COEVOLVE

a design journey
towards more
inclusive and circular
medical practices

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Appendix A: Design Brief

DESIGN FOR our future

IDE Master Graduation
Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

⚠ **USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT**
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME
Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 ! ⚠

family name	van Lent
initials	J given name Jard
student number	4351800
street & no.	
zipcode & city	
country	
phone	
email	

Your master programme (only select the options that apply to you):

IDE master(s): ★ IPD   ○ DfI   ○ SPD

2nd non-IDE master: _____

individual programme: __ - __ - ____ (give date of approval)

honours programme: ○ Honours Programme Master

specialisation / annotation:
- ○ Medisign
- ○ Tech. in Sustainable Design
- ★ Entrepeneurship

SUPERVISORY TEAM **
Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair	Jan-Carel Diehl	dept. / section:	DfS
** mentor	Stefan Persaud	dept. / section:	DfS
2nd mentor			
	organisation:		
	city:		country:

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a ⚠ motivation letter and c.v..

⚠ Second mentor only applies in case the assignment is hosted by an external organisation.

⚠ Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

comments (optional)

My supervisory team combines knowledge regarding medical device design, low-resource settings, design methodology and educational tools.

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair   Jan-Carel Diehl _____   date __ - __ - ____   signature _____

CHECK STUDY PROGRESS
To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: _____ EC

Of which, taking the conditional requirements into account, can be part of the exam programme _____ EC

○ YES   all 1st year master courses passed
○ NO   missing 1st year master courses are:

List of electives obtained before the third semester without approval of the BoE _____

name _____   date __ - __ - ____   signature _____

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: ○ APPROVED   ○ NOT APPROVED

Procedure: ○ APPROVED   ○ NOT APPROVED

comments

name _____   date __ - __ - ____   signature _____

IDE TU Delft - E&SA Department /// Graduation project brief & study overview /// 2018-01 v30   Page 2 of 7
Initials & Name   J   van Lent   Student number   4351800
Title of Project   Inclusive Circular Medical Product Design

4   5

Inclusive Circular Medical Product Design

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple.
Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 06 - 01 - 2021

09 - 06 - 2021 end date

INTRODUCTION **
Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Due to constant population growth and prevailing linear production and consumption patterns, the pressure on resources and raw materials increases globally. Africa's population is expected to double to approximately 2.5 billion by 2050 (Walton et al., n.d.). To restrain the continent's environmental footprint, this emerging market, alongside the rest of the world, needs to transform from a linear economy towards circular, less wasteful systems of which the advantages are not just related to environment and health, but also include economic growth and employment (European Commission, 2020; Golsteijn & Valencia Martinez, 2017).

The medical device industry itself is a large contributor to global problems of waste generation while holding fundamental social functions (Guzzo et al., 2020). While circular product design principles have been applied across industries, the medical industry presents unique challenges with its complex regulatory requirements and the high-risk nature of innovating with medical products (Ghelani, 2020). The design of medical devices primarily relates to patient outcomes and safety, above all other considerations (Ertz & Patrick, 2020).

An increasing awareness of health as a human right, mainly in low- and middle-income countries, is promoting universal health access for a growing number of people (Bianchi et al., 2017). However, many of the necessary medical devices are still inaccessible to the majority. In fact, 95% of medical devices have been developed in and for the healthcare context of high-income countries (Aranda-Jan et al., 2015; Hood & Rubinsky, 2020). The lack of functional equipment is due to a number of factors, including that much of the equipment in emerging markets is donated, arriving without manuals or service contracts; technologies are challenged by different conditions and situations, e.g. high temperatures and interrupted electrical supplies; lack of spare parts and consumables; and a lack of well-trained technicians to address these problems (Wong et al., 2018; Oosting et al., 2018; Aranda-Jan et al., 2015; Neighbour & Eltringham, 2012).

The non-functioning medical equipment ends up in the uncontrolled local landfills, see figure 1, and creates a severe e-waste problem. This improper and unsafe treatment and disposal of the e-waste pose significant challenges to the environment and human health (WHO, 2018). Alongside this, the local population has no access to proper healthcare.

There is an urgent need for innovations targeting the large global need for healthcare, a next generation of medical devices. The difficulty now lies in answering the questions: how should we shape the circular economy for medical products in low and middle-income countries? What kind of products and services should we be developing and what is their social impact?

Delft Global Initiative of TU Delft (more specifically the programs Healthcare for All and Inclusive Circular Economy), client of this project, is aiming to answer these questions by researching the social impact of medical devices in low resource settings and the circular economy. The vision of including People and Planet in the design of medical devices and the start of this project is schematically shown in figure 2.

space available for images / figures on next page

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introduction (continued): space for images

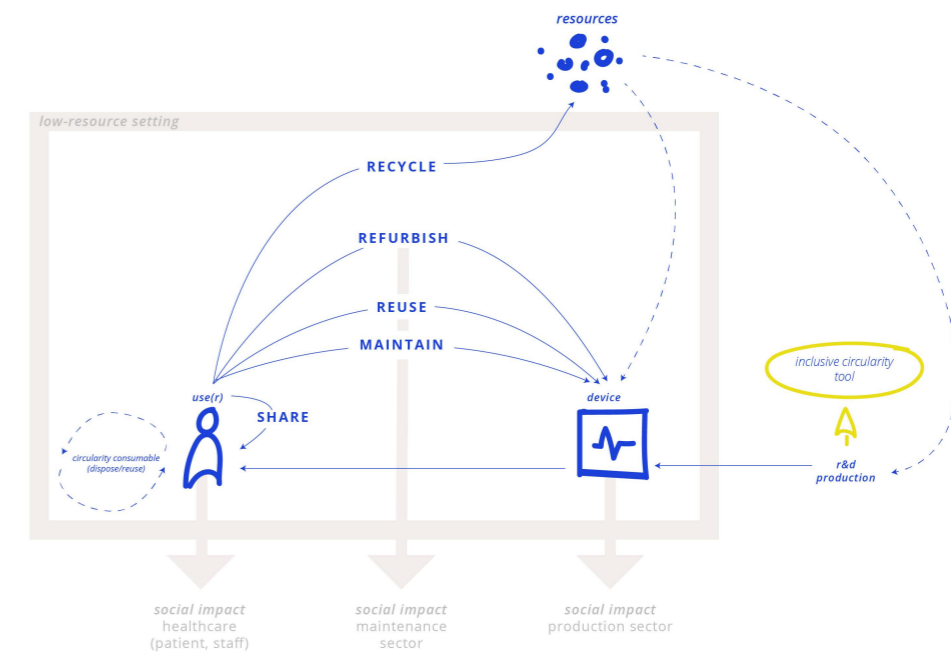image / figure 1:   Hospital graveyard of medical equipment

image / figure 2:   Schematic overview of an inclusive circular life cycle of medical devices in low-resource settings

PROBLEM DEFINITION **
Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

In recent years, research has been conducted regarding circular medical product design and business models, and medical products for low and middle-income countries. To improve the situation in low and middle-income countries and to create a next generation of medical devices, the social and environmental challenges need to be addressed simultaneously.

