering functions of the product" "Understand failure mode and maintenance procedures" "Solve aesthetic and structural problems with limited supplied components" "Understand logistics and distribution processes"

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Coordinating	Interpersonal: "Motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving" (Wiek et al., 2011, p. 211)	"Design … the interactions of the stakeholder of a particular satisfaction-system" (Vezzoli et al., 2014, p. 51) "Acting as facilitator to stimulate a strategic dialogue and co-design processes" (Ceschin & Gaziulusoy, 2016, p. 149) "Contributing to create relations between a variety of stakeholders of a value constellation" (Ceschin & Gaziulusoy, 2016, p. 149)
Strategic	Strategic: "Collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability" (Wiek et al., 2011, p. 210)	"Design … [offers] that continuously seeks new, beneficial eco-efficient and socially equitable, locally based and cohesive solutions" (Vezzoli et al., 2014, p. 51)
	Systems thinking: "Collectively analyse complex systems across different domains … and across different scales …." (Wiek et al., 2011, p. 207)	"Addressing sustainability operating on the integrated system of products, services and communication through which a company (or an institution, NGOs etc.) presents itself" (Ceschin & Gaziulusoy, 2016, p. 149)
	Anticipatory: "Collectively analyse, evaluate, and craft rich 'pictures' of the future related to sustainability issues …" (Wiek et al., 2011, p. 207)	Creating clear, comprehensible and shared visions to orient innovations" (Ceschin & Gaziulusoy, 2016, p. 149)

Based on this mapping, a gap was identified; all competencies listed for circular design are of a functional nature. In addition to this paper's main objective of identifying and mapping designers' roles and competencies for the creation of circular business models, we will, therefore, use the case study to seek for evidence of coordinating and strategic roles and competencies for circular design.

3.3 Methods

3.3.1 Case Study Research

We performed case study research on a single, longitudinal case on the development of a lease and remanufacturing system for baby strollers. This specific pilot, which ran over a period of two years as part of a four-year EU H2020 FP7 project, was chosen for two reasons. Firstly, a single longitudinal study allows to dive deep and obtain insight in the details of the case. (Dyer & Wilkins, 1991) argue that studying a single case in depth helps uncover details that are rooted within the context of the case. Given the emerging nature of circular design, such detailed case studies are especially relevant at this stage.

Secondly, baby strollers have received sustained interest in the literature as a promising product for an access model, which provides a basis for comparison with previous work. (Mont et al., 2006) describe a feasibility study of a lease and remanufacturing business model for baby strollers, noting that the short time of use and high recovery value of the (high quality) baby strollers makes this a very interesting product group for such a business model (Catulli et al., 2014, p. 7), however, find that product-service systems are often too focused on functionality and that highly-visible products, such as baby strollers, require companies to fully understand the 'complex symbolism and hedonic value consumers attribute to that product'. Clearly, the design of an access model for baby strollers requires the creation of an enticing value proposition, as well as a product that can be refurbished efficiently. This case study thus gives us an opportunity to identify relevant design competencies for different design roles.

The case is recorded from a constructivist viewpoint, meaning that we focus on gathering empirical data from research activities and experiences from individuals in the real world (Moses & Knutsen, 2012; Prendeville et al., 2016). Experiences are reported from the perspective of the individuals involved in the project (i.e., the lead designers).

3.3.2 Data Collection

Data collection was done through desk research (online project documents), informal talks and observations during bi-annual project meetings, design workshops that were held as part of the EU H2020 FP7 project, and semi-structured interviews. Using the project documents, a timeline of the pilot was reconstructed, including the involved parties and the (design) methods and tools used. Next, an interview guide was developed based on the gaps found when constructing the timeline. Three semi-structured interviews (Patton, 2002)were conducted between May and July 2017 at the headquarters of the company and over the phone. The respondents were the Senior Lead Designer (SLD), who is also the Vice President of Sustainability, and the Innovation Marketing Manager (IMM), who has a background in strategic design. They were selected based on their involvement in the EU H2020 FP7 project. Interviews were conducted in Dutch, transcribed verbatim and translated to idiomatic written English during analysis. Additionally, one design workshop was recorded and transcribed verbatim, while during the other project meetings extensive notes were taken. Table 3.2 gives an overview of the topics that we addressed and sample questions per topic.

3.3.3 Data Analysis

For the analysis of the collected data we followed coding and data reduction strategies (Charmaz, 2006; Miles & Huberman, 1984). First, we applied in vivo coding when coding the interviews line-by-line. This provided us with first-order codes, which we categorized into narrower second-order codes relating to the company, the pilot, design activities, the design process, barriers, learnings, and used methods. The notes that we made during the interviews, workshops and meetings were used as secondary sources that helped substantiate the categories. Next, we analysed the role of the designers by reviewing the type of activities and responsibilities they described and compared these with the roles defined in literature. The competencies were derived by reviewing the barriers and learnings relevant to design. Subsequently, we categorized the competencies based on the classification of roles (i.e., functional, coordinating, and strategic) and contrasted them with the framework in Table 3.1. Hence, it became clear which competencies corresponded to the ones already found in the previous literature and which new circular competencies emerged based on this case. Lastly, as advised by (Voss et al., 2002), the participants of the interview were asked to check a draft version of the paper and verify details. This gave them the opportunity to correct factual mistakes.

Table 3.2. Interview topics and sample questions.

Topics	Sample Question
The ResCoM-pilot	What was the main motivation in setting up the pilot? Who were involved executing the pilot and what was their role?
Role of product design and designers in a circular economy	Could you elaborate on the main change you had to make to the product design of the strollers to make them it in your circular value proposition? Based on your experience within ResCoM, how would you describe the role of industrial design(ers) in the transition towards a circular economy?
Design process	To what extent did you alter you design process to include more circular considerations? Could you name a few key decisions in the design process?
Challenges	What where the biggest barriers to implementing circularity within Bugaboo? To what extent did you encounter design dilemmas and how did you deal with this?
Learnings	Which knowledge areas do you see as essential for product designers so that they assist in developing the circular solution? What circular opportunities does Bugaboo see for the future based on the ResCoM pilot?

3.4 Results

This section highlights a selection of findings of the case study research, which are relevant for the identification of design roles and competencies.

3.4.1 Background of the Company

Bugaboo is a Dutch design-driven mobility concept developer established in 1994 and mainly known for developing the world's first modular stroller. Currently, the third generation of the Cameleon is on the market (€999). The company has approximately 1500 employees with 350 working at the headquarters in Amsterdam, including a core innovation team of seventy designers, and the rest spread over offices and factories around the world. The company made a profit of almost 14 million euros in 2016 over its global sales. Bugaboo employs a linear business model: the company develops the ideas for its mobility products, manufactures them in its factories in China, and sends

them to retailers worldwide, who distribute them to end-users via online and offline channels. Strollers contain recycled content and a limited number of components get recycled at the end of life. Bugaboo offers a warranty of two years and adds one year if customers register their stroller after purchase. Within the warranty period customers can get their strollers serviced or maintained. Generally, the strollers disappear out of the company's sight after sales.

3.4.2 The Pilot

Through the EU H2020 FP7 project, Bugaboo was given the opportunity to pilot a circular business model. The pilot's objective was to find a more sustainable, environmentally-friendly, closed-loop product system, whilst staying profitable and continuing to deliver the promise of longer lasting high-quality products. In 2013, at the start of the project, a fast-track life cycle assessment (LCA) was conducted to determine the sustainability baseline for Bugaboo's iconic stroller, the Bugaboo Cameleon, of which different versions have been in production for over 15 years. Figure 3.1 shows the third generation of the Cameleon

Figure 3.1. The third generation of the Cameleon line, (left) and the modules of the stroller (right): 1. rain cover, 2. under seat basket, 3. base seat fabric, 4. seat/ carrycot frame, 5. carry handle, 6. wireframe, 7. chassis with wheels, 8. extendable sun canopy, and carrycot apron, and 9. base carrycot (Bugaboo Cameleon 3, n.d.)

and its main components. Based on an average product lifetime of 10 years, the LCA showed that the environmental impact is the highest in the production phase. The materials with the largest impact (i.e., plastics and aluminium) are currently only recovered in limited amounts. In addition, connections such as rivets hamper the disassembly of the stroller. The recommendation was to reuse components made from impactful materials, such as the frame, to prolong product lifetime and decrease the relative eco-impact.

Based on the results of the LCA, the sustainability team developed a lease and refurbishment pilot scheme, named the Bugaboo Flex Plan. According to the scheme, the strollers would be leased for two consecutive use cycles and refurbished after each lease cycle (see Figure 3.2 for a schematic overview).

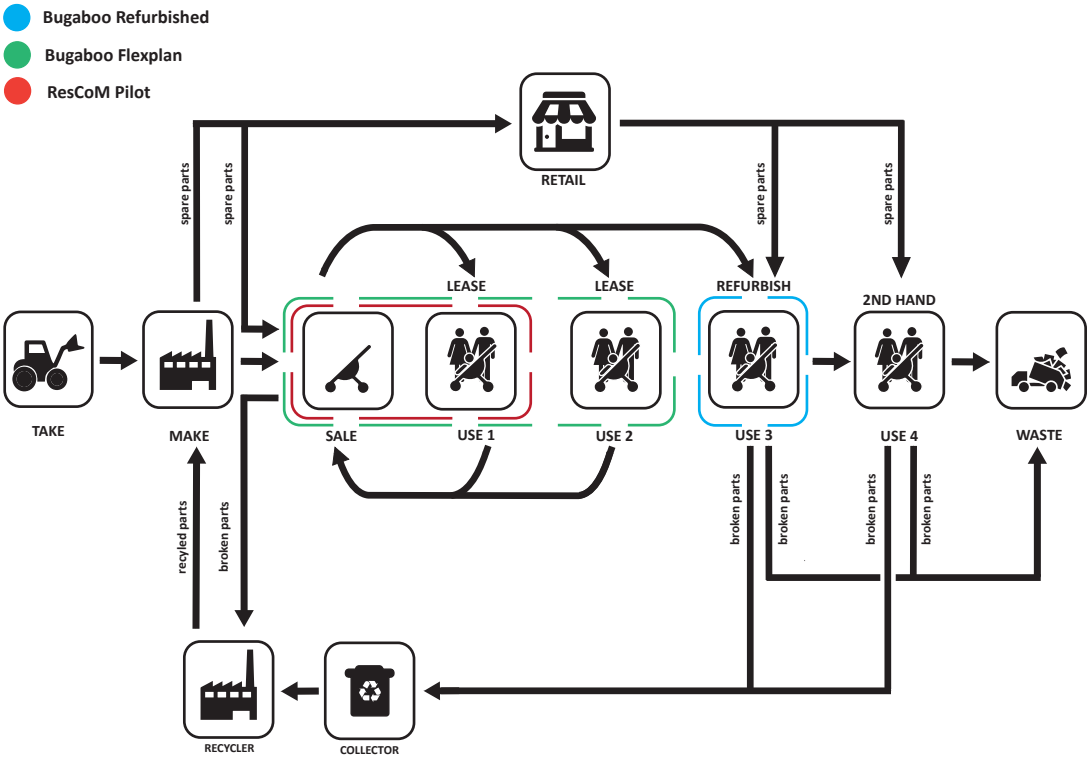

Figure 3.2. Schematic overview of Bugaboo Flex Plan and Bugaboo Refurbished

After the second lease cycle, the strollers would be refurbished, certified, and sold on the second-hand market (i.e., Bugaboo Refurbished). Participants could lease the strollers for a period of six months to three years, after which the contract would automatically end. Bugaboo would be responsible for delivering and picking up the stroller at the beginning and end of the contract period, and in cases of required maintenance or a 'swap'.

During the EU H2020 FP7 project, a single lease cycle was piloted. The pilot ran for two years and was conducted in the Netherlands, Bugaboo's most mature market. Flex Plan was advertised through Bugaboo's social media channels. Thirty-five families participated in the pilot. These families were subjected to a credit check to ensure they would be able to pay the monthly fee. Customers paid an initial deposit of €199, which would be returned at the end of the contract period depending on the condition of the stroller. The monthly fee for the stroller varied between €21 and €49 depending on the type of stroller each family leased. In addition, customers paid a small fee for the accessories they selected. Participants were allowed to 'swap' stroller models once a year for €49. The structure of the pilot resulted in each customer having an individual contract. During the pilot Bugaboo was responsible for the logistics (i.e., delivery and pick up), and for maintenance. Strollers were collected by Bugaboo's return logistics partner.

3.4.3 Getting Circular Buy-In

In 2016, the sustainability team hired an innovation marketing manager (IMM) with a background in strategic product design. She helped design, implement and operationalize the pilot, which initially required establishing relationships with all relevant departments: "It was a puzzle. Like, who do we need? Almost all departments." An internal multidisciplinary team was assembled (led by the IMM and the SLD) to get the pilot running. This team included employees from finance, credit control, legal, logistics, service, and two members from management. One of the challenges the IMM and SLD faced was convincing the team members of the benefits of the Flex Plan. In addition to designing the system behind the lease plan, the SLD initially acted as a visionary: "I needed to explain why we actually needed to lease. Why is this good for Bugaboo? Why is it fun? So really communicate a vision and convince people. But also, think along with the team. Like we were a kind of start-up." Convincing employees to buy into the concept of the circular economy and implement the pilot proved to be a challenge on different levels.

First, even though upper management agreed to pilot the Flex Plan, not all middle managers were aware of this. The SLD noted, "some employees were enthusiastic, but [the tasks were] different than they were doing before, so we encountered quite some resistance." Employees commented, "my manager doesn't allow me to do this" or "it is not part of my Key Performance Indicators" or "we are too busy." For instance, a proposal for a separate webpage announcing the Flex Plan could not be implemented because the brand department, in charge of the website, worked on a large campaign, which meant that there was no opportunity to assist with the webpage.

Second, differences in mindsets hindered the implementation of the pilot. The SLD was used to thinking conceptually. However, not all employees, had the same mindset. Initially the SLD forgot to convey his vision regarding Flex Plan and the benefits for Bugaboo. When asked how he would describe the activities that come with pushing the transition towards a circular economy, the SLD mentioned (1) thinking about new business models and pushing the implementation of these business models within the company whenever he thought it would be good for the company; (2) pushing others to think about circularity; and (3) convincing management. The SLD emphasized that convincing management, in particular, is essential because "without getting buy-in from management it takes a lot of energy to push the sustainability agenda."

3.4.4 Outcomes of the Pilot—Consequences for the Design of the Strollers

The pilot showed that Bugaboo had to do more refurbishment than expected; one third of the returned strollers were highly damaged. Due to the use of rivets the broken frames could not be repaired, but had to be replaced instead, which was very costly. This resulted in a debate about the extent to which Bugaboo should refurbish the strollers. A high degree of refurbishment (i.e., replacing all broken parts, as well as parts with cosmetic damage) would negatively affect the eco-impact. On the other hand, only replacing broken parts might affect the company's brand image, because it was assumed that customers would not accept cosmetic damage in otherwise fully-functional products. As a consequence, the sustainability team started reflecting on the lease-readiness of the strollers. The irreversibility of rivet connections was a problem, and so was the material of the frame. While the aluminium frame is recyclable, it is also scratch-sensitive, which makes it less attractive for a product with multiple use cycles. The team discussed which circular product design strategy would fit the lease model best: "Do you make the stroller more repairable on parts-level or do

Table 3.3. Product to last–part lifetime categorization. Some examples from the part lifetime list.

Categories	Long Lasting	Wear and Tear	Fabrics	Packaging
Example part	 Bugaboo Cameleon Frame	 Bugaboo Cameleon Snow wheel	 Bugaboo Cameleon Carry cot	 Bugaboo Cameleon Car seat adapter packaging
Life cycle	Lasts for three use cycles	Degrades during one use cycle	Replaced every use cycle (in lease model)	One-time use

you make the stroller more durable on product-level?" While the first approach means designing modules that can be easily exchanged between use cycles, the latter approach means making the stroller, as a whole, as robust as possible. This affects the choice of materials and connecting mechanisms. In addition, the team realized that developing new accessories in a lease and refurbishment model requires that these are compatible across all stroller lines and generations. The SLD commented: "At some point, we want to develop a generic interface for all of our accessories". As a result of the lease-readiness discussions, the team created Products to last: a categorization of parts with different lifetime requirements. Table 3.3 gives an overview of the four lifetime categories with examples. This categorization served as a guide to improve the modularity of the stroller and helped gain insights in redesign opportunities that would improve the readiness for lease and refurbishment.

3.4.5 Challenges for Scaling of the Pilot

The Flex Plan was designed to be very flexible; customers could swap strollers once per year and add accessories anytime. According to the IMM, this was a necessary part of an enticing value proposition: 'For [customers] to think [the Flex Plan] is attractive, we have to offer more than in the case of buying'. It turned out that customers used this option extensively, which resulted in increased logistics and costs. The IMM: 'We often had to drive up and down. Even when customers wanted to change colors from pink to blue'. As a consequence,

the sustainability team debated whether they should restrict the number of times customers could exchange strollers and accessories, and worried about whether such restrictions would affect customer interest.

Since Bugaboo had no previous experience in working with a leasing model, the implementation of the pilot triggered new information flows within and between departments, causing unexpected delays. For example, before Flex Plan participants could receive their strollers, they had to wait for Bugaboo to send a lease contract. After signing the contract, Bugaboo had to perform a credit check and co-sign the contract. The stroller would then be prepared and sent to the participating customer. The SLD noted: "The first time that we mapped everything and determined the lead time, it turned out the delivery time would be around three months. We thought this was not really convenient, because customers would have to wait for three months until they got their stroller."

The work flow also resulted in new information flows between departments and customers. For instance, the finance department had to directly deal with the participating customers during the pilot. Employees from the finance department, however, were used to communicating with other companies, not with customers. The service department had to step in and take over some tasks that initially were assigned to the finance department.

The sustainability team soon realized that offering multiple strollers simultaneously as part of the Flex Plan would result in problems with refurbish-readiness and compatibility issues. The SLD: "I can imagine that, when you get back all products and they have different qualities and it is a mix of old and new, you need an infrastructure to determine which components can be used for certain products". Bugaboo realized that in order to scale the leasing scheme, the company would need to implement a track and trace software system to gain control over its resources. In addition, the software system was not equipped to deal with these new information flows. In short, when piloting the lease scheme, the company realized its strengths and weaknesses. The SLD: "Bugaboo is very good at designing and producing high quality innovative mobility solutions. Its strength is not in chasing people who still need to pay their monthly lease fee".

3.5 Discussion

The objective of this paper is to identify and map designers' roles and design competencies for the creation of circular business models. In the Bugaboo case, all three design roles (functional, coordinating, and strategic) can be identified. The case study insights are used to distil design competencies for each of the three roles. These are subsequently compared to the framework of design competencies in table 3.1.

3.5.1 Functional Role and Competencies

An unexpected negative result of the lease pilot was the return of one third of the strollers in a severely damaged condition. It shows the need to investigate how leasing might affect the sense of ownership and the willingness of consumers to take good care of the leased products. Relevant competencies in this respect were identified by (De los Rios & Charnley, 2016): "understanding user expectations and perception of value", "understanding factors of the use experience", and "understanding the service experience and how to design services".

Of the other functional competencies that were identified by de los Rios and Charnley, most can be recognized, for instance, "understanding processes for reverse and re-manufacturing" and "understanding failure mode and maintenance" were some learnings from the Flex Plan case. The SLD made some commented related to this: "It is really important to take those people together with you on a journey regarding the ideas about refurbishing. Like: 'How do you ensure that a product is easy to refurbish. Or how do you guarantee that at the end of life the product does not harm the environment too much?' I feel designers and engineering can have the most impact on this".

Another functional competency that we observed stems from the instance where the sustainability team reviewed two potentially competing circular design strategies. Design for durability and design for reparability could both facilitate refurbishment but would have different consequences regarding manufacturing and environmental impact. Hence, this implies that product designers need to be able to assess and compare the environmental impact of different circular strategies. Recovery and multiple lifecycles are crucial elements of the circular economy, resulting in the timeframe being an important element as well. From this case we, thus, derive the following competency:

Estimate the environmental impact on a system level over multiple life cycles.