The main question of this graduation project will be: "What are the challenges of designing and integrating electrical medical devices used in hospitals for low and middle-income countries (Sub-Saharan Africa, Kenya and Uganda) into the Circular Economy and how can we, as designers, tackle those?"

The scope of this thesis is restricted to the implementation of circular design in the medical industry of Sub-Saharan Africa (Kenya and Uganda) by researching and prototyping an integrated (circular and social) approach that will enable the development of electrical devices used in hospitals. Both Product Journey Mapping, a method for mapping and visualising the life cycle of a product over multiple use cycles (van Boeijen et al., 2020) and the Equipment Journey, a tool to gain insights into the usage, stakeholders, and safety concerns of medical equipment (Hesselink, 2019), will be addressed and combined.

It is expected that such a structured overview of ecological and social challenges for electrical medical hospital devices in low and middle-income countries can result in a better understanding of the current pitfalls as well lead to new comprehensive sustainable solutions. Therefore, the solution space of this thesis is design tool oriented; guiding designers to improve the inclusive circularity of already in-use medical devices.

ASSIGNMENT **
State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

The objective of this thesis is to contribute to the integration of circularity in the design of electrical medical hospital equipment for low and middle-income countries (Kenya and Uganda). By creating a simple tool for designers to integrate the complex challenges of inclusive circularity in certain medical devices.

Research will be conducted regarding the ecological, social, and economic challenges influencing the design and life cycle of clusters of electrical medical products, and how to guide designers to improve the inclusive circularity of medical devices. To iterate on and validate this tool with two exploratory case studies.

The intended outcome consists of two parts:
• an integrated and comprehensible illustrated tool for designers in the Global North and the Global South designing inclusive circular medical devices for low-resource settings, based on Products Journey Mapping and Equipment Journey.
• iteration and validation of this tool into two socially sound and commercially successful product (or PSS) (re)designs (People, Planet, Profit); of which one is a suction pump design.

PLANNING AND APPROACH **
Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date   6 - 1 - 2021   9 - 6 - 2021   end date
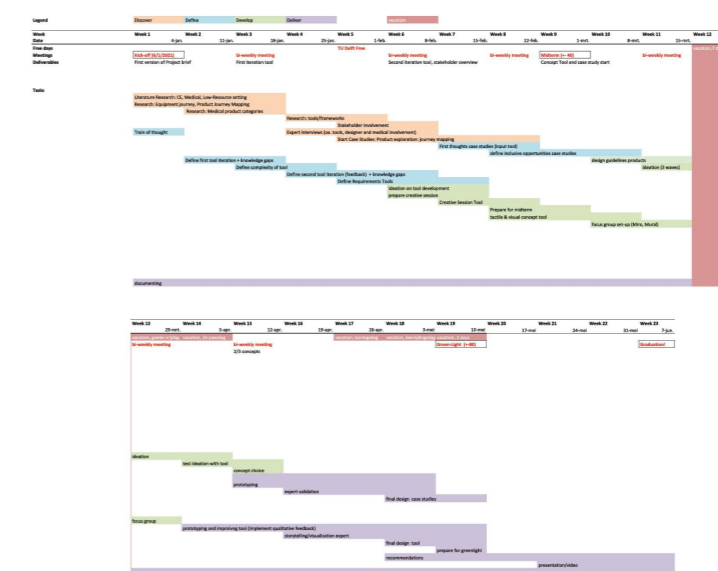
The Gantt chart above shows how this graduation project will be executed. The project will follow the double diamond model constructed by the Design Council UK (Design Council, 2019). This model divides the design process into four distinct phases. Discover, Define, Develop and Deliver.

The project starts with an analysis phase in which I will research several subjects regarding circularity (for medical products), electrical medical products for Sub-Saharan Africa and tools/frameworks (including Product Journey Mapping and the Equipment Journey) through (grey) literature research. With the knowledge gained, I will try to get a more in depth understanding of the stakeholders involved and their motivations, drivers, and values; and of obtained challenges by interviewing industry experts on current practices, which will lead me to the next phase: Define. The information I gained during the first part will be used to create an overview of design considerations through an integrated tool for the design of inclusive circular medical products, and creative sessions will be used to find and verify links. During the Develop phase, the created tool will be critically analyzed and tested/iterated on with a focus group, consisting of people with affinity to the subject and/or interest in the tool. This phase is followed by the Deliver phase where I will validate the iteration of the tool on two exploratory case studies through a product (or PSS) (re) design. Visualization, communication, and presentation are also part of this phase. Each week, I aim to find a balance between researching, documenting, drawing conclusions and preparing the coming week.

The project knows four project milestones:
1. Kick-Off (day 0), which is scheduled on 06/01/2021
2. Mid-Term evaluation (+- day 40), which will be scheduled in week 9
3. Greenlight meeting (+- day 80), which will be scheduled in week 19
4. Graduation (+- day 100), which will be scheduled in week 23

TUDelft

MOTIVATION AND PERSONAL AMBITIONS
Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, … . Stick to no more than five ambitions.