3.5.2 Coordinating Role and Competencies

Regarding the coordinating role, the case study showed that shifting to a leasing model required close internal collaboration. As a consequence of piloting a lease model, new flows of information became apparent between departments. The SLD and IMM created a multidisciplinary team and coordinated the setup and operation of the pilot. The associated competency was described by (Ceschin & Gaziulusoy, 2016) as "contribute to create relations between a variety of stakeholders of a value constellation". Based on this case study, we can further specify this competency for circular design as:

Facilitate collaboration between internal and external stakeholders who play a role in operationalizing a circular business model.

The sustainability literature (e.g. De Haan, 2006; Rieckmann, 2012; Wiek et al., 2011) refers to this as an interpersonal competency in the context of successful stakeholder collaboration. The case study clearly shows the importance of organizing and facilitating stakeholder interaction in the creation of circular business models.

3.5.3 Strategic Role and Competencies

The main role that the SLD fulfilled was strategic: The SLD was involved in both designing the value proposition, which can be seen as a management task, as well as setting up and leading teams and extracting learnings from the pilot. Based on the case we identified a number of strategic competencies.

First, the limited lease and refurbish-readiness of the stroller affected the results of the pilot. An integrated approach in which the development of products and services happens concurrently is, therefore, important. This has also been stated by (Ceschin & Gaziulusoy, 2016) in light of the expanding scope of design, which has moved from product focus to systems focus. These authors describe the designer's ability to address sustainability by applying an integrated system approach. Building on this case we formulate the following strategic competency:

Concurrently develop the circular business model and the product's design.

Second, within this case we observed that planning and anticipating on the future consequences of product development became increasingly important. For instance,

creating a universal interface would aid the exchange of parts between models and generations, but would also affect the compatibility with older models. It was deduced that product designers should be able to plan the development of modules and interfaces over time, develop refurbishment schedules, and think about forward and backward compatibility. In contrast to product development, which is finished after the product launch, circular business development requires designers to stay involved in solving issues throughout the service life of the product (Diehl & Christiaans, 2015). When designing for a circular economy, designers explicitly need to consider temporal aspects, such as the technical product lifetime and length of the use cycle. This affects the horizontal (i.e., product lines) and vertical (i.e., product generations) product development, as became apparent in the case. Building on this, we derive the following strategic competency:

Anticipate how the circular offering will evolve over multiple life cycles.

This is associated with the anticipatory competency (e.g. De Haan, 2006; Rieckmann, 2012; Wiek et al., 2011), which is about envisioning possible future scenarios.

3.5.4 Adapting the Framework

Table 3.4 shows the adapted framework with the new competencies that were derived from the case study added in bold. The Bugaboo case proved to be of great value. It both offered the opportunity to verify the functional competencies as identified by de los Rios and Charnley (2016), and also identified additional competencies, in particular those related to the strategic role of designers.

It should be noted that these new competencies were derived from a single-case study, which makes it difficult to generalize the results. Nevertheless, the in-depth nature of the case study, its design-driven character, and the fact that it was possible to follow the development and operation of the lease and refurbishment pilot for almost two years, adds to the robustness of the results.

Further research should focus on validating the identified set of circular competencies by conducting multiple-case study research. Additionally, analyzing cases other than leases in which companies piloted or adopted other business models in the context of a circular economy will help to further uncover the competencies that go along with the different design roles.

Table 3.4. Roles and competencies for sustainable and circular design (extended). New competencies based on the case study are added in **bold***).*

Role of Designer	General Sustainability Competencies	Design for Sustainability Competencies	Design for Circular Economy Competencies
	Wiek et al. (2011), de Haan (2006) and (Rieckmann, 2012)	Ceschin and Gaziulusoy (2016) and Vezzoli et al. (2014)	De los Rios and Charnley (2016, p. 118)
Functional	Normative: "Collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets" (Wiek et al., 2011, p. 209)		**Estimate the environmental impact on a system level over multiple life cycles**
		"Design … the satisfaction of a particular demand … and all its related products and services" (Vezzoli et al., 2014, p. 51)	"Understand the service experience and how to design services" "Understand user expectations and perception of value" "Understand factors of the use experience" "Understand processes for reverse and re-manufacturing" "Assess material physical and chemical properties "Understand product wear by use" "Understand engineering functions of the product" "Understand failure mode and maintenance procedures" "Solve aesthetic and structural problems with limited supplied components" "Understand logistics and distribution processes"

Coordinating	Interpersonal: "Motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving" (Wiek et al., 2011, p. 211)	"Design … the interactions of the stakeholder of a particular satisfaction-system" (Vezzoli et al., 2014, p. 51) "Acting as facilitator to stimulate a strategic dialogue and co-design processes" (Ceschin & Gaziulusoy, 2016, p. 149) "Contributing to create relations between a variety of stakeholders of a value constellation" (Ceschin & Gaziulusoy, 2016, p. 149)	**Facilitate collaboration between internal and external stakeholders who play a role in operationalizing a circular business model**
Strategic	Strategic: "Collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability" (Wiek et al., 2011, p. 210)	"Design … [offers] that continuously seeks new, beneficial eco-efficient and socially equitable, locally based and cohesive solutions" (Vezzoli et al., 2014, p. 51)	**Concurrently develop the circular business model and the product's design**
	Systems thinking: "Collectively analyse complex systems across different domains … and across different scales …." (Wiek et al., 2011, p. 207)	"Addressing sustainability operating on the integrated system of products, services and communication through which a company (or an institution, NGOs etc.) presents itself" (Ceschin & Gaziulusoy, 2016, p. 149)	
	Anticipatory: "Collectively analyse, evaluate, and craft rich 'pictures' of the future related to sustainability issues …" (Wiek et al., 2011, p. 207)	Creating clear, comprehensible and shared visions to orient innovations" (Ceschin & Gaziulusoy, 2016, p. 149)	**Anticipate how the circular offering will evolve over multiple life cycles**

3.6 Conclusions

This paper described a single, longitudinal case in which a design-driven original equipment manufacturer (OEM) piloted a circular business model (e.g., leasing of strollers combined with refurbishment). The paper aimed to identify and map designers' roles and associated design competencies for the creation of circular business models. This is relevant because there is still very little empirical evidence of how designers' roles and competencies are changing as a result of the increasing business attention for sustainable and circular models. Having a robust overview of relevant design roles and competencies is of foundational importance for the development of circular design tools and methods, and for the development of circular economy-based design curricula in higher education.

The paper developed a framework which distinguishes between three design roles identified in the literature (i.e., functional, coordinating, and strategic) and the relevant competencies for each role. Using a literature review and the case study analysis, we identified a range of competencies. Most notable, because they were first identified in the case study, are the strategic competencies that support design for a circular economy.

First, concurrently developing the circular business model and the product's design, the case convincingly showed how important it was to have a 'lease-ready' stroller, as the different demands that are set to a stroller that is returned and needs refurbishment could not be met with the original design and the different (less careful) user behavior was not accounted for..

Second, are the anticipatory and 'planning ahead' competencies that are needed to design a product that must stay relevant, desired, and cost-effective over multiple use cycles. Lease products come back in between use cycles and undergo a value recovery intervention, such as refurbishment. Hence, it becomes essential to put effort in planning temporal aspects, such as technical product lifetime and use cycles.
This could affect forward and backward compatibility of product lines, as well as horizontal and vertical product development.

While these competencies need to be further validated, it is striking to see their importance. It is clear that the role of product design will, and must, expand to assist businesses in going circular. This paper has given a first insight into the strategic design roles and competencies that are likely to shape the design methodology and design education for decades to come.

Author Contributions

D.S. is the corresponding author of this manuscript. She is the primary author of this manuscript. She was in charge of collecting and analyzing the data, wrote the initial drafts of the full paper, and produced the images for this manuscript. C.B. and R.B. supervised her in this process and contributed to reviewing the paper internally. All authors read and approved the final manuscript.

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Conflicts of Interest

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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CHAPTER 4

DESIGN COMPETENCIES FOR A CIRCULAR ECONOMY

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Abstract

Limited research has been done on design competencies for a circular economy in practice. Yet, an overview of design competencies for a circular economy would be useful to understand which topics should be emphasized in both education and practice. This paper focuses on deriving circular economy competencies for product designers working in industry. The study consisted of three focus groups with twelve designers that are actively exploring circular economy opportunities in an industrial product design context. We derived six design competencies for a circular economy: (1) circular economy understanding, (2) circular economy storytelling (3) setting circular criteria, (4) assessing circular solutions, (5) connecting reverse logistics with users, and (6) design for multiple use cycles. These six competencies are presented and reflected upon by comparing them to competencies found in literature. Two of the competencies found (i.e., circular economy understanding and storytelling) are new compared to those mentioned in literature. The other four competencies found in this study overlap or further specify competencies mentioned in literature. Ultimately, the relevancy of each of the six competencies for an individual designer is determined by the role this designer has in a company.

Keywords

circular economy; product design; design competencies.

4.1 Introduction

The increasing pressure on resources has become a growing concern. The circular economy, which is propagated by the Ellen McArthur Foundation (2013) as "restorative and regenerative by design", offers a compelling alternative to our current resource intensive systems. The proposal to cycle material resources is not new, but because the circular economy makes it operationalizable (Ghisellini et al., 2016; Kirchherr et al., 2017; Murray et al., 2017) the concept has gained traction among companies that want to contribute to sustainable development (Kirchherr et al., 2017). Circular economy emphasizes high value and high-quality cycling of materials. By advocating sharing and reusing it also connects sustainable production and consumption (Korhonen et al., 2018). Product designers are seen as potential facilitators and even leaders of the transition towards a circular economy (Andrews, 2015, p.305), because they can design products and services that fit multiple lifecycles. While design for a circular economy can be seen as part of the larger design for sustainability landscape, its aims are more explicit. Design for sustainability is aimed at the broad concept of reducing environmental impact. The aim of design for a circular economy, based on its focus on resource efficiency and economically viable closed-loop systems, is more focused and aims to maintain product integrity as long as possible over multiple lifecycles (den Hollander, 2018).

Research has also suggested that the transition towards a circular economy requires acquiring new competencies and knowledge (EEA, 2016). This reflects the notion that the competencies designers need to operate in the sustainability landscape are changing. Yet, there is a lack of understanding regarding these changing competencies (de los Rios & Charnley, 2016; Sumter et al., 2018). Although limited, some research has been done specifically on design competencies for a circular economy. Often, these competencies are derived from case studies with companies that are exploring circular economy opportunities. They are related to "understanding product and service aspects of the circular offering" (de los Rios & Charnley, 2016), "assessing environmental impact of the circular solution", "facilitating collaboration", "anticipating how the circular offering will evolve", and "integrating business model and product's design" (Sumter et al., 2018). In addition, earlier research suggests that the role designers have in companies determines which "circular" design competencies are relevant (Sumter et al., 2018, 2017).

This paper derives circular economy competencies for product designers working in industry through a series of three focus groups. We use the following definition of a competency: "a functionally linked complex of knowledge, skills, and attitudes that enables successful task performance and problem solving" (Wiek et al., 2011, p.204). The focus is on those designers that work for medium and large companies. These are believed to have a wider reach than small companies when pursuing their sustainable or social activities goals (Hockerts & Wüstenhagen, 2010).

4.2 Methods

This study is part of a wider collaborative project (hereafter: co-project) titled Circular Business Competencies Building: Business function specific knowledge and competencies for a circular economy. This co-project was initiated by Philips and the University of Exeter and facilitated by the Ellen MacArthur Foundation. While the co-project focused on

Table 4.1. Data Collection Process and Participant

Data collection method (number of participants)	Topics
Survey 1: (8)	Barriers and drivers in exploring circular opportunities
Call 1: (8)	Barriers in exploring circular opportunities and design challenges Enabling conditions
Call 2: (11)	Challenges for product creation Collaboration Communication
Survey 2: (-)	Company culture: supporting/ hampering circular economy
Call 3: (7)	Design for circular economy competencies Resources needed to address identified competencies

deriving wider competencies for a circular economy, this paper only presents and discusses the circular economy competencies relevant for product designers working in industry. The co-project offered the opportunity to gather perspectives from multiple designers who have a wide range of roles in companies that are actively exploring circular opportunities, and identify and validate gaps in the design competencies for a circular economy.

4.2.1 Data Collection

The full co-project ran from November 2018 until May 2019. Data was collected in three focus group calls and two surveys between March and April 2019. Table 4.1 shows the topics and the number of participants who took part in each step of the process. The principal researcher of this study facilitated the calls with the design practitioners in the co-project. A note taker from the Ellen MacArthur Foundation was present during each of the focus group calls to make minutes.

4.2.2 Participant selection

Companies selected employees with circular economy knowledge and/or who were actively exploring circular economy opportunities in their daily work. The selected employees took part in a kick of call, which each of the participating companies organized separately. During these calls the co-project was introduced. Each of the five companies then put forward two or three employees who took part in the focus group calls. Table 4.2 gives an overview of the participants and their job titles.

4.2.3 Data Analysis

The first survey and call were used to explore the context the participants worked in. This resulted in a wide array of barriers and drivers. We used Covey's "concern-circle of influence model" (Covey, 2004) to separate the challenges that were within their circle of concern (e.g., key performance indicators that are hindering the implementation of circular initiatives) from the challenges that were within their circle of influence (e.g., how to determine the useful lifetime of components after take back). The challenges that were within the participants' circle of influence were the focus point in the second call. In the second analysis round, based on challenges that were discussed in the second call, we derived and formulated design competencies for circular economy competencies. These identified competencies were then validated in the third call, by asking the participants to comment on the importance of the competencies that were formulated.

Table 4.2 Participants' Data

Company	Job title
H&M Group	Team Responsible for Engineers
COS Brand	Product Architect
Tarkett	Design Manager
Tarkett	Senior Design Manager
Tarkett	Project Manager Sustainability
Tarkett	Team Manager Design
Essity	Global Brand Innovation Manager
Essity	Global Brand Innovation Manager
Essity	Regional Brand Director
Philips	Senior Product Manager
Philips	Product Designer
Coty	Manager R&D Packaging

4.3 Results

Based on the collected data six design competencies for a circular economy were derived from the calls with the product designers working in industry (see table 4.3).

4.3.1 Circular economy understanding

"Circular economy understanding" is about having a clear understanding of the circular economy concept as well as mastering the vocabulary to be able to communicate with others. This competency was classified as foundational. It was seen as a more general competency that forms the basis for further actions. A participant remarked: "circular economy is often equated with recycling, while this is the least preferred solution". In order to tackle the challenge of getting to higher order circular concepts, such as reuse, refurbishment and prolonged life, it is vital one masters the ideas behind the circular economy and is able to verbalize those.

4.3.2 Circular economy storytelling

To master "circular economy storytelling" means being able to engage internal and external stakeholders (e.g., consumers, suppliers and partners) in the circular story. Product designer should be able to interpret what the benefits of a circular economy are and what the consequences of "going circular" are for the company and for the department they are working in, and "sell" this to others in an engaging way. This reflects the need to create involvement and get commitment, which was mainly expressed by the design managers.

4.3.3 Setting circular criteria

Setting circular economy criteria relates to being able to determine the circularity of products. This competency is based on the challenge the participants faced when it comes to checking whether products under development are circular. They indicated that they were struggling to determine what they should consider and whether they were on the right track when they were developing circular solutions. Setting circular criteria could be useful in guiding the design process: participants working as design managers mentioned that they were implementing criteria in the form of 'circularity' checklists and product scores (e.g., modularity, ease of disassembly and recyclability of material) to transform the design process. In addition, the criteria for circular materials can also be used as a standard in procurement when searching for and buying materials.

Table 4.3. Six design for circular economy competencies (validation)

Circular economy understanding
Circular economy storytelling
Setting circular criteria
Assessing circular solutions
Connecting reverse logistics with users
Designing for multiple use cycles

4.3.4 *Assessing circular solutions*

"Assessing circular solutions", is about being able to make financial and environmental assessments of the circular products over multiple use cycles. This competency is required as it can help to assess the viability of proposed circular solutions for the company. Participants mentioned that being able to make a financial assessment is necessary, and should be a starting point, as it helps designers to estimate whether developing a circular solution makes business sense. The environmental component of this competency entails being able to estimate what the impact is over multiple use cycles. A design manager mentioned that current environmental assessment methods, such as Life Cycle Assessment, did not align with the circular solutions they were trying to assess.

4.3.5 *Connecting reverse logistics with users*

To master the competency "connecting reverse logistics with users" entails being able to engage users to participate in the reverse logistics that have to be set up to facilitate the take-back of circular products. Essentially this competency connects two topics: customer engagement and reverse logistics. Creating customer engagement is connected with the ability to determine what the implications are for reverse logistics (e.g., which logistics channels should be in place to facilitate, for example, take back?). Participants stated that consumers should be engaged to participate in circular business models: "for the consumer it should be very clear how to use the product, how to give it back, how it is designed [...] what his benefits are and what environmental benefits are".

4.3.6 *Designing for multiple use cycles*

Being able to "design for multiple use-cycles", entails designing product-service systems that can serve multiple use cycles and/or users. In addition, it includes being able to set up a monitoring and tracking system to have an overview of where company resources are and the ability to determine in which state the products are upon take back. Participants found it important to be able to determine the remaining useful life of particular components upon takeback and to determine how often they could be reused.

4.3.7 *Role dependency of competencies*

During the validation call, participants emphasized that not all competencies were applicable to them because they were not involved in all phases of the design process. For example, a product engineer mentioned that he was not involved in initiating new product development. Therefore, it was

less relevant for him to be able to do financial assessments of circular solution. Instead, it was important that he could "design for multiple use cycles". He added that product designers are not always in the "driver's seat" when it comes to initiating the development of new circular products or services. The business model is often set by marketing. Design choices then have to align with the scope of the business model as determined by marketing: "if it is a business model only relating to recycled contents, then you only focus on that, if it is refurbished content, then you focus on that."

4.4 Discussion

The six identified design competencies for a circular economy as indicated by the product designers working in industry range from being new to partially overlapping and further specifying competencies found in literature.

First, "circular economy understanding" was found to be a core competency that could serve as a foundation to develop other competencies such as "circular economy storytelling". Circular Economy understanding and storytelling are highly connected competencies and were not earlier mentioned in literature. When previous research mentioned management buy-in and support as important driver for implementing circular solutions (Sumter et al., 2018, p.12) it was seen as a general requirement for introducing change in companies. Yet, the industrial design practitioners who participated in this study shared that they struggled with engaging stakeholders inter alia due to the fact that they insufficiently mastered the circular economy vocabulary. Hence, these competencies were derived and formulated.

Second, within this study, it appeared that there is a need to develop a competency in doing financial and environmental assessments over multiple use cycles for circular solutions. When it comes to environmental assessment a related competency was mentioned in literature: "estimating the environmental impact on a systems level over multiple life cycles" (Sumter et al., 2018, p.12). Yet, while relevant according to industry when it comes to financial assessment literature does not mention related competencies. While both competencies reflect a need to be able to also "anticipate how the circular offering will evolve over multiple lifecycles" (Sumter et al., 2018, p.12), financial assessment is done on company level while the environmental assessment is done on system level.

Third, "connecting reverse logistics with users" reflects the expanding design domain in which customers should be engaged to participate in circular business models. Literature shows that this competency also means there is a need to understand that in the context of access-based models consumers are framed as users (de los Rios & Charnley, 2016) as they temporarily get access to products. Within this context, literature furthermore mentions the following competencies: "understanding factors of the use experience", "understanding processes for reverse and re-manufacturing" and "understanding logistics and distribution processes" (de los Rios & Charnley, 2016, p. 118). This reflects an emphasis on the user within circular economy literature. Yet, industry is more concerned with how to set up of the (physical) reverse logistics system and connect it with the users

Fourth, the identified competency "designing for multiple use cycles" corresponds strongly to three competencies mentioned in literature that are all related to understanding product and service aspects of the circular offering: "understanding the service experience and how to design services", "understanding product wear by use", and "understand failure mode and maintenance procedures" (de los Rios & Charnley, 2016, p. 118).. Further, this competency relates to the competency to "anticipate how the circular offering will evolve over multiple life cycles" (Sumter et al., 2018, p.12). This challenges the current mindset of designers as it requires them to look further ahead predict how the product will be used, what the potential useful lifetime of product is and which value recovery strategy to apply.