My motivation for this project is found in my interest for designing novel, innovative solutions with a great social and/or environmental impact. I have been intrigued by the question: how can sustainability increase our quality of life? During previous projects in my studies, I worked on the following topics: 3D-printed smartphone-based diagnosis of Schistosomiasis in Nigeria, entrepreneurship and plastic upcycling for Kenya and the work/life balance of commuters in the Netherlands. This not only broadened my knowledge but also showed me the relevancy of inclusive design, sustainable opportunities, medical product design and user research.
Besides that, I have experiences with entrepreneurship, following several courses regarding entrepreneurship, doing an internship at a sustainable urban farming start-up and being chair of the BlueDot foundation, a start-up at the faculty IDE. Therefore, I am adding the Entrepreneurship Annotation to my IPD master's degree.
I am excited to have the opportunity to graduate on the described assignment. The project greatly fits my competences, overall interests, and learning ambitions. Although graduation is an individual project, I am pleased it can be part of greater and relevant research and it will not be left on the 'pile to be forgotten'. I am happy to work together with JC Diehl and Stefan Persaud, and I am sure that I am able to extend my (design) skills greatly with their supervision.

My main motivation for this graduation project is to apply my current theoretical knowledge about circular design, as I have not performed any practical assignments on circular design before and gain more in-depth knowledge about this subject. I see circularity as a big necessity within our society to become more sustainable and, for me, a 'purpose over profit mentality' is preferred. I am curious to experience the challenges of implementing circularity into design practice and combine it with my existing knowledge regarding medical product design and the Sub-Saharan African context.
The course Sustainable Consumer Behaviour has made me realize in what way designing should be approached and revised to enhance sustainable usage. I hope to use some of this theoretical information into a sustainable framework and design.

In my master, IPD, I did not have the opportunity to design a tool or framework, and to validate product or service designs with my own methodology. Therefore, I would like to research the design and implementation of tools and frameworks. I am eager to learn more about design methodology, either through research or from experts and my supervisory team, and experiment with new methods, such as the Equipment Journey and creative sessions.
As a designer, I am intrigued by storytelling and by communicating difficult subjects in a complete yet comprehensible manner. I hope to be able to put this part of my expertise into use in this project, either in visualizing the to be designed tool neatly or in my presentations through visuals or video. For me, this brings a lot of added value and joy to my process and designs.
Lastly, I am an ambitious person and often my plans and the time available do not match. This usually leads to me pushing myself to my limits. During my graduation project I want to challenge myself into finding the right balance between time available and ambition and to improve my project management skills.

FINAL COMMENTS
In case your project brief needs final comments, please add any information you think is relevant.

The references in this document can be found via the following link:
https://docs.google.com/document/d/1pnDXubIK3La2YW_dsXuhbOwGUQ1xritmnjUXailac9A/edit?usp=sharing

List of interviewees is anonymized for publication and available upon request.

List of interviewees is anonymized for
publication and available upon request.

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publication and available upon request.

List of interviewees is anonymized for
publication and available upon request.

Appendix C: Design journeys

An analysis based on 4 IPD master students' graduation projects, by interview and visuals, was executed. These projects were worked on for 6-10 weeks.

This analysis is executed to gain an understanding of how Inclusive Medical Design challenges are currently tackled. This analysis is used as a source of inspiration.
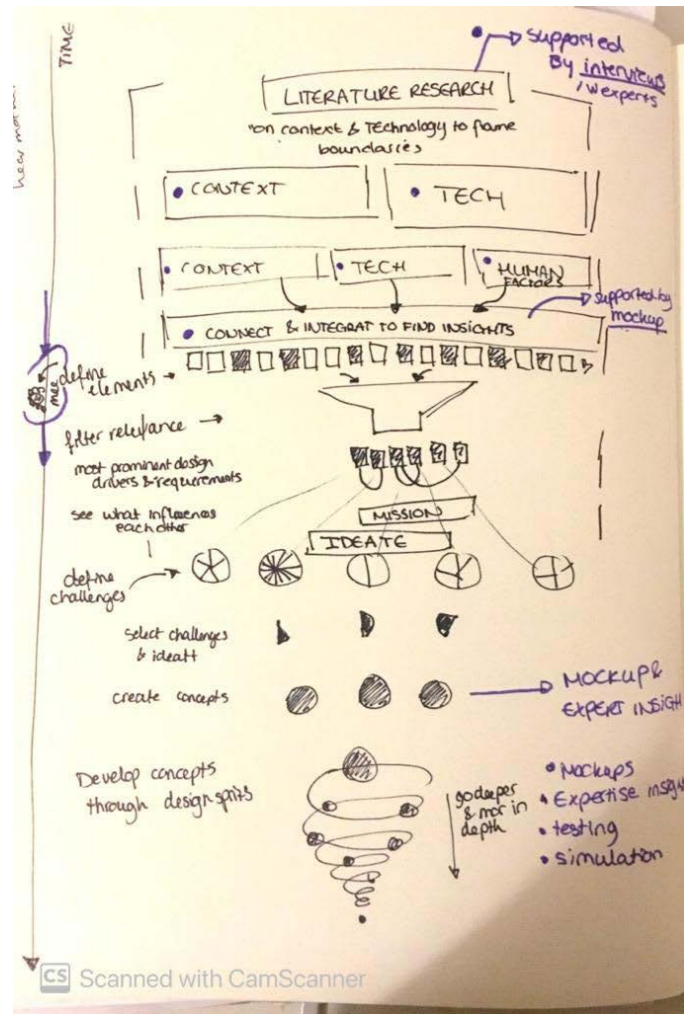
In these journeys, there is a lack of sustainable/circular focus.

MRI for Africa
Timeline until ideation:
Started researching context (physical), e.g. environmental, geographical and organizational factors, human factors (psychological), e.g. the drivers, needs, behaviour of stakeholders, and the technology.
This literature research is supported by interviews with (local) experts.
These insights are used to define design drivers & requirements, and eventually a mission statement. From there, the ideation phase starts.