Last, while the participants recognized the importance of certain competencies, they did not feel the need to acquire all the identified competencies. The perceived relevance seems to be dependent on the position that they are working in. For example, "setting circular criteria", was a competency that was mainly reflected by the participants working in more strategic roles as they felt responsible for guiding colleagues in the design process. There is a need to keep exploring circular design competencies, as they help to understand how organizations learn and how design roles evolve in the context of a circular economy. Further research should lead to a comprehensive framework in which design competencies for a circular economy are allocated to the roles designers could have in sustainability transitions.

4.5 Conclusion

In this study we derived six design circular economy competencies for product designers working in industry: (1) circular economy understanding, (2) circular economy storytelling (3) setting circular criteria, (4) assessing circular solutions, (5) connecting reverse logistics with users, and (6) design for multiple use cycles. "Circular economy understanding" and "circular storytelling" are new compared to those mentioned in literature. In addition, when it comes to the competency "assessing circular solutions", financial assessment was not mentioned before within literature. Furthermore, while literature focused on topics related to the changing role of consumers in circular economy, industry practitioners are more concerned in acquiring competencies that help them determine the implications for customer engagement on reverse logistics. This reflects that industry puts more emphasis on competencies to tackle short term barriers. The six competencies reflect the expanding role of product design needed to contribute to circular activities. Yet, the role designers have in these settings determines the relevancy of acquiring one of the six competencies. The insights following from these explorations can be used to shape and keep design education up to date.

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CHAPTER 5:

CIRCULAR ECONOMY COMPETENCIES FOR DESIGN

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Abstract

This study addresses what competencies (knowledge, skills, and attitudes) designers need in order to successfully design products and services for a circular economy. Existing literature, though sparse, has identified a number of circular economy competencies for design. Yet, a coherent overview is lacking. To complement the competencies found in the literature with insights from practice, we conducted 18 semi-structured interviews with design professionals. Our study identifies seven circular economy competencies for design: (1) Circular Impact Assessment, (2) Design for Recovery, (3) Design for Multiple Use Cycles, (4) Circular Business Models, (5) Circular User Engagement, (6) Circular Economy Collaboration, and (7) Circular Economy Communication. We used a general sustainability competencies framework to categorize our findings. Interestingly, we did not find evidence of the Systems Thinking competency in practice, although in the literature it is mentioned as a relevant competency for design for a circular economy. In addition, we found that methods and tools are still largely lacking or in a premature stage of development. We conclude that design for a circular economy can be seen as an upcoming, independent field within the sustainability domain, and that requires a specific set of competencies, methods, and tools. Our overview of circular economy competencies for design can guide the development of relevant methods and tools, circular economy-based design curricula, and training programs in the future.

Keywords

design education; competencies; circular economy; product design; sustainability; circular consumption

5.1 Introduction

It has been recognized that the linear throughput of materials and energy, which is focused on resource extraction, production, use and discarding of products (i.e., the so-called take-make-use-waste model), challenges sustainable development (Korhonen et al., 2018). The circular economy, which is described by the Ellen MacArthur Foundation as restorative and regenerative by design (Ellen MacArthur Foundation, 2015) offers an alternative. The aim of design for a circular economy is to maintain product integrity over multiple use cycles (for instance through repair, refurbishment, and remanufacturing), and to focus on closing loops (through recycling), while at the same time building economically viable product-service systems (den Hollander, 2018).

The European Commission emphasizes the role of design in the EU action plan for the circular economy: "better design can make products more durable or easier to repair, upgrade or remanufacture" (European Parliamentary Research Services, 2017, p. 7). The overarching aim of design for a circular economy is to contribute to sustainability (Ceschin & Gaziulusoy, 2016). It can be seen as one of the approaches in the design for sustainability field. Other approaches within the design for sustainability field include eco-design (Brezet & van Hemel, 1997), nature inspired design (de Pauw, 2015) sustainable product-service systems (Vezzoli et al., 2014), design for low resource settings (also knowns as design for the base of the pyramid) (Crul & Diehl, 2006; Kandachar et al., 2011), design for social innovation (Manzini & Coad, 2015; Meroni, 2007), and transition design (Irwin, 2015).

Similar to the other design for sustainability approaches, design for a circular economy has its own specific procedures and concepts. The concept of the circular economy has gained traction because it is considered operationalizable (Ghisellini et al., 2016; Kirchherr et al., 2017; Murray et al., 2017). The emphasis on high value, high quality cycling of material resources is novel. In addition, it easily connects sustainable production and consumption, advocated by means of sharing and reuse (Korhonen et al., 2018). Value recovery strategies, such as repair, refurbishment and remanufacturing, are used in the context of circular business models, in which for instance ownership of products is transferred from the user to the company (e.g., access or performance-based models). This results in new relationships between companies and customers, who now become temporary users of products (De los Rios & Charnley, 2016).

These novel approaches for a circular economy also require the development of new competencies and knowledge accordingly (EEA, 2016). While the amount of literature on circular economy is growing, there is limited academic literature that explores the competencies needed and the consequences for design education or practice. Hence, the main research question of this study is: what competencies do designers need in order to successfully design products and services for a circular economy? We follow the definition of a competency as "a functionally linked complex set of knowledge, skills, and attitudes that enable successful task performance and problem solving" (Wiek et al., 2011).

In this paper we first present a generic framework of sustainability competencies, based on Wiek et al. (2011). Second, we discuss the circular economy competencies for design found in literature according to this general framework. Third, we present seven circular economy competencies for design, based on the results of 18 semi-structured interviews. Last, we present a coherent overview of circular economy competencies for design, using a general sustainability framework.

5.2 Background

In this section we present the literature on generic sustainability competencies together with literature on circular economy competencies for design. The associated concepts and methods, if mentioned in literature, are also described.

5.2.1 Sustainability and design for circular economy competencies

Literature agrees on five key sustainability competencies needed to contribute to sustainable development. These are: (1) systems thinking, (2) anticipatory, (3) normative, (4) strategic and (5) interpersonal competencies (Wiek et al., 2011). These five key competencies are often reflected in overviews in the general sustainability literature (De Haan, 2006, 2010; Rieckmann, 2012). They are listed by UNESCO (2017) as essential for achieving the Sustainable Development Goals (SDGs). These five competencies also serve as a reference framework of a "distinct and recognizable qualifications profile for research and teaching." (Wiek et al., 2011, p. 211). Important to note is that solving sustainability problems requires the use of all competencies; they should not be viewed or used in isolation (Wiek et al., 2011). In the following sections we explain what these generic sustainability competencies entail and how they can be understood in the context of design for a circular economy. Table 5.1 gives an overview of the competencies. These five competencies also serve as a reference framework of a "distinct and recognizable

qualifications profile for research and teaching." (Wiek et al., 2011, p. 211). Important to note is that solving sustainability problems requires the use of all competencies; they should not be viewed or used in isolation (Wiek et al., 2011). In the following sections we explain what these generic sustainability competencies entail and how they can be understood in the context of design for a circular economy. Table 5.1 gives an overview of the competencies.

Systems Thinking competency

According to Wiek et al. (2011), the Systems Thinking competency entails: "[...] the ability to collectively analyze complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global) [...]" (p. 207). Systemic features such as cascading effects, inertia, cause-effect chains, feedback loops, and tipping points are essential concepts in systems thinking. This competency requires the use of participatory system approaches and tools that support modelling and system analysis (Wiek et al., 2011) to respectively understand and analyze, the sometimes, complex connections and flows between different nodes in a system.

In the context of circular economy, literature suggests that design and engineering education needs to offer students new skills for the circular economy, such as systems thinking (Ellen MacArthur Foundation, 2015; Webster & Johnson, 2010; Whalen et al., 2017). Systems thinking is seen as an enabler to "fully comprehend both the drivers behind the problems as well as the possible solution space" (Whalen et al., 2017, p. 335). It is used to both analyze a system as well as identify possibilities to change a system to satisfy the needs of a specific group. While literature acknowledges the need for systems thinking in (design for) a circular economy, this does not go beyond a generic call for 'more holistic thinking'. Systems thinking methods that could be useful in the context of design for a circular economy are: the Circularity Thinking method, that can help to explore the current system and possible future circular systems; the Circularity Compass that can help to identify where waste is being in systems; and the Circularity Grid (Blomsma & Brennan, 2018) that can generate understanding about the relationships between parts in the systems.

Anticipatory competency

The Anticipatory competency entails "the ability to collectively analyze, evaluate, and craft rich 'pictures' of the future related to sustainability issues and sustainability problem-solving frameworks" (Wiek et al., 2011, p. 209). This competency is linked to concepts like time, uncertainty, plausible futures and

risks. Methods related to this competency assist in looking towards and predicting the future.

In the context of design for a circular economy, literature mentions the ability to design for multiple use cycles (Sumter et al., 2018, 2019). We consider this an anticipatory competency as it requires designers to develop a design that is 'futureproof' and can be used during multiple cycles. Den Hollander refers to this as 'longitudinal value propositions' (den Hollander, 2018, p. 158) and 'longitudinal business models' (den Hollander, 2018, p. 160).

This implies that during the design process the value propositions and business models for all future use cycles should be consciously designed. Some of the general anticipatory sustainability methods, such as visioning and back casting, will be useful for design for a circular economy too. But, distinct circular anticipatory methods, that support the creation of longitudinal value propositions and product-service designs that can create value over multiple use cycles, will need to be developed. Distinct methods are also lacking for the creation of products with a fixed and pre-designed number of use cycles (Kane et al., 2018), after which these products are recovered and reused. An example of an anticipatory circular thinking method is the circular business model mapping tool (Nußholz, 2018). It helps to visualize planning of the product life cycle and assess how the circular offering will change during each use cycle. Another potentially useful tool is the framework on material change (Lilley et al., 2019). It is meant to help designers understand material change over time. However, these methods are still at an early stage of development.

Normative competency

The Normative competency is "[...] the ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets" (Wiek et al., 2011, p. 209) . Methods related to this competency are sustainability assessment methods such as life cycle assessment (LCA) (Ceschin & Gaziulusoy, 2016), risk analyses, and methods that are connected to the anticipatory competency as well, such as back casting (Wiek et al., 2011). The normative competency is also about formulating sustainability principles, being able to understand and discuss the ethical side and considering concepts such as justice and fairness.

In the context of design for circular economy, literature mentions competencies related to estimating environmental impact over multiple use cycles (Sumter et al., 2018, 2019). Den Hollander et al. (2017) mention that designers, when aiming

to extend product lifetime, need to be able to assess the environmental consequences of their design interventions. This falls within the normative competency as the underlying ability to estimate environmental impact relates to making assessments about circular solutions. Yet, the difference with general sustainability is that the assessments are to be made on a systems level over multiple use cycles, including take back options (e.g., circular impact assessment). A second relevant competency in this respect is the ability of setting circular criteria (Sumter et al., 2019) and using circularity indicators to determine the extent of circularity of current and future design projects. Useful methods within this context are (material) circularity indicators for products (Ellen MacArthur Foundation & GRANTA, 2015) and tools to estimate environmental impact of circular economy strategies (Pamminger et al., 2019). Research suggests that, while the current circularity assessment tools can help to give an indication of the product performance in the context of circularity, they do not reflect the complexity of the circular economy and guidance for designers is missing (Saidani et al., 2017)

Strategic competency

The Strategic competency is "the ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability" (Wiek et al., 2011, p. 210). This competency is associated with high-level concepts such as transitions, governance, viability, success and path dependencies (Wiek et al., 2011). It reflects the wider perspective of the sustainability field. Methods related to this competency are about creating change on and from a high level, and that help with planning and decision making as well as with organizational and behavioral change.

In the context of design for circular economy, literature mentions competencies related to concurrently developing circular business models and product designs (Sumter et al., 2018). Den Hollander et al. (2017) also suggest that design for a circular economy requires that products and business models that can capture economic value over multiple use cycles are design simultaneously. This competency can be categorized as a strategic competency in the framework of Wiek et al. (2011) as this reflects a need to think about the viability and scalability of the solution. A relevant tool for this competency is the circular business model canvas (Lewandowski, 2016). Competencies related to user engagement can also be gathered under the strategic competency (De los Rios & Charnley, 2016) as user

Table 5.1. Sustainability and circular economy competencies for design (literature)

engagement is essential for successfully implementing a circular business model. Currently, consumer acceptance of product access versus ownership is still a challenge (Poppelaars et al., 2018). A stigma on 'second-hand' products influences the consumer acceptance of 'recovered products' by means of repair, refurbishment or remanufacturing (Mugge et al., 2017). Hence, designers should consider the factors that influence user perception and acceptance of recovered products (Van Weelden et al., 2016) but useful design methods are scarce.

Interpersonal competency

The Interpersonal competency encompasses "the ability to facilitate collaborative and participatory problem solving, while ensuring a respective and empathetic exchange of perspectives and actions and dealing with conflict resolution" (Wiek et al., 2011, p. 211). This competency is associated with concepts such as leadership, success in teams and the dynamics of collaboration. Methods related to the interpersonal competency are about teamwork and participation.

In the context of design for circular economy, literature mentions the need to facilitate collaboration between stakeholders in an entire value chain or value network (Brown et al., 2019; Sumter et al., 2018). This can be categorized as an interpersonal competency as it reflects the need to identify and form partnerships. Methods that could aid in this process are, for example, stakeholder mapping, which can be used to create an overview of who should be involved and what the stakes and relationships are. Geissdoerfer et al. (2016) use the method of value mapping to inter alia harmonize stakeholder interest. Last, literature talks about co-creation, mainly in the form of innovation and living labs, as a method to stimulate collaboration between stakeholders for a circular economy (Dokter et al., 2019; Revillio et al., 2019). Yet, these experimentation spaces have not yet been around for long, so it is unclear what the outcomes will be in long term.

An essential element when it comes to collaboration is communication. In the context of design for circular economy, we previously identified competencies such as 'circular economy understanding' and 'circular economy story telling' (Sumter et al., 2019, p. 3). However, due to the newness of the field and the lack of formal circular economy vocabulary there is conceptual and terminological confusion among design researchers. Circular economy has even been called a 'catch-all philosophy' (Whalen

Competencies	Sustainability	Design for Circular Economy	Circular economy concepts and methods
Systems thinking competency	"[...] the ability to collectively analyze complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global) [...]." (Wiek et al., 2011, p. 207)	• Systems thinking (Ellen MacArthur Foundation, 2015; Webster & Johnson, 2010) and holistic thinking (Whalen et al., 2017)	Concepts • Restorative and regenerative by design (Ellen MacArthur Foundation, 2015) • Circularity Thinking (Blomsma & Brennan, 2018) Methods • Circularity Compass and Circularity Grid (Blomsma & Brennan, 2018)
Anticipatory competency	"the ability to collectively analyze, evaluate, and craft rich 'pictures' of the future related to sustainability issues and sustainability problem-solving frameworks" (Wiek et al., 2011, p. 207)	• "Considering product wear over time during the design process (De los Rios & Charnley, 2016) • "Designing for multiple use cycles" (Sumter et al., 2019, p. 3) • "Anticipate how the circular offering will evolve over multiple lifecycles" (Sumter et al., 2018, p. 13) •	Concepts • Multiple use cycles; longitudinal value propositions (den Hollander, 2018) Methods • Circular business model mapping tool (Nußholz, 2018) • Framework on material change (Lilley et al., 2019)
Normative competency	" the ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets " (Wiek et al., 2011, p. 209)	• "Setting circular criteria" (Sumter et al., 2019, p. 3) • "Assessing circular solutions" (Sumter et al., 2019, p. 3) • "Estimate the environmental impact on a system level over multiple life cycles" (Sumter et al., 2018, p. 12) • Consider the consequences on environmental impact of design interventions focused on product lifetime extensions (Den Hollander, Bakker, & Hultink, 2017)	Concepts • Measuring circularity; Circular impact assessment Methods • Circularity indicators (Ellen MacArthur Foundation & GRANTA, 2015) • Tool to measure impact of circular strategies (Pamminger et al., 2019)

Strategic competency	"the ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability." Wiek et al., 2011, p. 210)	• Considering the user experience, expectation and perception of value during (service) design process (De los Rios & Charnley, 2016) • Considering circular logistics and distribution process (De los Rios & Charnley, 2016) • "Connecting reverse logistics with users" (Sumter et al., 2019, p. 3) • Develop the circular business model in conjunction with the product's design (Den Hollander, Bakker, & Hultink, 2017; Sumter et al., 2018)	Concepts • Circular business models, access-based models; performance-based models; • User experience Methods • Circular business model canvas (Lewandowski, 2016) • No specific design methods for understanding user engagement for circular business models identified
Interpersonal competency	"the ability to facilitate collaborative and participatory problem solving, while ensuring a respective and empathetic exchange of perspectives and actions and dealing with conflict resolution." (Wiek et al., 2011, p. 209)	• "Circular economy understanding" (Sumter et al., 2019, p. 3) • "Circular economy storytelling" (Sumter et al., 2019, p. 3) • "Facilitate collaboration between internal and external stakeholders who play a role in operationalizing a circular business model" (Sumter et al., 2018, p. 12)	Concepts • Collaboration across value networks (Brown et al., 2019) • Circular economy vocabulary (Sumter et al., 2019; Whalen et al., 2017) Methods • Value mapping (Geissdoerfer, Bocken, et al., 2016); • Co-creation in experimentation labs (Dokter et al., 2019; Revillio et al., 2019) • No specific tools for circular economy communication

et al., 2017) for its lack of guiding language. This is an obstacle for designers and others to talk about circular solutions.

Table 5.1 gives a summary of the just discussed general sustainability and circular economy competencies for design, as well as the relevant methods and concept listed within literature. Categorizing the circular economy competencies for design listed in literature, using the sustainability framework (based on Wiek et al. (2011)) showed us that in general there is an overlap between the circular economy competencies for design and the sustainability competencies. Yet, in the specifics there are differences. The newness of the circular economy field is reflected by the limited number of methods available and the premature development state they are in. The following sections present our study that evaluates and (potentially) expands the list of competencies through a practice-based inquiry. The goal is to come to a coherent list of competencies that designers need to successfully design products and services for a circular economy.

5.3 Research Method

Learning in-depth from real life cases is an effective method to obtain insights about emerging fields such as design for a circular economy. To evaluate the listed competencies found in literature with empirical evidence, we conducted 18 interviews with design practitioners. The participants, who all have a design background and/or are working in the role of industrial designer, had experience developing circular solutions in practice.

5.3.1 Data collection

We conducted a total of 18 interviews. The interviews were conducted face-to-face (10) and via Skype (8) and took place between April 2018 and November 2019. They lasted 40 to 120 minutes. Interview number 14 was conducted with two participants simultaneously as they both participated in the same project. A standardized semi-structured interview (Patton, 2002) was used to ensure consistency between interviews. We queried the designers about their experience developing specific circular solutions. Table 5.2 gives an overview of sample questions per topic discussed during the interviews. Depending on the native language of the respondents, interviews were conducted in either Dutch or English. The interviews were recorded and transcribed verbatim. During the first round of coding, those interviews that were conducted in Dutch, were translated to idiomatic written English.

Table 5.2. Interview topics and sample questions

Topics	Sample questions
Defining circular economy	How would you characterize the circular economy?
Circular solution	Please elaborate on the circular solution that you have been working on? What did you do in practice/concretely to develop the circular solution?
Challenges	What hindered you in this process? How did the hurdles prevent you from completing the case?
Support	Which methods/tools did you use in this design process? When? What were you missing that could have helped you in terms of mindsets, knowledge?
Vision on the role of designers	How do you see the role of designers in (transition towards) a circular economy?