To enhance the process, creative sessions and hospital visits (also on site-in Africa) during each research phase would have been used if possible.
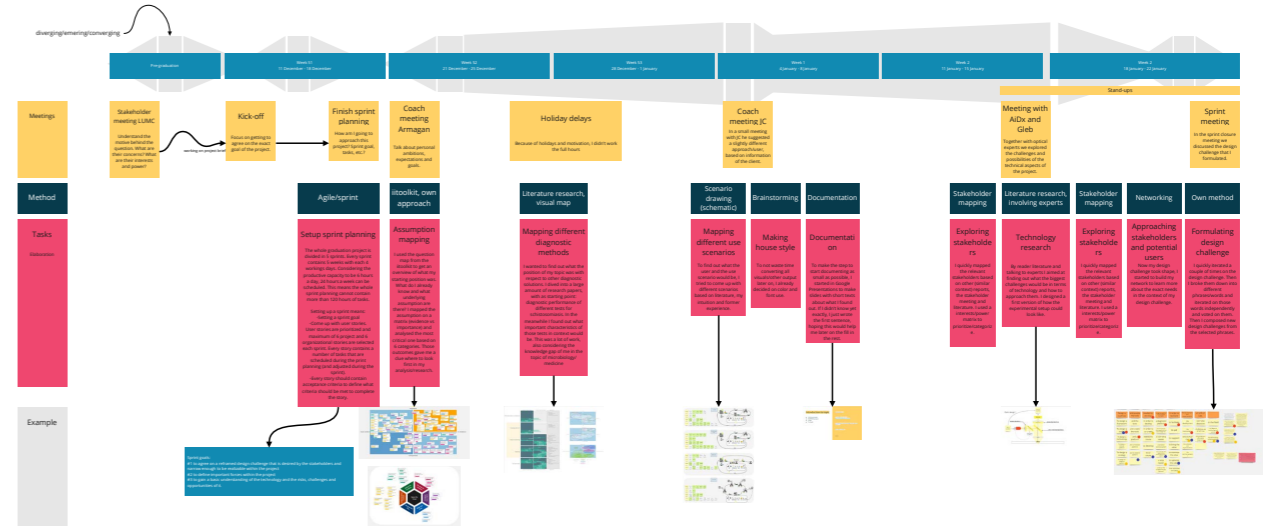
Diagnostic Device
The IITtoolkit and the assumption matrix (evidence vs importance) are used to find the first areas of research, which resulted in the first characteristics of the to-be-designed product. Afterward, user scenarios are used to find possible stakeholders, resulting in a stakeholdermap, and possible product-user interactions. Technology research is conducted and transformed in a first experimental setup.
A design challenge is the current end of the timeline.

Hand Device
Extended literature research is conducted on technology and context. Interviews and questionnaires are used to retrieve more information about both the technology and the context. VIP method is used to find valuable factors.
The problem was that technology research was put before learning about the field of occupational therapy. Therefore, connections were hard to make.
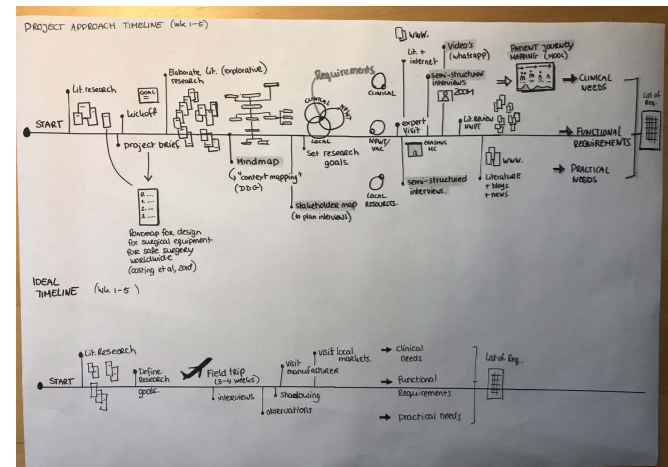
Negative Pressure Wound Therapy
The roadmap for surgical design (Oosting et al., 2018) is implemented, and literature research and mind mapping is used to find three research areas: clinical, technology, and local resources. These have been elaborated through research, interviews, video observations, and existing videos.
This resulted in clinical (from the surgical context) and practical (from the local context) needs, and functional requirements (technology focussed), which will form the base of the list of requirements.
To come to the clinical needs, patient journey mapping is used.

Appendix D: Design-in-a-Day

Goal
The goal of this pressure cooker - Design-in-a-Day - is to find and understand the knowledge gaps and potential relationships between research areas. It not only provides a kickstart for the project but also valuable insights into the process and the potential hiccups that can occur during this thesis. The results from this Design-in-a-Day session will be used to formulate research aims and questions.

Procedure
The double diamond method, consisting of the four phases Discover, Define, Develop and Deliver, is used during this Design in a Day. During the first phase, Discover, 2 hours of research is conducted regarding different subjects, such as (circular) medical product design, low- and middle-income countries, Product Journey Mapping, and the Equipment Journey. It is of importance to state that the designer has been doing extensive literature research beforehand, thus being acquainted with most of the subjects. The second phase, Define, consisted of clustering insights and finding connections to eventually formulate a design challenge. During this phase, methods such as WWWWWH, problem definition, and List of Requirements are used. Braindrawing and brainstorming are applied during the third phase, Develop. The Deliver phase included the design and prototyping of a card set.

Key insights
The design of the card set shows the designers main knowledge gaps regarding the following subjects:
- recycling/disposal
- Circular Economy in African context
- stakeholders
- integration of procurement and production
- local production/manufacturing/entrepreneurs
- availability of the equipment and its costs
- business strategies

The card set would be more comprehensible if accompanied by an introduction, potential canvasses, a certain mindset, previous knowledge of subject and jargon, more in-depth research references, and examples of equipment journey and product journey mapping.

What has been established as odd in the design of this card set is the fact that there is no clear ending, with what deliverables the user should finish, and in what way are trade-offs (such as hygienic recovery vs trust) implemented.

Appendix E: The approach

DESIGN DRIVERS   **IN-DEPTH CONTEXT**   **TRADE-OFFS**   **ACT**

product-user: why redesign?
business: why circular?

understand context and safety risks during product-interaction

analysis, parameters, and circular focus

implementation

design requirements

involvement

prototyping

to be redesigned product   *need identified*   *redesign focus*   *redesign plan*   *redesign*

DESIGN DRIVERS

Medical needs identified by scientific research, NGOs or local end-user could all act as a starting point for a design project.

Should the product be redesigned for circularity? Why?

intercontinental
continent
country
hospital

surgical theatre

criticality
value
+

-narrow loops
- slow loops
- close loops
10R's

IN-DEPTH CONTEXT

WIDER CONTEXT:
- barriers for patients
- structure of healthcare system
- surgeries performed
- aspects of safe surgery
    - operating process
    - team
    - infrastructure
    - surgical equipment
- level of cleaning, disinfection or sterilisation possible
- regulations/policy

- equipment journey (product interaction risk assesment, need of characteristics)

PRODUCT DESIGN:
- criticality/value matrix
- parts, materials (technical, biological)
- reusable, disposable
- donated/bought
- accessoires
- reason of obsolescence

TRADE-OFFS

BUSINESS/STRATEGY:
- circular business model
- design strategy (product integrity)
- product Journey mapping
- business model canvas (value capture: PPP)
- stakeholders (drivers, motivation, needs)
- relationships
- what happens at EOL?
- support/hinder circularity

PRODUCT DESIGN REQUIREMENTS:
- design strogegy dependent
- environmental conditions
- stakeholder conditions
- total cost of ownership
- materials

USAGE:
- envisioned usage (# use cycles)
- stakeholders (knowledge, training)
- support/hinder circularity

usage
design
design strategy
circl. strategy
consumer attitude

ACT

involve local end-users, stakeholders & partnerships

design, prototype, test

Appendix F: The framework 1 and booklet

Goal
determine the characteristics of a desired tool and receive feedback on the comprehensibility of the tool, the necessity of any clarifications or additions. The outcome of these feedback sessions will be divided into characteristics of a desired tool and adjustments to the tool, which will be implemented into the next iteration.

Procedure
The feedback sessions, based on semi-structured interviews, were executed with five individual participants and were around 20 minutes each. Firstly, the goal of the tool (Inclusive Circular Medical Product Design) is shortly introduced by the designer to the participant. The participant was asked what he/she expected from such a tool. Afterward, the overview and the booklet of the iteration were shown. The participants were asked to think-out-loud and share their doubts and feedback while reading and scanning through the documents. Two of the five participants were working on a global medical project, and all were IDE graduate students.

Key insights

A desired ICMPD approach would:
- Be an adjustment of existing circular and medical product design strategies
- Include checklists of necessary aspects within circular and medical product design
- Guide the user to an open end-result by introducing methods and providing structure
- Provide the user with new solutions or areas to focus on while stuck during the design process
- Supports the user in specific requirements and trade-offs, for example, environmental impact vs safety (materials, sterilization, reuse)
- Be interactive, based on the contribution of the user

Feedback Overview:
- It is unclear for the participants where to look first, suggested is to introduce an arrow and the term 'need' at the starting point and an arrow and the term 'design goal' at the end
- It is unclear for the participants in what way the Explore, Examine, Expose come back in the overview, suggested is to put these terms into the overview
- It is unclear for the participants if each phase should take the exact amount of time and work, suggested is to show difference through visualization
- It is unclear for the participants if the tool should be used from the outside in, or what exactly the order is.
- A participant suggest including the terms 'Context of Use' and 'Medical Device' in the overview
- A separate overview might not be necessary if it is included in the booklet.
- A participant suggest to colour code the design dilemma's for a clearer understanding
- A participant mentions the large influence of the context of use on the design dilemmas. The approach might be too much of a simplification
- A participant mention the large necessity of going on-site to retrieve information because the most important insights are often not retrieved from literature research
- The socio-cultural factors have a big influence on the usage of the product, and therefore should have a larger frame in the tool (ratio of each factor differs)
- A participant mentions the importance of analyzing the (global) market and current prices, availability, and usage (barriers) of certain products

Feedback Booklet:
- It is unclear for participants to what extent designing for medical products is included in the approach
- The participants appreciate the proposed methods at each phase of the process, suggested is to give a different colour to make it stand out.
- The participants appreciate the freedom that is given in the approach since not everything is spelled out
- It is suggested by the participants to include the following steps after reaching the design goal, what follows this approach (develop, deliver)
- The participants mention their appreciation for the written goal for each segment and the guidance that gives them
- The participants mention that too much information and explanation might make the approach more difficult to use

- The participants suggest to include more in-depth information of the 'why' and the value of each step, for non-designers, to understand why certain aspects need to be taken into account and researched
- An example of a case study would be beneficial
- A contradiction within the opinion of the participants is the fact that some enjoy the build-up of the tool (more information per step), others would find it beneficial to see it as a whole at first.
- A participant mentions the difficulty of researching and determining certain factors, such as the product life cycle (since R&D departments will not be open to questions or do not have this information) and the price of products (let alone the total cost of ownership)
- Circular Possibilities: extra guidelines (such as FDA and WHO) can be added
- The booklet might include a bit too much jargon, especially for the Circularity terms (closing, slowing loops etc)
- The participant find the 'Expose' Phase valuable because it provides grip by showing examples
- The participants state that there is no need for more information. They state that it currently gives an indication and as a designer, you can use it how you would like to
- The booklet might include more 'how to's' , meaning references or methods specific for certain questions
- A currently non-specified checklist might be beneficial

INCLUSIVE CIRCULAR MEDICAL PRODUCT DESIGN

A tool to guide you, as a designer, towards the most promising inclusive circular medical product design goal
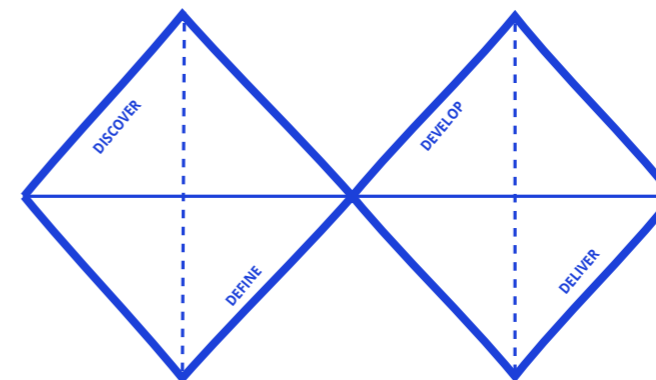
INTRODUCTION

The Inclusive Circular Medical Product Design approach (ICMPDa) has been developed to guide designers towards the most promising design goal for circular hospital equipment in Sub-Saharan Africa.

Usually, designers go through the double-diamond. However, the fuzzy-front end (discover and define) can be quite daunting when trying to develop inclusive, sustainable or medical products, let alone all of these combined!

The ICMPDa provides structure to the designers in the early stage of product design, from a fuzzy need towards a specific design goal.