5.3.2 Interviewees profile and selection

The designers worked on a wide variety of circular design offerings (e.g., from repurposing residual material streams to developing modular electronic devices). In order to have a broad array of perspectives we interviewed designers who worked in different sized companies (e.g., ranging from start-ups to multinational companies). The designers all had been actively involved in developing circular offerings. This ensured that we could query them about real life cases and experiences instead of hypothetical futures. Table 5.3 gives an overview of the interviewees, a description of their job title and the circular offering they developed.

5.3.3 Data Analysis

To ensure qualitative rigor during the analysis of the data we employed the Gioia methodology (Gioia et al., 2012). Transcriptions were coded and analyzed using qualitative data analysis program Nvivo. 384 quotes were categorized in 27 first order themes and 7 second order themes, using this tool. Table 5.4 lists the 27 first order themes and the 7 second order themes.

Table 5.3. Participants' Data

	Job title	Circular value proposition
1	Co-founder	Electronic devices as a service
2.	Managing Designer	Concept proposal for circular street furniture
3.	Design Engineer	House style of electronic devices as a service
4.	Senior Industrial Designer	Reusable product packaging
5.	(Product Design) Researcher	Circular product and value proposition design in the mattress industry
6.	Founder/Owner	Design of circular interior and furniture
7.	Operational Manager	Waste repurposing solutions
8.	Resource Efficiency Manager	Designing modular electronic devices and considering access-based models
9.	Sustainable and Circular Product Designer	Sustainable packaging using mono-material
10.	Founder/Owner	Mobility solution using bio-based materials and access-based models
11.	Founder/Owner	Modular office supply
12.	Game Designer & Consultant	Designing and manufacturing a strategy game about material resource-efficiency
13.	Senior Design Strategist	Circular design propositions within a corporate that manufactures household appliances & healthcare products
14.	Design Director (a) Design Engineer (b)	Circular reusable packaging system
15.	Senior Director/Head of Design	Circular propositions in electronics corporate business
16.	Industrial Designer	Assessing and improving repairability of vacuum cleaners sold by a corporate
17.	Industrial Designer	Modular product-service system for personal care
18.	Concept Design Manager	Modular train interior

In the first step of coding we stayed close to the terms used by the interviewees and came to 27 first order themes via an inductive approach. We iterated several times during this process, looking for similarities and differences between the initial themes and clustering these. In the process we labelled the first order themes with so-called phrasal descriptors (Gioia et al., 2012) (e.g., getting circular buy in, categorizing components by lifetime, considering alternative recovery strategies). In the second round of coding we categorized the 27 first order themes into overarching themes using relevant concepts from literature listed in table 5.1. For example, first order themes related to impact assessment were categorized in a second order theme about circular impact assessment. During the coding process we shared a set of transcripts between the authors of this paper for independent clustering, to ensure intercoder reliability. The final coding resulted in 7 second order themes. The final descriptions of these 7 themes came about in discussions between all authors. Finally, based on these themes, we formulated seven circular economy competencies for design.

5.4 Results

In this section, we describe the main insights that we derived from the study. The interviews enabled us to identify seven circular economy competencies for design: (1) Circular Impact Assessment, (2) Design for Recovery, (3) Design for Multiple Use Cycles, (4) Circular Business Models, (5) Circular User Engagement, (6) Circular Economy Collaboration and (7) Circular Economy Communication.

5.4.1 Circular Impact Assessment

17 out of 18 interviewees referred to topics related to circular impact assessment. First of all, the interviewees mentioned the impact assessment of alternative circular strategies and materials. They used fast track life cycle assessments instead of a full life cycle assessment (LCA) as time was their biggest constraint. Some participants felt tools fell short when they tried to measuring environmental impact over multiple use cycles. The large number of assumptions that are needed to build an LCA was seen as the reason that the final outcome cannot not be used to support decision-making. In addition, the interviewees mentioned that the disparity between theory and practice affects decision-making as well. Participant 14 a: "Plastic can be recycled well in theory, but in practice this appears to be different. You have to weigh those things and

Table 5.4. Coding scheme

First order themes	Second order themes
• Investigating materials sourcing and material performance in time • Estimating and comparing environmental impact of solutions over multiple use cycles	Circular Impact Assessment
• Considering alternative recovery strategy • Designing the supportive infrastructure relevant for recovery • Collecting information of product in market • Tracking technological trend development for recovery strategy • Determining implication for design embodiment based on recovery strategies	Design for Recovery
• Categorizing components by lifetime • Assessing product use cycle based on fashion trends • Planning exchange of component • Using visualization as tool to get an overview of the value chain	Designing for Multiple Use Cycles
• Considering the business case during the product's design • Determining prices for services and implication of new financial structure • Testing and piloting new initiatives • Considering the consequences of alternative business cases	Circular Business Model
• Investigating customer awareness and perception of ownership vs. access • Designing customer interaction with product • Collecting and sharing information about value chain • Tailoring service to customer context during use • Creating attractive incentives for customers to give back products	Circular User Engagement
• Identifying partners to share knowledge and activities to operationalize value proposition • Collecting and sharing information about value chain • Assessing consequences of changing stakeholder configuration • Using design as boundary object to collect stakeholder feedback	Circular Economy Collaboration
• Getting circular buy-in • Creating shared understanding • Facilitating empathetic conversations between stakeholders	Circular Economy Communication

that is complex". Another element mentioned here were the circular economy indicators that could help designers determine the circularity of the value proposition they were developing. Participant 13 noted that traditional design requirements have clear indicators that show whether "you pass or fail" and he mentioned: "What I think designers do not learn [...] is how to assess whether or not they are [on the right path to going] circular. They often have a subjective ability to rationalize if they have made progress." Based on the findings, we formulate the following competency:

Circular Impact Assessment: Estimating the environmental impact of circular offerings on a system level over multiple life cycles to support decision-making during the design process.

5.4.2 Design for Recovery

16 out of 18 designers referred to design for recovery (i.e., considering strategies such as repair, refurbishment and remanufacture meant to recover functionality and value in between use cycles and at the end of product life). Designing circular value propositions required the designers to consider recovery strategies and their consequences on the product and service-system design. Participant 3: "Your responsibility as a [supplier] of the product does not stop after sales. [...] You have to keep that in mind as a designer of the product". Participant 9 realized that next to developing the service she had to design a supportive infrastructure that would enable maintenance activities during use and take back of products: "Even if I am starting to sell a refillable bottle, there is not much opportunity for the consumer to refill". Further, the choice for a recovery strategy influences how the product will be designed. The interviewees realized that collecting information about products in use (e.g., where products are and in what state) could help them improve their recovery strategies and associated services. Participant 1 for instance, collected feedback about the rate of failure of certain components, both to improve the service as well as to improve the design of the next product. And participant 6 mentioned that collecting information about the state of their street furniture could help create an overview of where products are in the market.

Lastly, some designers mentioned that there should be ways to estimate the remaining useful product "lifetime" upon takeback after use. Participant 8: "So, imagine you are in a contract for a service proposition, and you use your device with

one battery for half a year. [...] I have no way to know how you have used that battery, so I do not know what is the health of that battery. [...] There is no fast method to test that. Hence, we formulated the following competency:

Design for recovery: Incorporating recovery strategies during the design process while taking into account multiple use cycles.

5.4.3 Design for Multiple Use Cycles

9 out of 18 designers also referred to how designing for multiple use cycles is different from their current way of designing. Design for multiple use cycles and design for recovery are highly related: designing for multiple use cycles automatically implies considering recovery strategies, such as refurbishment and remanufacturing, and how to implement these strategies in the design process.

The main differences with traditional design practice that surfaced from the interviews were thinking in terms of use cycles (e.g., knowing how the products and components will evolve during subsequent use cycles and how materials degrade over time) and considering the sourcing of materials (e.g., which materials are used in the product and where do they originate from). Thinking about multiple use cycles meant that designers had to determine to what extent future trends would impact the design of the current product. Participant 1: "So, you can easily do ten or fifteen years with the same headphone. Yet, the consumer wants something different. He wants to buy a new headphone every two or three years". This trend sensitivity also impacted the planning of introducing future products and accessories, both horizontally (e.g., product lines) and vertically (e.g., product generations). Participant 18 mentioned that even though designing modular train interior could support different prolonged use cycles, planning was required as to when to change the sitting configuration. Another challenging factor was the lack of knowledge regarding the environmental impact of different materials when use was prolonged. Participant 2: "I think, you have to understand what the material does, really understand the material. So, how does it look when it is fresh [a virgin material], which aspects can you encounter, where does it come from, how do you collect it, what is the source materials." Hence, we formulated the following competency:

Design for Multiple Use Cycles: Foreseeing the consequences of prolonged use and multiple use cycles.

5.4.4 Circular Business Models

15 out of 18 designers mentioned business models during the interviews. Some of them mentioned that developing a circular solution entailed developing both the physical product, intangible service and the business model. Participant 8: "You really need to think big and think not only [about] the physical thing but design the service in a way. Design the infrastructure" and participant 11 mentioned that more knowledge of the business model is required during the design of products. This included considering setting up and managing partnerships, reverse logistics, revenues and cost streams and pricing of spare parts. Participant 3 noted: "It has become clear to me how important the link is between the business aspect and the design. That the [product] design, is only a part of the challenge [...]. It also has a lot to do with how your income and expenses, your revenue streams, are structured." Some participants were not sure how to determine the financial and system consequences of switching from a linear to a circular business model. Participant 8 mentioned: "We made parts really cheap because we wanted to enable repairability so that people can just buy them for repair but that [...] [made it] really difficult to make any take-back program for them because there is no money to get back from those parts". Similarly, participant 6 did not know yet what prices and conditions to set for the service part of a leasing concept that he was developing around a furniture concept, which included placing the product, maintenance during use and removal of the at the end of use. In general, designing circular solutions seems to require a level of business knowledge. We formulated the following competency:

Circular Business Models: Concurrently developing the circular product, service and business model.

5.4.5 Circular User Engagement

12 out of 18 designers referred to user engagement as an important for circular offerings. One aspect was understanding why people bought into access-based models (e.g., what would be the benefits for the customers to lease a certain product). Participant 1: "because he [the customer] pays per month, [...] but he can also buy it, so what is the added value?" Participants also addressed the user-product interaction during and after the use of products. Participant 14b mentioned: "you need an active system to motivate people to [return products]". Participant 1, 8 and 17 explained that by applying modular design they supported the user to easily repair and upgrade certain

components. In addition, the way the service was set up seemed to influence whether users bought into access-based models. Participant 1 mentioned: "I think the amount of days in which you sent a new part to the client is really important of your service." Participant 14a mentioned that it was important to develop an active system that motives users to return products. This was a new topic to consider during product design as this has not been part of business as usual where products are being made for one-time sales. Hence, we formulated the following competency:

Circular User Engagement: Engaging users in the use and the (end-of-use) return of products.

5.4.6 Circular Economy Collaboration

14 out of 18 designers talked about the importance of collaboration, for instance as a way to create shared value. Collaborating with new external partners was found to result in new ways of looking at challenges, new goals being set and knowledge gained. In addition, participants saw both more internal and external collaboration as the way to operationalize circular offerings. Participant 11 talked about how going circular meant that she would need more information about the value chain and the materials, which she could obtain via intensified collaboration with suppliers. Instead of only requiring certain specifications from materials, some participants involved the suppliers in the design process. Yet, not all participants had experience working with their suppliers. Participant 13: "I have never really even entered a workshop together with a supplier to figure out how to come up with an offer". Participant 5: "It is going to be more and more important, to share your problems with your partners and together solve it, because we are not chemical specialists, we really need partners to help solve it". Designing for a circular economy requires the shared creation of value. Participant 15 mentioned that existing partnerships and contracts formed a challenge for creating new connections (e.g., convincing existing partners to change their roles or welcoming new participants in the value network). Based on this we formulated the following competency:

Circular Economy Collaboration: Identifying, mapping, facilitating and managing the collaboration between external stakeholders in operationalizing a circular business model.

5.4.7 Circular Economy Communication

13 out of 18 designers referred to communicating internally and externally about circular solutions. Some participants faced problems related to external communication about circularity of, for example, materials. Some experienced, what participant 13 called "the Tower of Babel problem with the circular economy" when they communicate about the topic internally. This was seen as a challenge for collaboration on circular initiatives. Participant 16 mentioned that when he discussed product repairability with the engineers he was working with, these engineers associated repairability with product modularity. Yet, his intentions were to improve the repairability of household appliances by making critical components easier to reach, which can be done in other ways than through modular designs. The plurality of interpretations of the circular economy made it difficult to get circular buy-in from people within the organization suggesting that communication problems affected collaboration; in order to collaborate designers needed to get circular buy in and create a shared understanding with both internal and external partners, reflecting that there is a strong link between Circular Economy Collaboration and Circular Economy Communication. Hence, we formulated the following competency:

Circular Economy Communication: Telling coherent stories about the circular offerings.

5.5 Discussion

The main scientific contribution of this study is the coherent and interlinked set of circular economy competencies relevant for designers. We ensured embedding in existing knowledge, by relating the competencies for design for circular economy to the generic sustainability competencies framework developed by Wiek et al. (2011). In this section we reflect on the circular economy competencies for design as found in our empirical study.

The competencies Designing for Multiple Use cycles and Designing for Recovery can be categorized as Anticipatory competency as they require designers to envision prolonged use of products. In comparison with other design for sustainability approaches, such as eco-design, design for a circular economy puts more emphasis on multiple use cycles. When designing circular propositions in practice, designers need to be able to envision and make prediction about what prolonged use will look like and make design decision based on these predictions.

Design for Multiple Use Cycles and Design for Recovery further entail considering the effects on the reverse logistics channels. Within literature these circular offerings that last multiple use cycle have been describes as longitudinal value propositions (den Hollander, 2018). Design for Multiple Use cycles and Design for Recovery further reflect a move away from developing fixed end-solutions (de Koning, 2019).

Circular Business Models and Circular User Engagement can be categorized as Strategic competency as these both aim at interventions at the business strategy level. The strategic competency 'Circular Business Models' was identified in previous work before based on a single case study (Sumter et al., 2018). There was suggested that designers need to get more proficient in business model development. A new and essential element found in this study is the 'Circular User Engagement' competency. Literature mentioned the related competencies "considering the user experience, expectation and perception of value during (service) design process" (De los Rios & Charnley, 2016) and "connecting reverse logistics with the user" (Sumter et al., 2019, p. 3). This study shows that the changing relationship with users in a circular economy requires designers working in practice to guide users in the decision-making, use and take-back phase in order to optimally employ certain business models.

The analytical and evaluative nature of the competency Circular Impact Assessment led us to categorize it as Normative competency. The need for the Circular Impact Assessment competency shows that designers in practice need support in decision-making and reducing uncertainty during the design process. In previous research the need for the associated competency of "setting circular criteria" (Sumter et al., 2019, p. 3) was also identified, in relation to guiding circular solutions under development. Yet, in practice useful methods supporting this competency are lacking. We need to understand what circular economy indicators could support decision making in the design process. It also raises the questions whether current environmental assessment methods should be altered to also assess environmental impact over multiple use cycles.

Circular Economy Collaboration can be categorize under what Wiek et al. (2011) call the Interpersonal competency as this relates to identifying and forming external partnership. Previous research already suggested that collaboration is essential in the context of a circular economy (Brown et al., 2019; Sumter et al., 2018). This study shows that in order to develop and implement realistic circular solutions designers need to identify partners and facilitate collaboration. Currently

Table 5.5. Sustainability and circular economy competencies for design (extended)

Competencies	Design for Circular Economy
	Literature
Systems thinking competency	• Systems thinking (Ellen MacArthur Foundation, 2015b; Webster & Johnson, 2010) and holistic thinking (Whalen et al., 2017)
Anticipatory competency	• Considering product wear over time during the design process (De los Rios & Charnley, 2016) • "Designing for multiple use cycles" (Sumter et al., 2019, p. 3) • "Anticipate how the circular offering will evolve over multiple lifecycles" (Sumter et al., 2018, p. 13)
Normative competency	• Setting circular criteria" (Sumter et al., 2019, p. 3) • "Assessing circular solutions" (Sumter et al., 2019, p. 3) • "Estimate the environmental impact on a system level over multiple life cycles" (Sumter et al., 2018, p. 12) • Consider the consequences on environmental impact of design interventions focused on product lifetime extensions (Den Hollander et al., 2017)
Strategic competency	• Considering the user experience, expectation and perception of value during (service) design process (De los Rios & Charnley, 2016) • Considering circular logistics and distribution process (De los Rios & Charnley, 2016) • "Connecting reverse logistics with users" (Sumter et al., 2019, p. 3) • Develop the circular business model in conjunction with the product's design (Den Hollander et al., 2017; Sumter et al., 2018)
Interpersonal competency	• "Circular economy understanding" (Sumter et al., 2019, p. 3) • "Circular economy storytelling" (Sumter et al., 2019, p. 3) • "Facilitate collaboration between internal and external stakeholders who play a role in operationalizing a circular business model" (Sumter et al., 2018, p. 12

Practice
• No specific competencies identified
• Foreseeing the consequences of prolonged use and multiple use cycles (Design for Multiple Use Cycles) • Incorporating recovery strategies during the design process while taking into account multiple use cycles (Design for Recovery)
• Estimating the environmental impact of circular offerings on a system level over multiple life cycles to support decision-making during the design process (Circular Impact Assessment)
• Concurrently developing the circular product, service and business model (Circular Business models) • Engaging users in the use and the (end-of-use) return of products (Circular User Engagement)
• Identifying, mapping, facilitating and managing the collaboration between external stakeholders in operationalizing a circular business model (Circular Economy Collaboration) • Telling coherent stories about the circular offerings. (Circular Economy Communication)

methods to support collaborative activities around designing and implementing circular solutions are limited. An essential and supporting competency within this collaboration is Circular Economy Communication. Designers need to be proficient in creating engaging stories around circular offerings in order to get, for example, circular buy-in and to aid in collaborations. Useful tools to aid this communication could be agreed-upon and coherent set of concepts and benchmarks related to design for a circular economy. Previous research lists limited methods or tools that can aid Circular Economy Communication and subsequently benefit Circular Economy Collaboration.

Interestingly, none of the competencies emerging from our interviews relates to what Wiek et al. (2011) formulate as the Systems Thinking competency. The designers from the study used system mapping in the context of collaboration to analyze current collaborations and assess and identify potential future collaborative needs. Yet, Systems Thinking according to literature also entails identifying where waste is being created and understanding the relationships between actors (Blomsma & Brennan, 2018). The fact that none of the circular economy competencies identified in this study relate to Systems Thinking suggest that there is a gap between literature and practice. Possible explanations could be that while designers might have heard about systems Thinking, that there is a lack of knowledge about Systems Thinking or how to apply it in practice. Other possible explanation are that while designers might have heard about Systems Thinking they do not see the relevancy of Systems Thinking or how it can aid the circular design process. Last, applying Systems Thinking might be too difficult in practice. Yet, future research is needed to be able to formulate a conclusive answer about the lack of Systems Thinking in practice. Table 5.5 lists the circular economy competencies for design identified within this study.

We observed that the seven circular economy competencies for design are broadly recognized by a large variety of designers in industry, working on different product categories and in different sized companies. This allowed us to formulated a coherent set of competencies. Yet, these competencies are limited by a business perspective. In our results the system thinking competency did not come forward as clearly present in practice. This might be due to the focus of this study on designers working in industry.

This study reflects that design for a circular economy can be seen as an independent, upcoming field in the ever-evolving sustainability domain, and for which specific

competencies, tools and methods are needed. Further research should investigate how designers could be supported to develop the seven competencies. Future development and testing of methods and tools for these competencies should help designers in contributing to the transition towards a circular economy. In addition, future research could focus on exploring how the seven competencies compare to what is being taught in design curricula and how to teach these competencies in higher education.

While this study provides a current overview of relevant circular economy competencies for design, it might change as the field matures. This reflects what Wiek et al. (2011, p. 21) indicated previously: "Because the field is problem driven, sustainability will continue to be dynamic, and while the field and the problems are evolving our understanding of what kind of competencies are required will evolve as well.".

5.6 Conclusion

This empirical study responds to a growing need in industry and academia for a coherent set of circular economy competencies for design that can guide the development of dedicated courses and training programs. Interviews with 18 design practitioners revealed that there were several discrepancies between the circular economy competencies identified in literature, and those perceived to be most relevant in practice. First, we learned that the emphasis on prolonged and extended use requires designers to master Design for Recovery and Design for Multiple Use cycles (i.e., the Anticipatory competency) and Circular Impact Assessment (i.e., Normative competency). Second, we did not find the Systems Thinking competency in practice, although in literature it is mentioned as relevant competency for design for a circular economy. Lastly, methods and tools to address the identified competencies are largely lacking or are in a premature stage of development. We conclude that design for a circular economy is an upcoming, independent field in the design for sustainability field that requires specific competencies, methods and tools. This overview of circular economy competencies for design could help to assess where competency building is needed in design practice. For higher design education, a focus on these competencies in curricula could enable a push for the transition to a circular economy. In short, this paper has given a first overview of competencies that can help shape circular design methodologies and education for

decades to come.

Author Contributions

D.S. is the corresponding author of this manuscript. She is the primary author of this manuscript. She was in charge of collecting and analyzing the data, wrote the initial drafts for the full paper, and produced the tables for this manuscript; J.d.K, C.B. and R.B. supervised her in this process, analyzed part of data to ensure intercoder reliability, and contributed to reviewing the paper before it was submitted. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the result.

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CHAPTER 6

KEY COMPETENCIES IN DESIGN FOR A CIRCULAR ECONOMY: EXPLORING GAPS IN DESIGN KNOWLEDGE AND SKILLS FOR A CIRCULAR ECONOMY

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Abstract

In a recent study, we identified seven key circular competencies for design: (1) Design for Multiple Use Cycles, (2) Design for Recovery, (3) Circular Impact Assessment, (4) Circular Business Models, (5) Circular User Engagement, (6) Circular Economy Collaboration, and (7) Circular Economy Communication. These were derived from small-scale studies with designers working in the Netherlands. We set out to assess to what extent this set of seven competencies is recognized by an international group of designers and to evaluate whether any competencies are missing. We used an online survey to collect data from 128 respondents from 25 countries working on circular economy projects. The survey results showed that respondents use and have expertise in all seven competencies and they stressed the practical importance of two new competencies: Circular Systems Thinking and Circular Materials and Manufacturing. The resulting set of nine key competencies is the first internationally verified, coherent set of key circular economy competencies for design. This set will strengthen the pedagogical base of design for a circular economy and will guide the development of circular design methodology.

Keywords

Circular economy; circular design; product design; competencies; design education; sustainability

6.1 Introduction

The circular economy is an alternative to the linear economy. It emphasizes making more effective use of resources by closing and slowing resource loops (Bocken et al., 2016) thereby creating a system without waste and emission (Blomsma & Brennan, 2017). Research has shown that better design can assist in closing and slowing loops (Ellen MacArthur Foundation, 2015; European Parliamentary Research Services, 2017). Moreno et al. (2016) state that designers have a significant responsibility for shaping how products and services are built. The design decisions we take now will greatly impact future product recovery (Tam et al., 2019).

Design for a circular economy (DfCE) aims to maximize the length of product integrity (Den Hollander et al., 2017). Following the inertia principle (Stahel, 2010), value recovery strategies aimed at maintaining integrity on a product level (i.e., repair, refurbishment, and remanufacturing) are prioritized over those that work on a material level (i.e., recycling). We frame DfCE as a field within the design for sustainability domain. Similar to other design for sustainability approaches such as eco design (Brezet & van Hemel, 1997), nature inspired design (de Pauw, 2015) and transition design (Irwin, 2015), DfCE aims to contribute to sustainability. What differentiates DfCE from other design for sustainability approaches, is its emphasis on high value, quality cycling of materials (Korhonen et al., 2018) and its use of circular business models (Bocken et al., 2016).

A circular economy requires new competencies (European Environment Agency, 2016; Medkova & Fitfield, 2016). We define competency as: "a functionally linked complex overview of knowledge, skills, and attitudes that enable successful task performance and problem solving" (Wiek et al., 2011). Research suggests that competencies can inform the development and use of methods and vice versa (Daalhuizen, 2014; Lindahl, 2005) as well as informing the discourse of education. For instance, UNESCO (2017) uses key sustainability competencies (De Haan, 2010; Rieckmann, 2012; Wiek et al., 2011) to frame learning objectives for education for Sustainable Development. Education plays an important role in driving the transition toward a circular economy (Forslund et al., 2018; Kirchherr & Piscicelli, 2019), making it relevant to further investigate circular economy competencies.

In a recent study, we derived an overview of seven circular economy competencies for design (Sumter et al., 2020): (1) Design for Multiple Use Cycles, (2) Design for Recovery, (3) Circular Impact Assessment, (4) Circular Business Models, (5) Circular User Engagement, (6) Circular Economy Collaboration,

Table 6.1 Circular economy competencies for design categorized following the Wiek et al. (2011) sustainability competencies framework.

Circular economy competencies for design (Sumter et al., 2020)	Sustainability Competencies (Wiek et al., 2011)
No specific competencies identified	**Systems thinking Competency** "(...) the ability to collectively analyze complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global) (...)." (p. 207)
Design for Multiple Use Cycles Foreseeing the consequences of prolonged use and multiple use cycles **Design for Recovery** Incorporating recovery strategies during the design process while taking into account multiple use cycles	**Anticipatory competency** "the ability to collectively analyze, evaluate, and craft rich 'pictures' of the future related to sustainability issues and sustainability problem- solving frameworks" (p. 209)
Circular Impact Assessment Estimating the environmental impact of circular offerings on a system level over multiple life cycles to support decision-making during the design process	**Normative competency** "the ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets" (p. 209)
Circular Business models Concurrently developing the circular product, service and business model **Circular User Engagement** Engaging users in the use and the (end-of-use) return of products	**Strategic Competency** "the ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability."(p. 210)
Circular Economy Collaboration Identifying, mapping, facilitating and managing the collaboration between external stakeholders in operationalizing a circular business model **Circular Economy Communication** Telling coherent stories about the circular offerings	**Interpersonal competency** "the ability to facilitate collaborative and participatory problem solving, while ensuring a respective and empathetic exchange of perspectives and actions and dealing with conflict resolution." (p. 211)

and (7) Circular Economy Communication (Table 6.1). These were categorized using a general sustainability framework (Wiek et al., 2011), see Table 6.1. This overview was the result of a series of studies in which we compared findings from literature with practice (Sumter et al., 2018, 2020, 2019) and interviewed several designers predominantly working in the Netherlands.

In this study, we will assess the extent to which these seven competencies are recognized by an international group of designers and evaluate whether any competencies are missing from the overview. To achieve this, we conducted a survey in which we asked respondents how often they used these competencies, how they assessed their expertise in using them and which other competencies they used. The literature suggests that the need to acquire a competency varies according to the role or profile of the designer (e.g. De los Rios & Charnley, 2016; Sumter et al., 2018), thus we also looked at the influence of factors such as the professional background and work environment of the respondents.

6.2 Research Method

A survey was conducted to understand the use of and expertise in circular economy competencies for design, in practice.

6.2.1 Survey

The seven circular economy competencies for design (Table 6.1) form the foundation for the survey. We followed the cycle of constructing an effective survey as formulated by Peterson (Peterson, 2000): we determined which (types of) questions we should ask based on the study's objective. We then reviewed the specific wording and the order of the questions, and pre-tested the survey. In the survey we phrased the competencies in less academic wording, for example, we referred to "design skills for a circular economy" instead of "circular economy competencies for design". We tested whether the newly formulated competencies were interpreted as intended with a with a small sample of design professionals. Table 6.2 gives an overview of the competencies as formulated in previous studies and the re-formulation for the online survey. The full online survey can be found at https://doi.org/10.4121/13213610.

The survey contained 37 open and closed ended questions. For each competency, we asked the respondents how often they used it (Use Frequency) and what their level of expertise (Self-Reported Expertise) was. The Use Frequency of the competencies was shown on a four-point Likert scale (1 =

Table 6.2: Descriptions of circular design competencies in survey

	In Sumter et al. (2020) Circular economy competencies for design	In the online survey Design skills for a circular economy
Design for Recovery	Incorporating recovery strategies during the design process while taking into account multiple use cycles.	You contribute to the development of products that can be repaired, refurbished, remanufactured and/or recycled, or services that allow products to be refurbished, remanufactured and/or recycled.
Design for Multiple Use Cycles	Foreseeing the consequences of prolonged use and multiple use cycles.	You design products that can be used over and over again, by the same or different users.
Circular Impact Assessment	Estimating the environmental impact of circular offerings on a system level over multiple use cycles to support decision-making during the design process.	You measure the circularity of design solutions. For example, by using indicators like 'recycled content' (i.e., the percentage of recycled materials used in a product), or repairability scores (i.e., the level of repairability of a product).
Circular Business Model Integration	Concurrently developing the circular product, service, and business model.	You design products that fit in a circular business model and vice versa. For example, when you design products fit for a leasing scheme you ensure that they can be repaired and maintained.
Circular User Engagement	Engaging users in the use and the (end-of-use) return of products.	You design products and services that engage users in the circular economy. For instance, by developing services that allow the sharing of products or by creating products that are easy to maintain.
Circular Economy Collaboration	Identifying, mapping, facilitating, and managing the collaboration between external stakeholders in operationalizing a circular business model.	You engage and collaborate with many different stakeholders throughout the whole life cycle of products and services. For example, you engage and collaborate with partners from recycling facilities to think about how products can be recovered at the end of the life.
Circular Economy Storytelling	Telling coherent stories about the circular offerings.	You use storytelling and other communication strategies to engage stakeholders, colleagues and/or customers to join in on a circular economy. For instance, you use storytelling to create a shared circular economy vocabulary in your company.

never, 2 = in one project, 3 = in half of the projects, 4 = in all projects). Self-Reported Expertise was shown on a five-point Likert scale (1 = no experience, 2 = beginner, 3 = intermediate, 4 = advanced, and 5 = expert). We used a five-point Likert scale on Self-Reported Expertise to give the respondents who had indicated to 'never' use a competency in a project (four-point Likert scale on Use Frequency) the opportunity to indicate that they had 'no experience'. The choice to include 'no experience' in the Likert scale on Self-Reported Expertise expanded the scale from 4 to 5 points. Respondents were also asked to give an example of how they applied each competency in their circular economy projects. This question was used to assess whether the respondent had interpreted the competencies as intended and to further understand their use in practice. Respondents were finally asked to describe additional competencies: competencies they used in practice, but not listed among the seven competencies in the survey. Last, respondents were asked to describe their professional background and work environment (e.g., company size, job title and whether they were involved in developing products, services, strategies, brands and/or buildings).

The survey was developed in Qualtrics XM (Qualtrics, Provo, UT)(Qualtrics, Provo, UT, 2005). To test the survey, we first conducted a small-scale pilot with four design professionals from the target population. The survey was revised according to their feedback. Finally, a native English-speaking communication specialist checked the language before the survey was published.

6.2.2 Respondent Recruitment

Survey respondents were recruited via different channels. We directly contacted designers in our personal network by email and asked them to forward the survey to designers in their own network in order to benefit from snowballing. In addition, larger organizations such as the Ellen MacArthur Foundation and CIRCO (a Dutch government-funded program for companies interested in exploring circular economy opportunities) allowed us to share the survey in their networks. This was done via posts in their LinkedIn groups which focused on DfCE: 'Circular Design Guide' (18,526 members) and 'CIRCO creating business through circular design' (1205 members). We also shared the link to the survey in two other LinkedIn groups focused on designing and teaching for a circular economy: 'Circular Design: Learning for Innovative Design for Sustainability' (162 members) and 'Circular Economy Teaching and Learning' (3620 members). The survey was open for responses between 14 April and 22 May 2020.

6.2.3 Data Analysis

A total of 315 responses were recorded in Qualtrics. The survey included a check question to assess whether the respondents had worked on a circular economy project. We excluded 48 responses from the analysis when the respondents answered 'no' to the question 'Have you ever worked on a circular economy project?'. These 48 respondents did not get to see the rest of the survey. Instead, they were thanked for their contribution. In addition, we excluded another 121 respondents because their responses were not completely recorded i.e., we did not collect data about the use of and expertise in the competencies. Lastly, responses from 18 students were excluded as the study was aimed at design practice. This resulted in a total of 128 responses.

We used IBM SPSS Statistics Version 25 (International Business Machines Corporation, Armonk, New York, United States) to make a statistical overview of the demographic data, as well as the Use Frequency and Self-Reported Expertise. A one-way analysis of variance (ANOVA) was used to determine any statistically significant differences in the indicated Use Frequency and Self-Reported Expertise based on (1) the type of organization in which the respondents worked and the (2) years of experience they had. This enabled us to evaluate the effect of the professional background and work environment on the indicated Use Frequency and Self-Reported Expertise of the competencies. Finally, we established whether there was a correlation between the indicated Use Frequency and Self-Reported Expertise. An α value of $p < 0.05$ was used to determine statistical significance.

The answers to the open-ended question "what skills are you missing" were analyzed and thematically clustered in order to identify potential new competencies, or to see whether we needed to adapt the descriptions of the original seven competencies. We used the definitions in Table 6.2 when clustering the answers. This process was guided by three questions: (1) does the description of this additional competency fit under one of the seven competencies in Table 6.2, (2) should the existing description of the competencies be expanded or changed, and (3) how should the description be adapted? This helped us assess whether the given examples were potential new additions to the set of seven competencies or whether the original descriptions needed to be adapted to more accurately reflect practice.

6.3 Results

We first present the professional background and working environment of the 128 respondents and then discuss the respondents' familiarity with the competencies. Finally, we present an overview of competencies perceived as missing from the original set by the respondents.

Figure 6.1. Professional background and work environment of the respondents represented in (A). Employment Status (n = 123), (B). Type of organization (n = 76), (C). Work Focus (n = 106), and (D). Years of work experience (n = 111).

6.3.1 Professional Background and Work Environment

Of those respondents who reported their country of work (n = 97), 78% worked in Europe and the other 22% in the rest of the world (25 countries were represented in this sample). The most prominently represented European countries were the Netherlands (38%), United Kingdom (12%) and Germany (9%). Countries most prominently represented in the rest of the world were the United States of America (29%), Australia (19%) and India (14%). Furthermore, most respondents were employed (84%), had a design background (63%), worked in a large organization (45%), and focused on developing products, services, and strategies. There was an even spread in work experience. Full details are shown in Figure 6.1A–D.

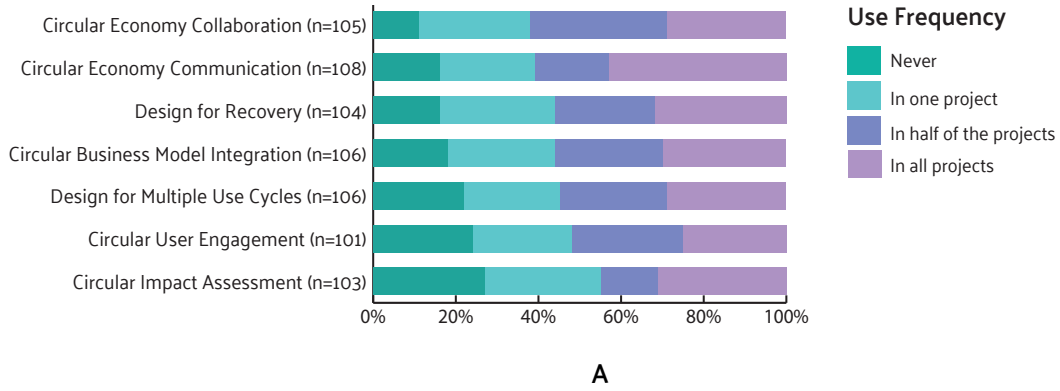

Figure 6.2 Distribution of response regarding (A) Use Frequency and (B) Self-Reported Expertise.

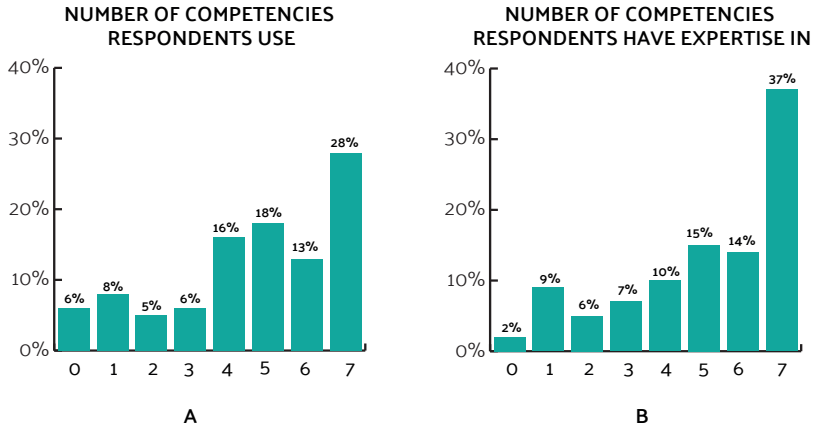

Figure 6.3 Distribution of the number of competencies respondents used (A) and distribution of the number of competencies respondents had expertise in (B). 0 = none of the competencies used or no expertise. 7= all seven competencies used or expertise in all seven competencies.

Examples of other activities that respondents worked on included education, research, and relationship/partnership management. The main focus on products, services, and strategy was reflected in the project examples given: 'working on assessment tools for circular cities', 'developing biodegradable packaging for the food industry', 'closing the loop in the mattress industry', and 'stimulating mobile phone users to send back their products'.

6.3.2 Use of and expertise in circular economy competencies

To assess the extent to which the competencies were recognized by an international group of designers, we analyzed the responses for Use Frequency and Self-Reported Expertise. The responses for Use Frequency for each of the seven competencies is shown in Figure 6.2A. With the exception of Circular Impact Assessment, more than 50% of the respondents indicated that they used each competency in half or all of their circular economy projects. The Self-Reported Expertise of the respondents per competency is shown in Figure 6.2B. There was a significant correlation between Use Frequency and Self-Reported Expertise for each of the competencies. The correlation coefficients were positive and ranged between 0.65 and 0.83. This implies that a higher Use Frequency goes hand in hand with a higher Self-Reported Expertise of the competency.

Figure 6.3 shows how many respondents used and had expertise in specific competencies. Of the respondents, 28% reported using all seven competencies and 37% reported having expertise in all seven competencies.

We asked the respondents to give examples of how they used the competencies in practice. While not all respondents provided examples, we did collect a set of illustrative examples which reflected how the competencies were used in practice. These examples helped us understand whether the respondents had interpreted the competencies as intended and what knowledge they had regarding underlying concepts. Table 6.3 lists the examples, including quotes from the survey, and the approaches that the respondents used. The examples informed the adaptations we made to the descriptions of the competencies (see section 6.4.2).