The approach consists of three consecutive phases:
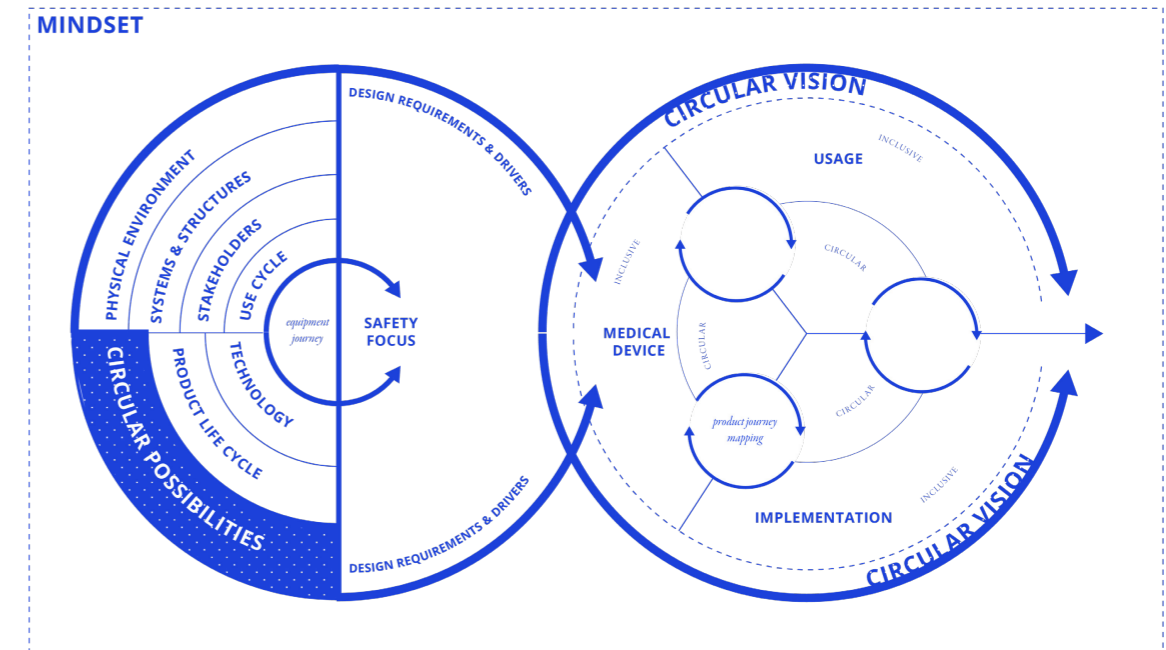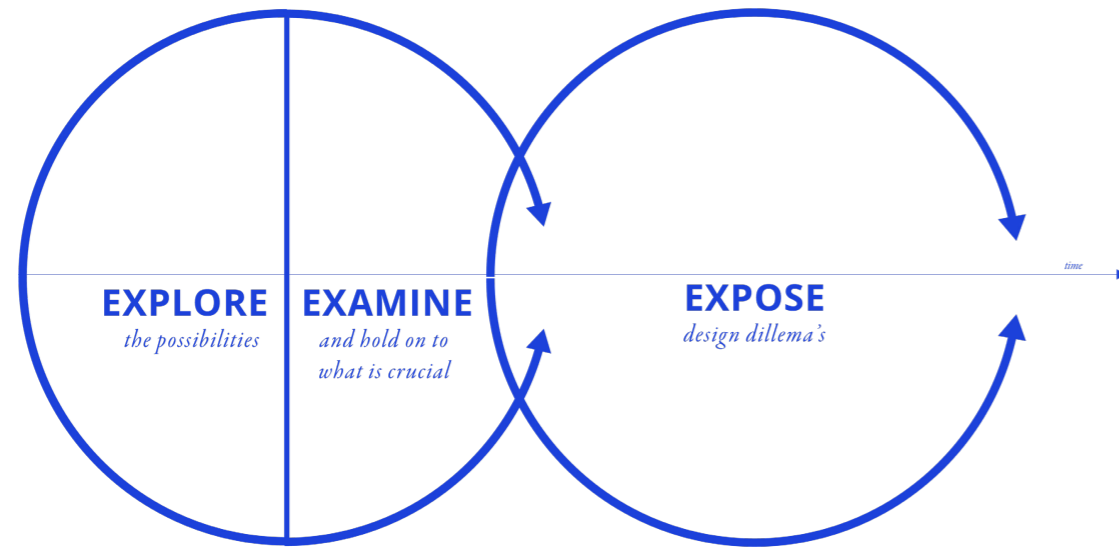**Explore** the possibilities: research the context of use and the to be designed product
Examine and hold on to what is crucial: find requirements & drivers
Expose design dilemma's: base decisions on systematic thinking, and know what challenges the product will face

In this booklet, you will be guided though each phase individually.

EXPLORE
the possibilities

EXAMINE
and hold on to what is crucial

EXPOSE
design dillema's

time

ICMPDa

The following approach will be explained in detail, following explore, examine and expose.