We asked the respondents which competencies they considered to be missing in the presented overview. They responded by giving 69 examples of which 58 were descriptions of competencies, the other 11 were related to character traits such as "perseverance or commitment". The 58 descriptions of the competencies were clustered as described in Section 6.4.1. Table 6.4 gives an overview of the resulting clusters, including

Competency	Examples of Use of Competencies in Circular Economy Projects (*n*= Number of Responses)
Design for Recovery	• Following design strategies that would enable recovery (e.g., modularity, disassembly) (***n*** = 22)
Design for Multiple Use Cycles	• Focusing on services that keep products in use longer (***n*** = 13) • Using circular design strategies (e.g., timeless design, simple design, design for durability, design for disassembly) (***n*** = 12) • Investigating changing user needs (***n***= 9)
Circular Impact Assessment	• Creating project specific indicators (***n*** = 26) • Using existing environmental impact assessment tool and indicators (***n*** = 24)
Circular Business Model Integration	• Exploring circular business model strategies (***n*** = 27)
Circular User Engagement	• Making users experience the benefits of circular solutions (e.g., sharing pilots) (***n*** = 12) • Focusing on customer benefits (e.g., ease of use, ease of repair) (***n*** = 9)
Circular Economy Collaboration	• Involving multiple partners (e.g., suppliers, recyclers, and clients) in the early on in the development process (***n*** = 47)
Circular Economy Communication	• Giving examples of available circular economy through cases studies and physical prototypes (***n*** = 21) • Creating shared understanding of purposes, needs and vocabulary (***n*** = 19)

Table 6.3 Examples of use of competencies in circular economy projects

Quote	Approaches/Methods Used (*n*= Number of Responses)
"Devised ways to enable the easy collections of discarded products and evaluated the reverse logistics involved."	• Product/user journey insightful (***n*** = 4)
"We have recreated our methodology in a way that our user journeys always have the possibility for multiple use cycles, over a single one."	• User journey mapping (***n*** = 7)
"We use a multi-criteria assessment including Circular Life Cycle Assessment (we developed our own circular LCA), Material Flow Analysis, Life Cycle Costing (together with our colleagues)."	• Life Cycle Assessment (***n*** = 9) • Recycled content (***n*** = 10) • Material passport (***n*** = 3)
"In product development we always make continuous [...] serviceability evaluations."	• Circular/Sustainable Business model Canvas ***n*** = 11) • Stakeholder dialogue/analysis (***n*** = 7)
"I work with numerous groups to host sharing economy events–swap shops, repair cafes, promoting second hand shopping over fast fashion."	• User research via co-creation, diaries, surveys, and interviews (***n***= 13) • User journey mapping (***n***= 3)
"We look with partners at trade-in and buyback programs of IT servers and workstations, which also stimulates the Original Equipment Manufacturer to launch certified pre-owned programs or re-use parts for repair."	• Co-creation, creative and brainstorming sessions (***n*** = 12) • Surveys and Interviews (***n***= 7) • Stakeholder mapping and analysis (***n***= 4)
"We are always asked to bring business cases to the table, or success stories". "I designed a strategy to talk about transition. I created the visual language to make sure everybody was talking about the same thing."	• Storytelling (***n*** =42)

illustrative quotes; most of which could be clustered under one of the seven competencies. We found two clusters that did not fit the existing competencies: Circular Systems Thinking and Circular Materials and Manufacturing.

6.3.3 Comparing Use Frequencies and Self-Reported Expertise levels between groups

We found no significant differences in Use Frequency and Self-reported Expertise for most competencies based on the type of organization, the geographical location in which the respondents worked, or their years of experience. We performed one-way ANOVAs to test the assumption that the professional background and work environment influenced the Use Frequency of and Self-Reported Expertise in a competency. The exceptions are described below.

Respondents working for design agencies reported having a lower expertise in Circular Business Model Integration and Design for Recovery than respondents working at consultancies. Respondents with only a few years of work experience (i.e., 0–2 years) reported lower expertise in Circular Economy Communication and Circular Business Model Integration than those who had greater experiences (i.e., 10 years or more). In addition, respondents working for design agencies used Circular Impact Assessment less than those working for private companies and respondents working at consultancies used Circular Economy Communication less than respondents working at universities.

6.4 Discussion

We conclude our study with the addition of two competencies to our original list of seven key circular economy competencies for design: a total of nine. We first discuss the two additions made to the original set before reflecting on how we adapted some of the descriptions of the original competencies. We close with a discussion on the implications of our findings and opportunities for further research.

6.4.1 Two additions to the original set of competencies

We added two new competencies to the original set of seven: Circular Systems Thinking and Circular Materials and Manufacturing.

Circular Systems Thinking

In the literature, Circular Systems Thinking is widely identified as an important competency for a circular economy (e.g. Blomsma & Brennan, 2018; Ellen MacArthur Foundation, 2015; Webster & Johnson, 2010; Whalen et al., 2017). Yet, its actual use in practice was not evident in previous studies (Sumter et al., 2020). This survey, however, shows that systems thinking is also deemed important by practitioners. Respondents stressed the importance of "learning about systems and the flows within

Table 6.4. Clusters of respondents' additions to the seven circular economy competencies for design

Competencies	Quotes	Number of respondents
	Competencies not mentioned in original set of 7	
Circular Systems Thinking	• "[..] Being able to zoom in and zoom out on product and wider context." • "Learning to think about systems and how flows behave in them." • "A true market perspective [...] and clear business benefits - but beware in the same time rebound effects and dangerous growth promises."	11
Circular Materials and manufacturing	• "Materials and design; Material selection, design for manufacture or disassembly, recycling material properties" • "Designing and technical production experience and knowledge is needed before any circular solutions can be explored.	10
	Overlap with the original set of 7 competencies	
Design for Multiple Use Cycles	• "Design for modularity and pure material cycles." • "...in the building sector, we call it 'Design for Disassembly' - basically designing buildings as elements, which could be reused as Lego"	4
Design for Recovery	• "Circular (reversed) logistics cost and organization."	4
Circular Impact Assessment	• "We cannot forget to address ethical questions; what is the impact our product has on users, producers, manufacturers, communities and cultures." • "Integrating social and ecological domains in the circular economy by the design of new products. i.e. how do you balance design to be good for people, planet and profit."	4
Circular Business Model Integration	• "Business value (monetary impact) of circular economy projects."	6
Circular User Engagement	• "So you have to be a designer, not only focusses on sustainability and circular economy, because the users you are aiming for do not use/buy a product 'just because it is circular." • "Consumer/stakeholder behaviour change towards circularity."	6
Circular Economy Collaboration	• "I notice it requires different techniques when working together in a complex system with people with different expertise, like the circular economy is."	4
Circular Economy Communication	• "Educating those who are not familiar with the concept." • "Strategic alignment and visioning within corporations."	9

them" and "being able to zoom in and out" between the design of the physical product and the wider system. In the final set, we describe the competency Circular Systems Thinking as the ability to "adopt an approach to design that regards the circular economy as a complex system, taking into account that circular design interventions will have systemic effects". This description of the competency reflects the thought that circularity is not the property of an individual product or service but that of a system (Konietzko et al., 2020). In addition, this description of the competency signals the need to adopt a system-focus throughout the design process. This systems perspective is needed to both analyze which systems are needed to develop and operationalize circular products, services, and systems, and to assess the consequences of the circular design interventions on a wider system throughout and beyond the product-service life cycle. Systemic effects include, feedback loops, cascading effects, inertia, tipping points, cause-effects chains (Wiek et al., 2011), and rebound effects (Zink & Geyer, 2017).

Circular Materials and Manufacturing

Second, expertise related to Circular Materials and Manufacturing was indicated as an important additional competency. In the final set, we describe this competency as "the ability to select and use materials and manufacturing methods for a product to minimize the impact (environment, health, social), while taking the full lifecycle of the product and its recovery into account". We included Circular Materials and Manufacturing as a separate competency, as the focus on closing material resource loops lies at the heart of the circular economy. Respondents often mentioned the need for know-how about materials and manufacturing in connection with circular design strategies, such as regenerative design, design for the bio-cycle, and design for disassembly. The need for support when it comes to selecting and using materials is also recognized in the literature. In light of the future shortages of critical raw elements, Köhler et al. (2010) called for designers to develop competencies around resource-aware product design. Lilley et al. (2019) developed a framework on material change that helps designers gain more insights in the interaction between product use and material degradation. In addition, when it comes to limiting the impact of sourcing and recycling, the selection of suitable material and manufacturing processes is essential. Sauerwein and Doubrovski (2018), for example, specified a process in which they used local recyclable bio-based materials as input in the additive manufacturing process. In short, Circular Materials and Manufacturing reflects a need in practice to align material and manufacturing choices with the chosen recovery opportunities.

6.4.2 Adapting competency descriptions

We evaluated and adapted the descriptions of the initial seven circular economy competencies in light of the results. We changed the description for all seven competencies from a process-oriented to a result-oriented description as this signals the end-goal instead of prescribing a potential path to reach that goal. In this section, we elaborate on and give reasons for the adaptation of each specific competency.

Design for Recovery

Design for Recovery is now described as "develop product-service systems that allow for products, components and materials to be recovered and looped back into a circular economy". The term product-service systems was explicitly chosen to signal that circularity goes beyond the design of a tangible product. Product-service systems are "a mix of tangible product(s) and intangible service(s) that are designed to jointly meet customer needs" (Tukker, 2015). The examples given by the respondents (Table 6.3) showed that this competency entails designing products and associated services so that they can be taken back and recovered (e.g., through repair, refurbishment, remanufacturing or recycling).

Design for Multiple use Cycles

Design for Multiple Use Cycles has been rephrased "create product-service systems that are designed to have more than one use cycle while retaining value in a circular economy". We noticed an overlap in the interpretation of Design for Multiple Use Cycles and Design for Recovery suggesting that the original descriptions might not have been sufficiently distinctive. The rephrased descriptions of the competencies clarify that Design for Recovery focuses on the operations needed for recovery, while Design for Multiple Use Cycles focuses on the use cycles after recovery.

Circular Business Models

Circular Business Model (Integration) has been renamed Circular Business Propositions: "develop circular business propositions that aim at fully closing product and material loops and thereby keeping resources in use for as long as possible". Examples of the use in practice of this competency given in the survey, included exploring circular business model strategies. However, the given additional competencies (Table 6.4) reflected a need for assessing the business value as well as the regulations and policy necessary to ensure embedding of circular products services systems in practice. We chose Propositions as this better indicates the value that product-service systems can deliver to the user. It is a more general term that signals which and how value is created, while Circular Business Models points to a more specific detailing of how the value will be delivered and captured. Please note, however, that Circular Business Propositions are in line with circular business models.

In the literature these are described as models that focus on slowing resources loops by prolonging the use of products and components in consecutive cycles, and closing resources loops by capturing end-of-life-material value (Bocken et al., 2019; Nußholz, 2018).

Circular User Engagement

The description of Circular User Engagement has been adapted to "engage users in all aspects of the circular economy, for instance by enabling users to share and care for (shared or owned) products and stimulate them to loop back products at the end of a use cycle". The examples given by the respondents (Table 6.3) suggest that some users might be reluctant to adopt circular product-service systems. As the dominant business models are those in which the ownership of the physical product is transferred to users, these same users are central when it comes to the voluntary return of products. Poppelaars et al. (2020) argue that designers should be aware of the key steps in the divestment process in order to help users part with their product. Circular User Engagement highlights a new dimension of the design process as designers need to engage users in the circular economy and speed up the acceptance and adoption of both owned and access-based circular products.

Circular Impact Assessment

For Circular Impact Assessment, we adapted the description to "measure the environmental, economic and social impact of circular design interventions throughout the full product-service life cycle". The examples of additional competencies given by respondents (Table 6.4) reflected a need to also include dealing with social, financial, and environmental consequences e.g., "balance design to be good for people, planet and profit" and "assessing the impact products have on users, producers, manufacturers, communities and cultures." The need to consider social impacts reflects the wider call in the literature to consider the social domain in the circular economy discourse (Geissdoerfer et al., 2016; Kirchherr et al., 2017).

Circular Economy Collaboration

Circular Economy Collaboration is now described as "facilitate and engage collaborations across value networks in order to create circular product-service systems and stimulate the transition toward a circular economy". Identifying which stakeholders should be involved is a crucial step to inform efforts around engaging and facilitating collaborations. The examples of how Circular Economy Collaboration was used in practice reflected that designers were involved in facilitating and engaging stakeholders who play a role across the full product-service life cycle to support the development and implementation of circular product-service systems. Additionally, the adapted description uses the term value networks

as described by Brown et al. (2019) to signal that a circular economy requires an eco-system in which multiple stakeholders collaboratively develop and operationalize circular products service systems.

Circular Economy Communication

Circular Economy Communication has been renamed Circular Economy Storytelling. Its description has been adapted to "create engaging visions and narratives of the circular economy in order to make it a shared idea for which support can be garnered among various stakeholders". Circular Economy Storytelling not only serves to convince peers to participate in developing circular product-service systems solutions, but also helps to gather support for circular strategies on an organizational level and embed circular practices in organizations. Lack of circular buy-in from stakeholders proved to be a challenge that prevented designers from moving forward with the implementation of circular product-services systems. In an earlier study, we noted that Circular Economy Communication was essential to support Circular Economy Collaboration, and we suggested that developing a circular economy vocabulary is an essential component to support this competency (Sumter et al., 2019). The literature also emphasizes the need for designers to develop future-oriented visions and narratives to guide sustainability transitions (Gaziulusoy & Ryan, 2017; Irwin, 2015). This supports the notion that designers could inspire and persuade other stakeholders to work toward building sustainable futures.

6.4.3 A coherent set of key circular economy competencies for design

We validated a set of key circular economy competencies for design. In this section, we address the coherence of the set, we reflect on how it compares to other overviews of circular design competencies, and we address paths for future research.

Figure 6.4 shows the nine circular economy competencies for design. None of these competencies can be used in isolation, they form an interconnected set. The circular diagram shows that each competency is equally important. The icons form a visual representation of each competency, and similar colors were used to denote the relationships between competencies. Circular Systems Thinking argues that a systems approach is an essential element of the complete design process. Design for Recovery and Design for Multiple Use Cycles are competencies aimed at slowing and closing resource loops. These are also the 'newest' competencies, in the sense that the others (business proposition development, user engagement, materials and manufacturing knowledge, impact assessment, collaboration and storytelling) are recognizable for any design scholar– albeit

in a circular context. However, Design for Recovery and Design for Multiple Use Cycles are at the heart of what a circular economy is about, which is slowing down and looping back the flows of products and materials in the economy. Circular Business Propositions, Circular User Engagement, and Circular Materials and Manufacturing enable the development process of circular product-service systems and reflect the integrative nature of design to connect business, users, and technology. Circular Impact Assessment guides the development of the design process and helps to determine the impact of the design interventions. Circular Economy Collaboration and Circular Economy Storytelling represent the interpersonal side of the design process i.e., involving and engaging stakeholders.

Our nine competencies differ from the circular economy competencies for design identified by De Los Rios and Charnley (2016). Ours are formulated so that they are result-driven and indicate how they are applied in practice. Our results show that the competencies form a coherent set. A substantial number of respondents used and had expertise in all of the seven original competencies. Professional background and work

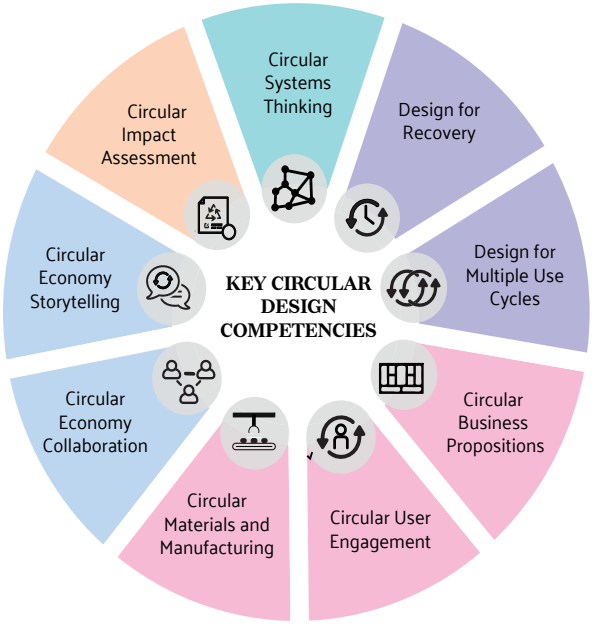

Figure 6.4 Nine key circular economy competencies for design (The circular design competencies wheel)

Circular Systems Thinking

Adopt an approach to design that regards the circular economy as a complex system, taking into account that circular design interventions will have systemic effects.

Design for Recovery

Develop product service systems that allow for products, components and materials to be recovered and looped back into a circular economy.

Design for Multiple Use Cycles

Create product service systems that are designed to have more than one use cycle while retaining value in a circular economy.

Circular Business Propositions

Develop circular business propositions that aim at fully closing product and material loops and thereby keeping resources in use for as long as possible.

Circular User Engagement

Engage users in all aspects of the circular economy, for instance by enabling users to share and care for (shared or owned) products and stimulate them loop back products at the end of a use cycle.

Circular Materials and Manufacturing

The ability to select and use materials and manufacturing methods for a product to minimize the impact (environment, health, social), while taking into account the full life cycle of the product and its recovery.

Circular Economy Collaboration

Facilitate multi-stakeholder collaboration across value networks in order to create circular product service systems as well as stimulate the transition towards a circular economy.

Circular Economy Storytelling

Create engaging visions and narratives of the circular economy in order to make the idea understood and to garner support for it amongst various stakeholders.

Circular Impact Assessment

Measure the environmental, economic and social impact of circular design interventions throughout the full product-service life cycle.

environment were shown to have little influence on the use of, or expertise in, a competency. With a few exceptions, there were no significant differences based on the type of organization and geographical location in which the respondents worked and their years of work experience, in contrast to suggestions in the literature (e.g. De los Rios & Charnley, 2016; Sumter et al., 2018). This implies that all seven original competencies were used and considered valuable, independent of respondent background or work experience. Even though the competencies might not all be applied in each project, overall they reflect the main qualification of competent designers who specialize in DfCE.

Based on this research, we expect that acquiring these circular design competencies warrants the successful development and implementation of circular product-services systems. However, several barriers that persist outside the influence sphere of design need to be dealt with. Examples of these are financial (e.g., limited suitable sources for finance), operational (e.g., value chain management), and structural (e.g., lack of information) (Ritzén & Sandström, 2017), but they can also be related to policy and legal frameworks (Rizos et al., 2015).

Wiek et al. (2016) detail a process for operationalizing competencies for different educational levels, which entails formulating learning outcomes and related concepts and methods. A similar process could be followed with the set of nine key circular economy competencies for design. This would be valuable when developing circular design methods and for curriculum development.

6.5 Conclusions

We conclude this study by presenting a set of nine key competencies for design in a circular economy: (1) Circular Systems Thinking, (2) Design for Recovery, (3) Design for Multiple Use Cycles, (4) Circular Business Propositions, (5) Circular User Engagement, (6) Circular Materials and Manufacturing (6) Circular Impact Assessment, (8) Circular Economy Collaboration, and (9) Circular Economy Storytelling. This internationally validated set of interlinked competencies provides a foundation for the growing interest in circular design competencies that support design practice and guide the development of design methods and courses in circular design. Our international survey with 128 respondents shows that the set is recognizable in practice. Ours is one of the first studies to provide empirical evidence for the need for such competencies. The results further indicate that the field is still relatively young, dynamic, and developing. We expect that in the future. designers will acquire more circular design

expertise through practice which will enable them to better articulate the specific competencies they have acquired and still need, as well as which methods and educational programs could offer support. Therefore, we foresee that similar studies will be performed more regularly in the future to monitor the progress toward a circular economy and to understand the accompanying design competencies.

Lastly, while this set is not the 'final' answer in the search for circular design competencies, the international validation and consolidation of these nine key circular design competencies offers grounds for operationalizing them in practice; they serve as a foundation for the development of circular economy-based methodology and curricula.

Author Contributions

D.S. is the corresponding author of this manuscript and the primary author of this manuscript. She was in charge of collecting and analyzing the data, wrote the initial draft of the manuscript, and produced the tables and figures included in this manuscript. J.K, C.B. and R.B. supervised her in this process and contributed to reviewing the manuscript multiple times before it was submitted. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data presented in this study are openly available in the 4TU repository at https://doi.org/10.4121/13213610.v2.

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Conflicts of Interest

The authors declare no conflict of interest.

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CHAPTER 7

DISCUSSION AND CONCLUSIONS

In this concluding chapter, I reflect on the outcomes of the studies described in chapters 2-6. In section 7.1, I summarize the studies' findings. Second, in section 7.2 I reflect on the changing role of design in a circular economy. In section 7.3, I elaborate on the set of nine key circular economy competencies. In section 7.4, I discuss the theoretical contributions of this thesis and, in section 7.5, I expand on the implications for design practice. Last, in section 7.6, I present my recommendations for future research.

7.1 Summary of findings

The overarching aim of my thesis was to develop a set of design competencies for a circular economy. With the uptake of the circular economy in national (Ministerie van Infrastructuur en Milieu, 2016) and international policy (European Parliamentary Research Services, 2017) as well as the pledge to support the transition towards a circular economy through the European Skills Agenda (Circular Economy Action Plan, 2015), the relevance of developing an overview of key circular design competencies became manifest. Competencies can both inform methodology use and development and vice versa (Daalhuizen, 2014; Lindahl, 2005), and they can guide the development of education (e.g. UNESCO, 2017). When starting working on this thesis, very few studies had been published on circular economy design competencies (e.g. De los Rios & Charnley, 2016; Ellen MacArthur Foundation, 2015; Whalen et al., 2017). Moreover, the lists of competencies mentioned in these studies did not yet offer a coherent overview.

My main research question was: What competencies do designers need to develop products and services for a circular economy? I took a mixed-method approach (i.e., a single longitudinal case study, focus groups, individual face-to-face interviews, and an international survey) through which I developed a set of competencies for the emerging field of design for a circular economy. Chapter 2 highlights the role designers could fulfill in the transition towards a circular economy. Chapter 3 focuses on investigating design roles and competencies for a circular economy. My aim was to connect the identified competencies to design roles. Yet, as the studies progressed, it became clear that the design roles identified in the literature could not be distinguished quite as strongly in practice; roles appeared to be much more fluid in practice. For example, a design manager – at first glance seen as fulfilling a strategic role – could also be tasked with working on the embodiment of products and services. In the literature this task was viewed as being associated with an operational role. Therefore, in chapters 4-6, I shifted the focus to solely look at circular economy design competencies.

I conclude by presenting a set of nine key circular economy design competencies. The set was developed iteratively in chapters 3 - 6, and based on empirical studies with designers who have actively been developing circular products-service systems (see table 7.1). From one study to the other, I validated and extended the previous set of competencies by contrasting the literature with findings from the studies. I used a generic

framework on sustainability competencies developed by Wiek et al., (2011) to categorize the competencies, ensure coherence, and embed the set in existing scientific knowledge. In chapter 6, the key competencies were validated and expanded based on a survey with an international network of designers, ensuring that they offered a reflection of the needs in practice.

The thesis was set in a period with many international calls for a "transition towards a circular economy" (Ellen MacArthur Foundation, 2015; European Parliamentary Research Services, 2017; Ministerie van Infrastructuur en Milieu, 2016). The subjects of the PhD studies were designers, situated in the current linear system, who had experience in developing products and services following circular strategies and principles. The choice to work with designers in practice followed from the desire to understand how they design circular products and services in practice, and the competencies they perceived to be necessary to achieve their goals. Working with designers who are currently pioneering when it comes to the development of circular products-service systems, also gave us the opportunity to dive deeper into needs in practice. My studies also brought to light the challenges of designing for a circular economy in the real world (e.g., a lack of circular buy-in, and limited adoption of systems-thinking within design). Understanding the needs of designers in practice offered insights in the specific competencies important to designing circular product-service systems. The set of nine key circular design competencies enables us to reflect on the consequences of aiming to close and slow down resource loops on design competencies i.e., direct more focus towards concepts such as systems thinking, timeframes, life cycles, environmental considerations, and societal effects.

	Chapter 2	Chapter 3	Chapter 4
Roles	Functional; Coordinating and Strategic	Functional; Coordinating; Strategic	
Competencies			
		• Anticipate how the circular offering will evolve over multiple life-cycles	• Design for Multiple Use Cycles
		• Concurrently develop the circular business model and the product's design	
			• Connecting Reverse Logistics with Users
		• Facilitate collaboration between internal and external stakeholders who play a role in operationalizing a circular business model	
			• Circular Economy Understanding • Circular Economy Storytelling
		• Estimate the environmental impact on a system level over multiple life cycles	• Setting Circular Criteria • Assessing Circular Solutions

Table 7.1 Overview of the identified roles and competencies per chapter

Chapter 5	Chapter 6
	Circular Systems Thinking Adopt an approach to design that regards the circular economy as a complex system, taking into account that circular design interventions will have systemic effects
Design for Recovery Incorporating recovery strategies during the design process while taking into account multiple use cycles	**Design for Recovery** Develop product service systems that allow for products, components and materials to be recovered and looped back into a circular economy
Design for Multiple Use Cycles Foreseeing the consequences of prolonged use and multiple use cycles	**Design for Multiple Use Cycles** Create product service systems that are designed to have more than one use cycle while retaining value in a circular economy.
Circular Business Model Integration Concurrently developing the circular product, service, and business model	**Circular Business Propositions** Develop circular business propositions that aim at fully closing product and material loops and thereby keeping resources in use for as long as possible.
Circular User Engagement Engaging users in the use and the (end-of use) return of products	**Circular User Engagement** Engage users in all aspects of the circular economy, for instance by enabling users to share and care for (shared or owned) products and stimulate them loop back products at the end of a use cycle.
	Circular Materials and Manufacturing Select and use materials and manufacturing methods for a product to minimize the impact (environment, health, social), while taking into account the full lifecycle of the product and its recovery.
Circular Economy Collaboration Identifying, mapping, facilitating, and managing the collaboration between external stakeholders in operationalizing a circular business model	**Circular Economy Collaboration** Facilitate multi-stakeholder collaboration across value networks in order to create circular product service systems as well as stimulate the transition towards a circular economy
Circular Economy Communication Telling coherent stories about the circular offerings	**Circular Economy Storytelling** Create engaging visions and narratives of the circular economy in order to make the idea understood and to garner support for it amongst various stakeholders
Circular Impact Assessment Estimating the environmental impact of circular offerings on a system level over multiple use cycles to support decision-making during the design process	**Circular Impact Assessment** Measure the environmental, economic and social impact of the transition to a circular economy.

7.2 The changing role of designers in a circular economy

It has been known for some time that the roles of designers are subject to change. Both within the field of design for a circular economy as well as the wider field of design for sustainability the roles are increasingly expanding towards realizing strategic and systemic change (Baldassare et al., 2019; Dokter et al., 2021). In the field of design management, a similar shift in design roles has been described (Meyer & Norman, 2020; Price & Straker, 2017; Voûte et al., 2020)- "Designers today are often asked to address new kinds of problems at scales quite different from those of the past" (Future of Design Education, 2020). These scales are described as systemic, global and complex (Meyer & Norman, 2020). This thesis confirms these expanding roles.

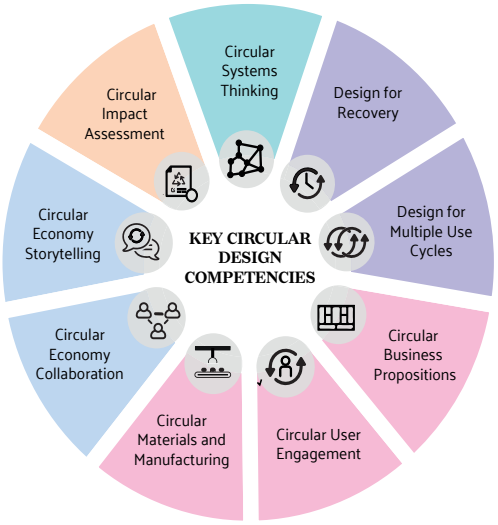
New and additional competencies are needed for designers fulfilling both more functional as well as more strategic roles. The circular design competencies identified in within this thesis are in line with competencies earlier identified in context of design management. The need for a competency such as Circular Business Propositions, for example, shows how design for a circular economy requires for designers to contribute to strategic activities within their organization. A similar competency e.g., managing organizational change, was identified by Chiva and Alegre (2009) who formulated a set of 5 dimensions of the design management competency i.e., basic competency, specialized competency, competency in involving others, competency in managing organizational change and competency in managing innovation. In the context of design for a circular economy, Circular Economy Collaboration and Circular Economy Storytelling and even Circular User Engagement show an increasing importance of engaging and involving other stakeholders in the design process. Design for a circular economy also asks designers to also develop new "specialized competencies" such as Design for Recovery, Design for Multiple Use Cycles and Circular Materials and Manufacturing. The findings in this thesis, however, also suggest that in the context of design for a circular economy the role of design managers would expand even further, for example, when looking at the need for Circular Systems Thinking and Circular Impact Assessment. These competencies form a reflection of the shift away from creating singular objects towards creating systems (Ceschin et al., 2016; Dokter et al., 2021).

Design for a circular economy requires designers to reflect on their role in the design process. In this thesis I developed a set of key circular economy competencies which is generalizable to a certain extent. "Generalization is a good first step to the application of the competencies in specific context" (Conley, 2010, p. 12). Designers need to learn to determine how to apply their competencies best according to the context instead of being confined to one role. This requires broadly trained designers (Conley, 2010) who can play varied roles across organizations (Perks et al., 2005).

7.3 The nine key circular economy competencies for design

In this section, I elaborate on each of the nine key competencies developed in this thesis (figure 7.1). Each description highlights why the competency is relevant, is illustrated with a quote or example of how the competency is used in practice, and shortly lists methods, tools or approaches that could help designers develop the competency.

At the end of this paragraph in table 7.2 I summarize the associated activities and methods for each of the competencies. These activities and methods are a culmination of the findings throughout the different studies in this thesis.



The ability to...

Circular Systems Thinking
Adopt an approach to design that regards the circular economy as a complex system, taking into account that circular design interventions will have systemic effects

Design for Recovery
Develop product service-systems that allow for products, components and materials to be recovered and looped back into a circular economy

Design for Multiple Use Cycles
Create product service-systems that are designed to have more than one use cycle while retaining value in a circular economy

Circular Business Propositions
Develop circular business propositions that aim at fully closing product and material loops and thereby keeping resources in use for as long as possible

Circular User Engagement
Engage users in all aspects of the circular economy, for instance by enabling users to share and care for (shared or owned) products and stimulate them loop back products at the end of a use cycle

Circular Materials and Manufacturing
The ability to select and use materials and manufacturing methods for a product to minimize the impact (environment, health, social), while taking into account the full lifecycle of the product and its recovery

Circular Economy Collaboration
Facilitate and engage collaborations across value networks in order to create circular product service-systems as well as stimulate the transition towards a circular economy

Circular Economy Storytelling
Create engaging visions and narratives of the circular economy in order to make it a shared idea for which support can be garnered amongst various stakeholders

Circular Impact Assessment
Measure the environmental, economic and social impact of circular design interventions throughout the full product-service life cycle

Figure 7.1 Nine key circular economy competencies for design (The circular design competencies wheel)

7.3.1 Circular Systems Thinking

Ceschin and Gaziulusoy (2016) describe an evolution in the design for sustainability field from product-focus (e.g., green design and eco-design) to an emphasis on socio-technical systems and sustainability transitions (e.g., transition design and design for system innovations and transitions). This evolution reflects the overall shift or expansion of the design field, whereby design increasingly deals with solving complex societal problems (Price & Straker, 2017). In design education, for example at Delft University of Technology, the shift from product to services and systems has been recognized. Societal challenges such as sustainability are framed as topics to be addressed at a systemic level, whereby the focus is now on complex systems (Voûte et al., 2020). The growing involvement tackling these wider societal and systemic problems requires designers to adopt systems thinking. In the context of design for a circular economy, this need has already been recognized (Ellen MacArthur Foundation, 2015; Webster & Johnson, 2010; Whalen et al., 2017). Forslund et al. (2018) identified that although systems thinking appears in circular economy-based courses, it is unclear how the competency is understood, as it is equated with setting up collaborations or LCAs.

Forslund et al. (2018) analyzed learning offerings on the circular economy: of the 51 identified learning offerings, 22 included systems thinking. Although, systems thinking is considered important, its operationalization varies greatly across the different offerings. In chapter 6 of this thesis, I describe how the need to master systems thinking in practice became apparent. Circular Systems Thinking is about adopting an approach to design that regards the circular economy as a complex system.

According to the literature, useful methods in the context of design for a circular economy are the Circularity Compass and the Circularity Grid (Blomsma & Brennan, 2018). These tools help identify opportunities to intervene in the system from a resource perspective, and explore current and future systems. Alternatively, serious games such as In the Loop could be of support when developing Circular Systems Thinking as they provide room for experimenting and acquiring concrete experience, and can support planning and reasoning (Whalen et al., 2017).

Design for Recovery 7.3.2

Design for Recovery follows from the aim to close the loop e.g., recover products, components and, as a last step, material resources. This requires designers to design products and service-systems which accommodate the different types of strategies (e.g., repair, refurbishment, remanufacturing, and recycling), and which focus on recovering functionality and value in between use cycles and at the end of product life. Design for Recovery focuses not only on optimizing and aligning the design of the physical product with the chosen recovery strategy, but also refers to the design of the service-systems or supportive infrastructure which enables product return so that recovery activities can be performed. Design for Recovery requires designers to develop anticipatory thinking as it requires them to make design choices based on the appropriate recovery pathways that will enable recovery of the product, components and materials at a later stage.

A review of the literature reveals a number of studies that focus on developing support for Design for Recovery. Flipsen et al. (2016), for instance, tested and improved an existing indicator to assess the reparability of products. Cordella et al (2018) specifically developed an approach for the repairability assessment of Energy-related Product (e.g., refrigerators) specifically. De Fazio (2019) developed a practical design tool for designers to (visually) assess the disassembly depth and sequence of the product components.

Integrating the knowledge at an early stage in the design process is important for the uptake of design for remanufacturing (Boorsma et al., 2020). Pigosso et al. (2010) made an overview of methods for use in the earlier stages of the design process in order to stimulate product recovery, in particular remanufacturing. The REMPRO Matrix developed by Sundin and Lindahl (2008) provides an overview of product features that are preferable for the steps taken in the remanufacturing process. Pozo Arcos et al. (2018) provide a comprehensive overview of design strategies, guidelines, and product features that can be used to optimize the functional recovery of products.

7.3.3 Design for Multiple Use Cycles

In Design for Multiple Use Cycles, designers are expected to envision how products and components can be used in consecutive (cascading) use cycles by the same or different users after recovery. The aim is to maintain product integrity across more than one use cycle (den Hollander, 2018). Design for Multiple Use Cycles mostly refers to durable consumer goods and is much less applicable to consumables or non-durable fast-moving consumer goods, which mostly only have one use cycle.

Design for Multiple Use Cycles is associated with anticipatory thinking as it requires designers to envision and detail the design of products so they can last across multiple use cycles. My findings show that designers have to account for how and to what extent future trends will impact the design of a product and the length of the use cycle. Furthermore, designers are involved in the adaptability and upgradability of product-service systems, so that they align with both horizontal (e.g., product lines) and vertical (e.g., product generations) planning. By extension, this competency is connected to concepts like time, potential futures; the uncertainty related to this competency assists in future visioning (e.g., product journey maps). For example, Franconi (2020) developed an online interactive tool that supports designers to envision future product use cycles.

Circular Business Propositions 7.3.4

The need for designers to be more involved in developing circular business propositions became apparent throughout our studies in this thesis. Chapters 3 and 5 show the importance of aligning the business proposition with the product's design. A designer in chapter 5 mentioned, "It has become clear to me how important the link is between the business aspect and the design; that the (product) design is only a part of the challenge (...)". Circular Business Propositions was classified as a strategic competency as it reflects the need for design interventions at a business strategy level, balancing circular product strategies and business factors such as feasibility, viability and scalability.

The emphasis on developing business propositions in line with closing resource loops reflects the need for designers to assume strategic roles. Circular Business Propositions can also be associated with anticipatory thinking, as the aim of circular business propositions is to keep resources in use for as long as possible. Nußholz (2018) developed a circular business mapping tool that helps designers envision how the value proposition will change throughout multiple use cycles.

7.3.5 Circular User Engagement

Circular User Engagement comes to the forefront as the circular economy advocates cycling of resources at a high value level. Mastering Circular User Engagement requires designers to take into account how users take care of products, stimulate users to return products, as well as creating acceptance for preowned products. In practice, it has proved to be a challenge to create acceptance for pre-owned products as well as acceptance of non-ownership or access-based models. The perception of a recovered product is still contaminated by the stigma of "second hand" products (Mugge et al., 2017). Moreover, there are various barriers, such as the change required to the user's lifestyle, that prevent access-based models from being adopted (Tunn, 2020). My findings are in line with the literature that suggests that design should engage users in the care and return of products (e.g., F. Poppelaars et al., 2018; Van Weelden et al., 2016; Wastling et al., 2018). For example, respondents from my studies mentioned the importance of actively motivating users to return products. In addition, they stressed the importance that service be in line with customer needs: "you need an active system to motivate people to (return products)".

While access based-models are especially seen as being potentially relevant for sustainable consumption, users still value ownership above access (Catulli, 2012; Tukker, 2015). Poppelaars et al. (2020) carved out a role for design by explaining how design for divestment can stimulate the return of products. The design for divestment principles, together with the design for circular behavior process (Wastling et al., 2018), can be used as guidance when addressing the user perspective in the context of a circular economy.

Circular Materials and Manufacturing 7.3.6

Circular Materials and Manufacturing arises from the resource perspective of the circular economy. In contrast to traditional design and other sustainable design, design for a circular economy presupposes more understanding of the full product and material journey; from mining to turning the materials into products, to recovering these products and recycling the materials. Circular Materials and Manufacturing signals a need to understand (the effect of) materials and manufacturing in time; to quote a respondent "I think, you have to understand what the material does, really understand the material. So, how does it look when it is fresh [...] where does it come from, how do you collect it, what is the source material?" When it comes to circular materials, designers are tasked with investigating where material are sourced as well as determining how materials will degrade over time in order to select "the right" materials that are in line with the applied circular product design strategy (e.g., regenerative design, design for the biocycle, design for disassembly). In essence, designers have to ensure that they select and use materials and manufacturing processes in line with the chosen recovery strategies, while taking into account the impact of these materials and the manufacturing processes.

The findings in this study indicated that the lack of knowledge regarding the prolonged use and selection of materials proves a challenge. While research related to materials and manufacturing processes has been explored in the context of ecodesign, research focusing on Circular Materials and Manufacturing has focused more on recovery and material integrity. Sauerwein and Doubrovski (2018), for instance, specify a process of how to develop materials for additive manufacturing from local waste material. Joustra et al. (2019) explored the opportunities of circular design with composites. The findings of these material-oriented studies signal the importance for designers to be more actively involved in exploring, and understanding the barriers and opportunities of different types of materials and manufacturing processes in order to master Circular Materials and Manufacturing.

7.3.7 Circular Economy Collaboration

The need for Circular Economy Collaboration within design is a reflection of the overall increasing involvement of design in developing solutions for complex societal problems (Ceschin & Gaziulusoy, 2016).

Our studies show that working in silos formed a barrier for designers to implement the circular product and services they were developing. For example, in the Bugaboo case (Chapter 3), offering the strollers through leasing instead of selling them demanded new flows of information between, and responsibilities of, the different departments. In addition, the studies showed that relationships with partners further upstream and downstream in the value chain needed to be established to gain more insights in materials information to support materials selection and use, as well as to ensure that product, components and materials could be recovered. A quote from a respondent in chapter 5 showed that that collaborations of this type were not necessarily common practice, "I have never really even entered a workshop together with a supplier to figure out how to come up with an offer".

What makes collaboration in the context of a circular economy different is the focus on value networks, or what Ceschin and Gaziulusoy (2016, p. 149) frame as, "create relations between a variety of stakeholders of a value constellation". Collaborations are now happening earlier in the development process, and they focus on collectively developing circular product and services that are aimed at prolonging product life time, reuse and lastly value capture (Brown et al., 2019). Designers operated as intermediaries or facilitators in this collaboration process which included initiating, setting up and sometimes managing the collaboration. Morelli (2007, p. 18) noted that, "designers will no longer be proponents of a set of products and services to passive users, but rather the facilitators of a system of value co-production". In participatory design, approaches such as co-creation and co-design are foreseen as not only being useful for involving users, as described by Sanders and Stappers (2008), but also for other stakeholders (i.e., business partners). Alternatively, living labs are seen as a fruitful method to experiment and stimulate collaboration between stakeholders for a circular economy (Dokter et al., 2019; Revillio et al., 2019).