MINDSET

CIRCULAR VISION

USAGE

DESIGN REQUIREMENTS & DRIVERS

PHYSICAL ENVIRONMENT
SYSTEMS & STRUCTURES
STAKEHOLDERS
USE CYCLE
TECHNOLOGY
PRODUCT LIFE CYCLE
CIRCULAR POSSIBILITIES

equipment journey

SAFETY FOCUS

MEDICAL DEVICE

product journey mapping

IMPLEMENTATION

DESIGN REQUIREMENTS & DRIVERS

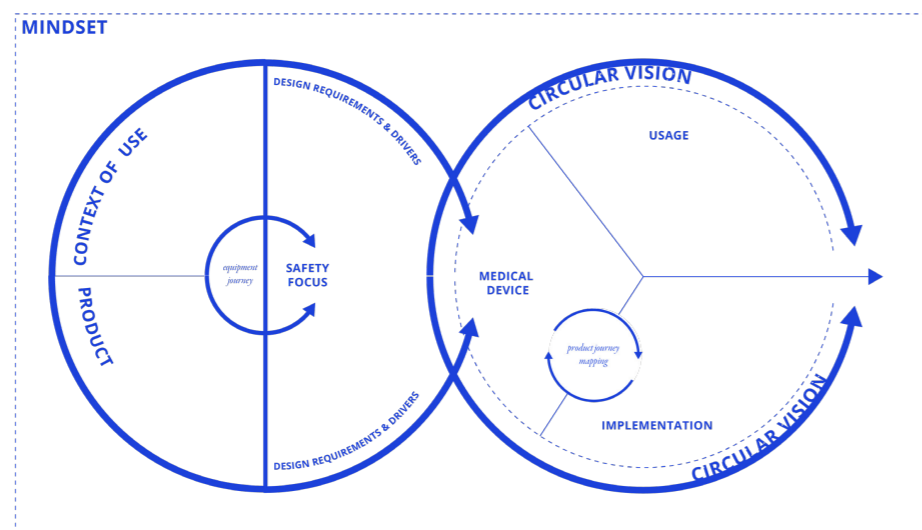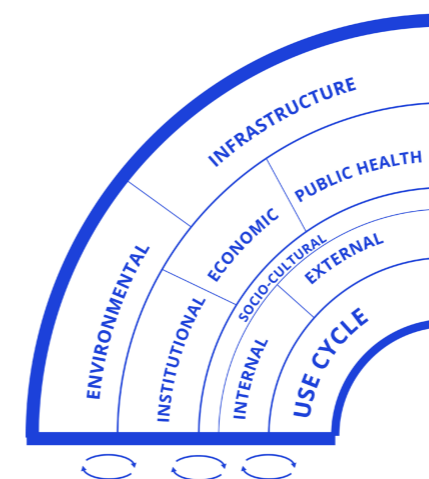CIRCULAR VISION

INCLUSIVE / CIRCULAR

MINDSET

This approach asks for a systematic thinking mindset, meaning that all aspects are intertwined and influence each other. To design circular and inclusive, multiple different factors, besides the to be designed product, should be taken into account such as the user(s) and beneficiaries; and the implementation strategy.

During all steps of this approach, you should have an open attitude, stay flexible and trust the process!

To enhance the social sustainability, keep in mind Advancement (does it create jobs), Empowerment (does it reduce dependecy) and Systemic (is the solution insular).

MINDSET

CONTEXT OF USE

DESIGN REQUIREMENTS & DRIVERS

CIRCULAR VISION

USAGE

equipment journey

SAFETY FOCUS

PRODUCT

MEDICAL DEVICE

product journey mapping

IMPLEMENTATION

DESIGN REQUIREMENTS & DRIVERS

CIRCULAR VISION

EXPLORE : context of use

INFRASTRUCTURE
PUBLIC HEALTH
ENVIRONMENTAL
ECONOMIC
SOCIO-CULTURAL
EXTERNAL
INSTITUTIONAL
INTERNAL
USE CYCLE

on-site context research

− / +

The following methods can be used:

Methods to retrieve information:
surveys, site visits, semi-structured interviews, (grey) literature research,

Methods to map information:
stakeholder map, stakeholder influence/impact grid, persona, Design4Wellbeing

Ask yourself the following questions during this phase:

Physical Environment:
Environmental:
What are the environmental contextual factors that you should take into account (temperature, altitude, humidity, dust)?
Infrastructure:
What are the infrastructure contextual factors that you should take into account (eruptive power supply, power outlet, available cleaning supplies, language, public mobility)?

System & Structures:
Institutional:
What are the characteristics and budget of your specific healthcare centre?
Economic:
What percentage of people live below the poverty line?
Public Health:
What are the regulations and policies regarding health in the country to design for?

Stakeholders:
Socio-Cultural factors:
What are the characteristics (skills/knowledge), drivers (environmental and economic) and barriers (cultural, financial, structural) of the stakeholders involved?
Internal:
Who is the patient and who are part of the local team (nurses, surgeons,anesthetist, BMET)?
External:
Are there any other important stakeholders involved in the use cycle of the product? (local distributors, procurement officers and donation agency)

Use Cycle:
Which steps are taken during an use cycle and what are the challenges?
What is the main reason for obsolescence?

A more extensive list of questions can be found on page ...

EXPLORE : product

Ask yourself the following questions during this phase:

Product Life Cycle:
How is the total cost of ownership influenced? (donated/procured/bought, accessoires, consumables, cleaning, cost of disposal etc)
Is the product available (reason of availability) in your context and what is its location?

Technology:
What are the medical regulations or policies regarding this product?
How does the product (and technology) work and what potential safety risks for the user and the patient can occur?

Circular Possibilities:
What are the circular economy regulations or policies regarding this product?

According to the criticality/value matrix (spaulding scale, see page...), is there cost/benefit for recovery of this product and is this possible in terms of disinfection/cleaning/sterilization?

According to the criticality/value matrix (spaulding scale), what is the most promising circular design strategy and what are the trade-offs that you are already aware of?

Do not forget to always take into account the closing loop and to look at the difference of criticality of multiple components and their reason of obsolescence.
slowing loops: long life products / product life extension
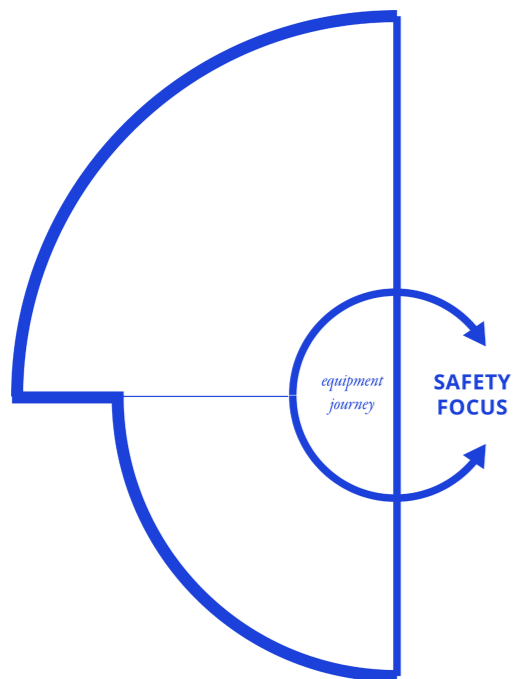closing loops: tech vs bio (design for seperation, dis- and re assembly)

The following methods can be used:

Methods to retrieve information:
semi-structured interviews, (grey) literature research.