Circular Economy Storytelling *7.3.8*

Circular Economy Storytelling reflects the twofold focus of the competency: (1) build an understanding of what the circular economy as a paradigm entails, and (2) create engaging stories that move stakeholders to buy-into the circular economy. Throughout the studies in this thesis, it became clear that some of the designers who bought into the promise of the circular economy and were convinced about the urgency of the transition, struggled to get the stakeholders on board. In addition, the lack of coherence and unified vocabulary caused confusion about what individuals understood, "the circular economy is often equated with recycling, while this is the least preferred solution" (Chapter 4) and "the Tower of Babel problem with the circular economy" (Chapter 5).

Storytelling, in particular, has found its way into design as it can help build understanding and commitment. (Sametz & Maydoney, 2010). As collaborative working in globalized contexts generally has become the norm, designers are expected to develop stories and narratives to engage various stakeholders. The designer, whose strength is articulated as 'connector' (Manzini, 2009) or 'spider in the web', are generally seen as individuals who can make connections and develop engaging stories. The literature emphasizes the need for designers to develop future-oriented visions and narratives to guide sustainability transitions (Gaziulusoy & Ryan, 2017; Irwin, 2015), reflecting the idea that designers have a quality to inspire and persuade stakeholders to join in when building sustainable futures.

7.3.9 Circular Impact Assessment

Circular Impact Assessment brings together a focus on environmental, economic and social impact in the context of circular product-service systems. My findings indicate that estimating the different types of impact over multiple use cycles is what makes impact assessment both specific to the context of design for a circular economy as well as complex. The literature mainly stresses the need for designers to be able to assess the environmental consequences of their design interventions when aiming to extend product lifetime (Den Hollander et al., 2017). The respondents in chapter 6, however, noted that there was a real need in practice to measure environmental, societal and financial impact.

When it comes to environmental circular impact assessment specifically, the studies showed that in addition to using existing environmental assessment tools like (fast-track) Life Cycles Assessments (LCAs), some respondents have developed their own environmental assessment tools (chapter 6). This implies that current methods may insufficiently meet their needs. Reasons for this mentioned in the literature are that the tools do not reflect the complexity of the circular economy and that they do not provide guidance as to how to improve the circularity of product and services (Saidani et al., 2017). Overall, the studies that form this thesis reflect that designers are in need of tools to make impact assessments, as this helps them determine whether they are on the right track to "going circular".

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Table 7.2 (p.178-179) summarizes the associated activities and methods for each key circular economy competencies for design.

7.3.10
An interlinked set of key circular design competencies

In this section, I elaborate on how the interlinkage of these nine key competencies. Figure 7.2 shows how the key competencies can be positioned in design perspective. The technology-people-organization triangle (figure 7.2A) used at the Industrial Design Engineering faculty of the TU Delft serves as guidance to reflect on how the competencies relate to each other. This technology-people-organization triangle brings together the different perspectives integrated in industrial design (Industrieel Ontwerpen, 2020). In this triangle, technology focuses on the physical and digital design and mechanical/electrical functionality of product-service systems ranging from materials and manufacturing methods to electronics and data. People focuses on the users, their needs, experiences and the interaction with product-service systems as well as societal perspectives and ethics in design. Lastly, organizations focuses on the organizational context in which product-service systems are developed and the value that these product-service systems then provide for the organizations.

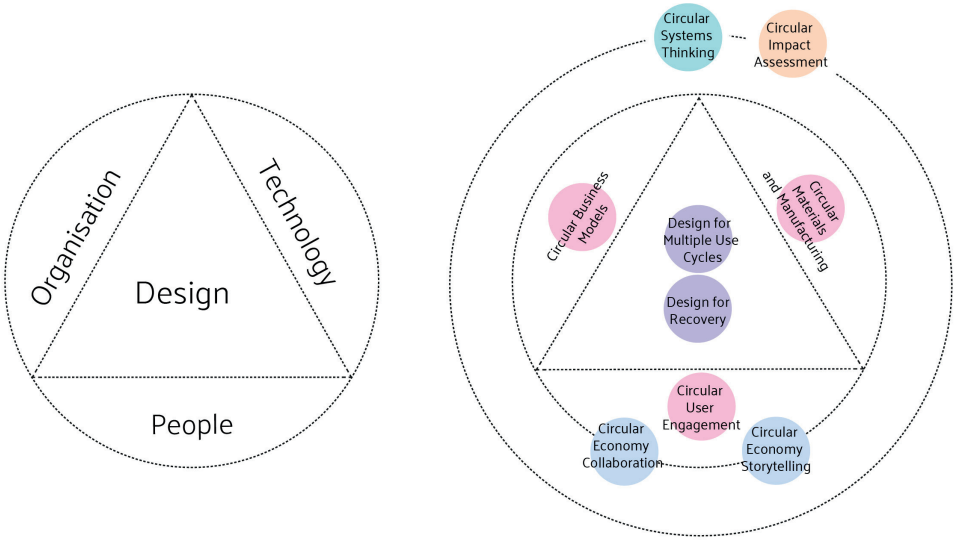

Figure 7.2 Technology-people-organization triangle from Industrial Design Engineering at the Delft University of Technology (A) and A coherent set of nine circular economy competencies for design (B).

Competencies	Description
Circular Systems Thinking	Adopt an approach to design that regards the circular economy as a complex system, taking into account that circular design interventions will have systemic effects
Design for Recovery	Develop product service systems that allow for products, components and materials to be recovered and looped back into a circular economy
Design for Multiple Use Cycles	Create product service systems that are designed to have more than one use cycle while retaining value in a circular economy.
Circular Business Propositions	Develop circular business propositions that aim at fully closing product and material loops and thereby keeping resources in use for as long as possible.
Circular User Engagement	Engage users in all aspects of the circular economy, for instance by enabling users to share and care for (shared or owned) products and stimulate them loop back products at the end of a use cycle.
Circular Materials and Manufacturing	Select and use materials and manufacturing methods for a product to minimize the impact (environment, health, social), while taking into account the full lifecycle of the product and its recovery.
Circular Impact Assessment	Measure the environmental, economic and social impact of the transition to a circular economy.
Circular Economy Collaboration	Facilitate multi-stakeholder collaboration across value networks in order to create circular product service systems as well as stimulate the transition towards a circular economy
Circular Economy Storytelling	Create engaging visions and narratives of the circular economy in order to make the idea understood and to garner support for it amongst

Table 7.2 Key Circular Economy Competencies for design, Activities and Methods

Activities	Methods
• Analyze which systems are needed to develop and operationalize circular product and services • Assess the consequences of the circular design intervention	• Circularity Compass and Circularity Grid (Blomsma & Brennan, 2018) • Serious games (e.g., In the loop) (Whalen et al., 2017)
• Set design requirements that are in line with the chosen recovery strategy for the circular product services system at hand • Make design decisions that are in line with the chosen recovery strategy	• Overview with product features, design strategies and guideline to optimize recovery of products (e.g., REMPRO Matrix by Sundin and Lindahl (2008) or framework by Pozo Arcos et al. (2018) • Repairability Indicator (Flipsen et al., 2016) • Disassembly Map (Fazio, 2019)
• Envision what prolonged use and multiple use cycles look like • Make longitudinal value propositions (den Hollander, 2018) • Create products with a fixed or pre-designed number of use cycles (Kane et al., 2018)	• Product journey mapping • Design for X framework (Franconi et al., 2019)
• Develop the business propositions as part of the circular product and/or service proposition (using the guidelines on circular business model strategies)	• Circular business model mapping tool (Nußholz, 2018) • Circular business model canvas (Lewandowski, 2016)
• Guide users to choose for circular product and services. • Develop product and/or service features that enable users to care for and bring back their products	• Customer journey map • Design for circular behavior process (Wastling et al., 2018) • Design for divestment (Poppelaars et al., 2020)
• Investigate the sourcing and recycling opportunities of materials • Make design decisions regarding materials based on the full product life cycle • Align manufacturing choices with recovery opportunities	• Framework on material change (Lilley et al., 2019)
• Design long lasting networks and relationships between stakeholders throughout the different stages of the design process and product life cycles(Dokter et al., 2021)	• Co-creation in living Labs (Dokter et al., 2019; Revillio et al., 2019) • Value mapping (Geissdoerfer et al., 2016)
• Develop illustrative stories and visions of circular product-service systems • Create a common vocabulary to talk about circular design	• Storyboards and case studies, Circular economy vocabulary (Dokter et al., 2021)
• Identify and balance design interventions affecting people, planet and profit throughout the product life cycle • Assess the social, environmental and financial impact of these design interventions	• Circularity Indicators (Ellen MacArthur Foundation and GRANTA, 2015) • Impact assessment tools

In figure 7.2.b, the nine key circular economy competencies for design are mapped on the technology-people-organization triangle to showing how they draw on the different perspectives integrated in industrial design. An additional outer 'layer' was added to accommodate the Circular Systems Thinking and Circular Impact Assessment competencies. This layer is added following the observation that design for a circular economy shifts away from creating singular objects towards creating systems (Ceschin & Gaziulusoy, 2016; Dokter et al., 2021).

Circular Systems Thinking reflects the need to view 'circularity as a property of an eco-system and not of an individual product or service' (Konietzko et al, 2020). Circular design requires foreseeing the systemic effects that emerge as a consequence of circular design interventions throughout the product-service life cycle and beyond. Therefore, Circular Systems Thinking is positioned on the outermost layer of the system.

Circular Impact Assessment is a competency that summarizes the overall need for designers to evaluate whether they are 'on the right track' towards a circular economy from a financial, societal and environmental perspective. It requires assessments to be made over multiple use cycles on a systems level, over time. Therefore, it also positioned on the outermost circle, together with Circular Systems Thinking.

Design for Recovery and Design for Multiple Use Cycles are at the heart of what design for a circular economy is about i.e. slowing down, looping back and reusing the flows of products and materials in the economy. Therefore, they are positioned in the center of the triangle. Design for Recovery focuses on the activities needed for recovery to ensure products get looped back. Design for Multiple Use Cycles focuses on the use cycles after recovery. Design for Recovery and Design for Multiple Use Cycles both require anticipatory thinking, as these competencies require designers to foresee how products can be recovered and how they can be used in a consecutive use cycle, respectively.

Design for Recovery and Design for Multiple Use Cycles relate to Circular Business Propositions, Circular User Engagement, and Circular Materials and Manufacturing. Circular Materials and Manufacturing, Circular User Engagement, and Circular Business Propositions reflect the integrative nature of design to connect technology, people and organizations. Therefore, these competencies are positioned at the sides of the triangle, around Design for Recovery, and Design for Multiple Use Cycles.

Circular Economy Collaboration goes further than the competencies mapped in and along the three sides of the triangle, as the circular economy requires a value network or eco-system in which multiple stakeholders collaboratively develop and operationalize circular products service-systems (Brown et al. 2019). Specifically, Circular Economy Collaboration reflects the dependency on stakeholders (partners, peers and users) to develop, implement and adopt circular product-service systems. The studies show that designers are increasingly expected to develop narratives to engage and convince stakeholders, resulting in a need for Circular Economy Storytelling. Circular Economy Collaboration and Circular Economy Storytelling occur on the value chain level and company level, and enable the development of circular products and services. Therefore, they are positioned on the inner circle around the triangle.

The empirical studies in this thesis provide evidence that these nine key circular design competencies are what those needed by designers to successfully design circular product-services systems.

7.4 Theoretical contribution

The number of empirical case studies about the role of design in a circular economy was limited when I started working on this thesis in 2016. Applying empirical research has helped create a better understanding about circular design in practice. In this thesis, I have framed design for a circular economy as an alternative approach in the design for sustainability domain (e.g., eco design, sustainable product-service systems, and transition design). One of my main assumptions was that existing design for sustainability competencies were not sufficient, because circular design poses different challenges than the other design for sustainability approaches.

The studies forming this thesis explored design for a circular economy in practice, with the aim of developing a set of key competencies. The set of key competencies was created by (1) deriving the competencies from the world of design practice, (2) categorizing the competencies using a generic framework on sustainability competencies (Wiek et al., 2011), and (3) elaborating on the relationships between the competencies. In Chapters 3 – 6, I addressed the same research question using different methods. By applying different methods, I ensured that different perspectives were taken and that any potential bias resulting from using one method only, could be overcome. In a series of

iterative studies (i.e., chapter 4, 5 and 6), I compared findings from the literature with practice, enabling theory building. The development of this new set of key circular economy competencies for design strengthens the frame of design for a circular economy as an independent research area.

The set is the first internationally verified, coherent set of circular design competencies which provides designers with a vocabulary around circular design competencies.

7.5 Contribution to practice

The studies in this thesis provide insights relevant in practice for educators, developers of circular-economy-based curricula and methodology. The current lack of competency in circular design forms a barrier for design to contribute to the UN sustainable development goals (Schroeder et al., 2019). At the same time, jobs in the circular economy are growing (Circle Economy, 2020) and companies are looking for guidance to develop internal training programs focusing on the circular economy (Ellen MacArthur Foundation et al., 2019). This set of circular design competencies can now be used as a base to start developing new and/or updating circular design methodology and courses.

First, the overview of competencies can be used to inform competency building in design education. Design plays a role in circular economy-based courses (Forslund et al., 2018). The set of nine key circular design competencies can be used to detail learning outcomes for circular design education. To assist in this, methodologies that detail how to operationalize competencies for higher education can be followed (e.g. Wiek et al., 2016). In addition, the set can be used to guide and inspire circular-economy-based design courses currently under development.

Second, design researchers and developers of circular design methodology can use the set both to guide the development of supportive resources as well as a 'vocabulary' in workshops. After an initial phase of excitement and inspiration, the circular economy has now arrived at a phase of operationalization, whereby a plethora of methods and tools are being developed (Bocken et al., 2019). It is especially in this phase that any lack of coherence in methodology development could lead to the validity of the circular economy being challenged (Blomsma & Brennan, 2017). From my research, initial links are

now in place between the circular economy competencies and methods in practice. This investigation reflects the state of competency development in practice, and shows how method development finds itself at a premature state of development. My findings also show that existing methods are being adapted and used to support the identified circular design competencies, implying that there should not only be a focus on developing new methodology, but also on finding a way to making existing design methods and tools applicable to the context of design for a circular economy.

7.6 Recommendations for future research

When starting this thesis, I aimed to better understand the practice of circular design and the competencies needed to design circular products and services. Both the findings from and limitations of the different studies described in this thesis inform paths for future research.

As the scope of my study was to look at which competencies are important to successfully develop circular products and services, I did not address how to develop circular design competencies (pedagogy), or how to evaluate the competencies (pedagogical assessment). The studies focused mainly on expert designers who are currently pioneers when it comes to the development of circular product-service systems. The underlying assumption was that learning from expert designers who are currently developing circular products and services would help determine what the circular design field should aim for.

This new set of nine key circular design competencies offers grounds for further investigating how the competencies are used, which methodology and curricula should be developed, and how the competency levels can be assessed. Chapters 5 and 6 made an initial attempt at connecting methods and approach with competencies, and thereby reflect the state of methodology development (i.e., addressing which methods could support the development of the competencies). This set of key competencies provides an opportunity to inform the development of (visual) assessment tools (e.g., competency wheels). These can then help determine the extent to which designers have mastered the circular economy competencies, and determine where competency-building is needed. Future research could focus on developing and testing competency assessment tools based on this set of nine key circular design competencies.

In this thesis, I show how the field of design for a circular economy is developing. My aim was to provide insights into the set of competencies needed by designers to contribute to a circular economy. The set of key circular design competencies is the result of a series of extensive investigations in the circular design field. My findings show that the field is relatively young, yet developing dynamically. It is expected that as designers in the field acquire expertise, they will be able to further explicate their needs. The nine key competencies can immediately be used as a reference for competency development in design when developing circular economy-based methodology and curricula.

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Acknowledgements

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About the Author

In 1992, Deborah Sumter was born in Willemstad (Curacao) in a Surinamese family. She lived in Curacao and Bonaire for the first 9 years of her life, after which she moved to Rotterdam (the Netherlands). She started the bachelor program in Industrial Design Engineering at Delft University of Technology (DUT) in 2010, and then moved on to the master program of Strategic Product Design. The minor International Entrepreneurship and Development, during which she worked on a project in Tanzania (2012), sparked her interest in social and sustainable design. In the years after, she worked on more social and sustainable design projects in Tanzania and Indonesia. In her time as a student, Deborah participated in several competitions focused on sustainable entrepreneurship such as Duurzame Dinsdag (2014), the ASN Voor de Wereld van Morgen Prijs (2014) and the Clean Tech Challenge (2015).

Her interest in sustainable design is also what prompted her to start her PhD in 2016. Embarking from an initial focus on the role of designers (in the transition) towards a circular economy, she later shifted the focus to circular economy competencies for design. As part of her studies, she interviewed and observed a wide range of pioneers in the field of circular design. In addition, she was active as coach in different sustainable design courses. She has also shared her research at various international conferences and workshops.

Deborah was the TU Delft representative in the last cohort of the Schmid-MacArthur Fellowship (2017) organized by the Ellen MacArthur Foundation. Here she had the opportunity to connect with an international group of peers with different perspectives on the circular economy. Later she participated in a collaborative project on Circular Economy Competencies for Businesses, and became part of the Design Interest Group of the Ellen MacArthur Foundation.

During her research, Deborah has been active as a volunteer in projects focused on supporting marginalized communities. She started organizing inclusive events together that center marginalized communities with the music/DJ collective, AMPFEMININE. And, to keep fit, she enjoys running.

List of Publications

Journal Publications (Peer reviewed)

Sumter, D., Koning, J. De, Bakker, C., & Balkenende, R. (2021). Key Competencies for Design in a Circular Economy : Exploring Gaps in Design Knowledge and Skills for a Circular Economy. Sustainability (Switzerland), 13(2), 1–15. https://doi.org/10.3390/su13020776

Sumter, D.X., de Koning, J., Bakker, C., & Balkenende, R. (2020). Circular Economy Competencies for Design. Sustainability, 12(4). https://doi.org/10.3390/su12041561

Sumter, D.X., Bakker, C. A., & Balkenende, A. R. (2018). The role of product design in creating circular business models: A case study on lease and refurbishment of baby strollers. Sustainability, 1–15. https://doi.org/10.3390/su10072415

Conference Proceedings (Peer reviewed)

Sumter, D., de Koning, J., Bakker, C., & Balkenende, R. (2019). Design competencies for a circular economy. In N. F. Nissen & M. Jaeger-Erben (Eds.), PLATE Product Lifetimes and The Environment 2019 (pp. 1–6). ISBN 978-3-7983-3124-2 (print), ISBN 978-3-7983-3125-9 (online).

Sumter, D X, Bakker, C. A., & Balkenende, A. R. (2017). The role of product designers in the transition towards the circular economy: A reality check. In C. Bakker & R. Mugge (Eds.), Product Lifetimes and The Environment Conference 2017 (pp. 391–396). https://doi.org/10.3233/978-1-61499-820-4-391.

Non-Academic Contributions

Ellen MacArthur Foundation, Business, C., Building, C., 2019. Circular Business Competencies Building: Gaps in Business Function-Specific Knowledge and Skills for a Circular Economy (pp. 1-7)

The circular economy offers an alternative to the linear economy (also called the take-make-use-waste society) we live in. It puts emphasis on using resources effectively by slowing and closing resources loops. Design is seen as enabler in a circular economy. Design decisions taken now have an impact on the recovery of products in the future. The transition towards a circular economy requires new competencies. Competencies can be used to inform the development of circular-economy-based methodology and curricula. However, limited research has been done when it comes to circular economy competencies for design.

Through a set of five studies this thesis explores both design roles and competencies for a circular economy. The studies detail an in depth case of a design-driven Original Equipment Manufacturer piloting a circular business model and highlight learnings from interviews, focus groups and a survey with front running designers in the circular design field. The thesis concludes with a set of nine key circular economy competencies for design, which can be as a reference for competency development in design when developing circular economy-based methodology and curricula.

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