Methods to map information:

EXPLORE method: Equipment Journey

To end the Explore phase, the methods Equipment journey can be used.

The Equipment Journey (EJ) is a method that can be used to determine potential (safety) risks that might occur during the procurement, use & maintenance, and disposal of a medical device in a certain context of use (often LMICs). The method provides information on potential risks during specific phases of use, and reveals who are involved during each phase (Hesselink, 2019).

Hence, research focuses on the product-user interaction and combines literature research with user-centred design (Oosting, Ouweltjes, et al., 2020). The goal of the EJ is to enhance the user(s) safety by tackling potential risks during an use-cycle. The outcome of the EJ are potential safety concerns that can be redesigned to enhance the safety of the user and/or patient when using a medical device.

EXAMINE
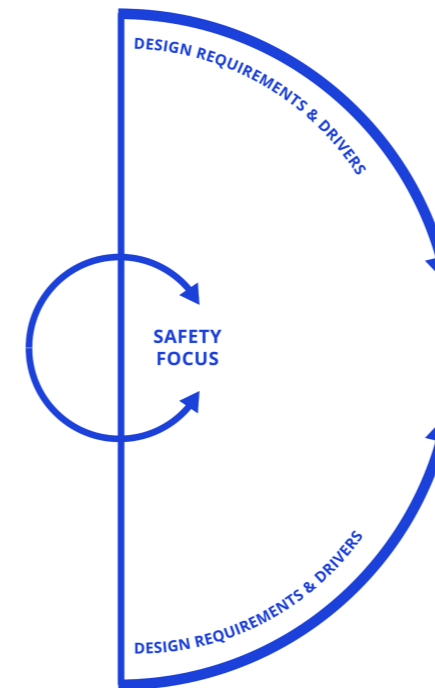
During the EXAMINE phase, the outcomes of the EXPOSE phase needs to be reviewed and reformulated to a list of requirements and design drivers. Together with the safety focus, established from the Equipment Journey, this will form the base of your to be re-designed product.

There are some common requirements for LMIC's settings of which the priority will fluctuate for each different medical device (Oosting et al., 2019) :
Low cost
Easy to use and maintain (low training needs)
Compact and portable
Flexible in terms of required accessories (option to use different brands of accessories/types of monitors)
Robust (able to withstand high temperatures, humidity, power fluctuations
Elimination of the necessity of external powersources

EXPOSE
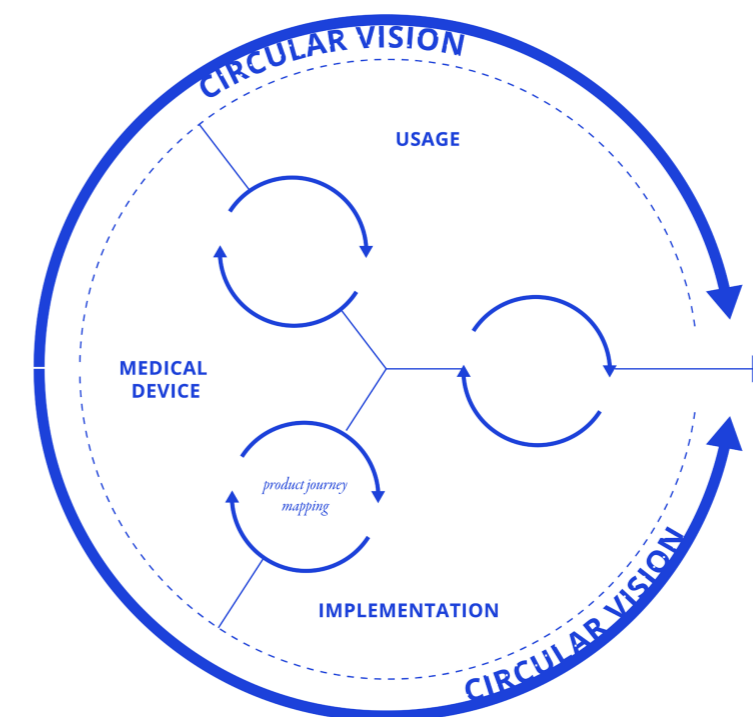
The EXPOSE phase needs a long-term perspective from the designer.
The EXPOSE phase consists of multiple components.
To find a circular solution, an overall circular vision is necessary. Ask yourself: 'What will be challenged?'

Designing the right product, for the right usage and with the right implementation strategy asks for multiple dilemmas which need to be solved in conjunction.
With each new idea, ask yourself: "How will this influence the other aspects?"

You could consider dilemmas such as:
design for durability vs design for repairability
leasing strategy vs feeling of ownership
refurbishment vs trust

Product Journey Mapping (PJM) is a strategic method to explore the feasibility of going circular for a business, used in the early phases of development putting the product at centre stage. During the EXPOSE phase, this method can be used to find and enhance potential service touch points and opportunities to capture value in each use cycle, by improving the efficiency and effectiveness of the multiple use cycles

The end goal of the EXPOSE phase is a circular and inclusive design goal to start the second phase of the double diamond: develop.

The following questions can be used to find the most interesting dilemmas:

Medical Device
Inclusive:
Is the solution accessible and affordable now and in the future?
Is there supporting documentation?

Circular:
Which product design strategy/strategies are you going to implement, that fit the circular business model, and how?
Have you considered the differences of the product design requirements, main parts and their materials for each different use cycle?

Usage
Inclusive:
Think about drivers, motivation, ownership, responsibility and feasible costs (the payment structure)
Circular:
What will each use cycle look like and how will this influence the consumer attitude towards the product?

Implementation
Inclusive:
Is there room for local manufacturing, repair or empowerment in any other way?
Circular:
Who are the stakeholders involved in the value and supply chain and what are their individual interests, economic/environmental drivers and needs, and how are the stakeholders related (also towards the user)?
What circular business models are you going to implement, which fits the design strategy/strategies, and what will your value proposition(s) be for each use cycle?

The following methods can be used:

Methods to retrieve information:
surveys, semi-structured interviews, (grey) literature research,

Methods to map information:
Product Journey Mapping, Business Model Canvas

INCLUSIVE CIRCULAR MEDICAL PRODUCT DESIGN

Appendix G: The framework 2
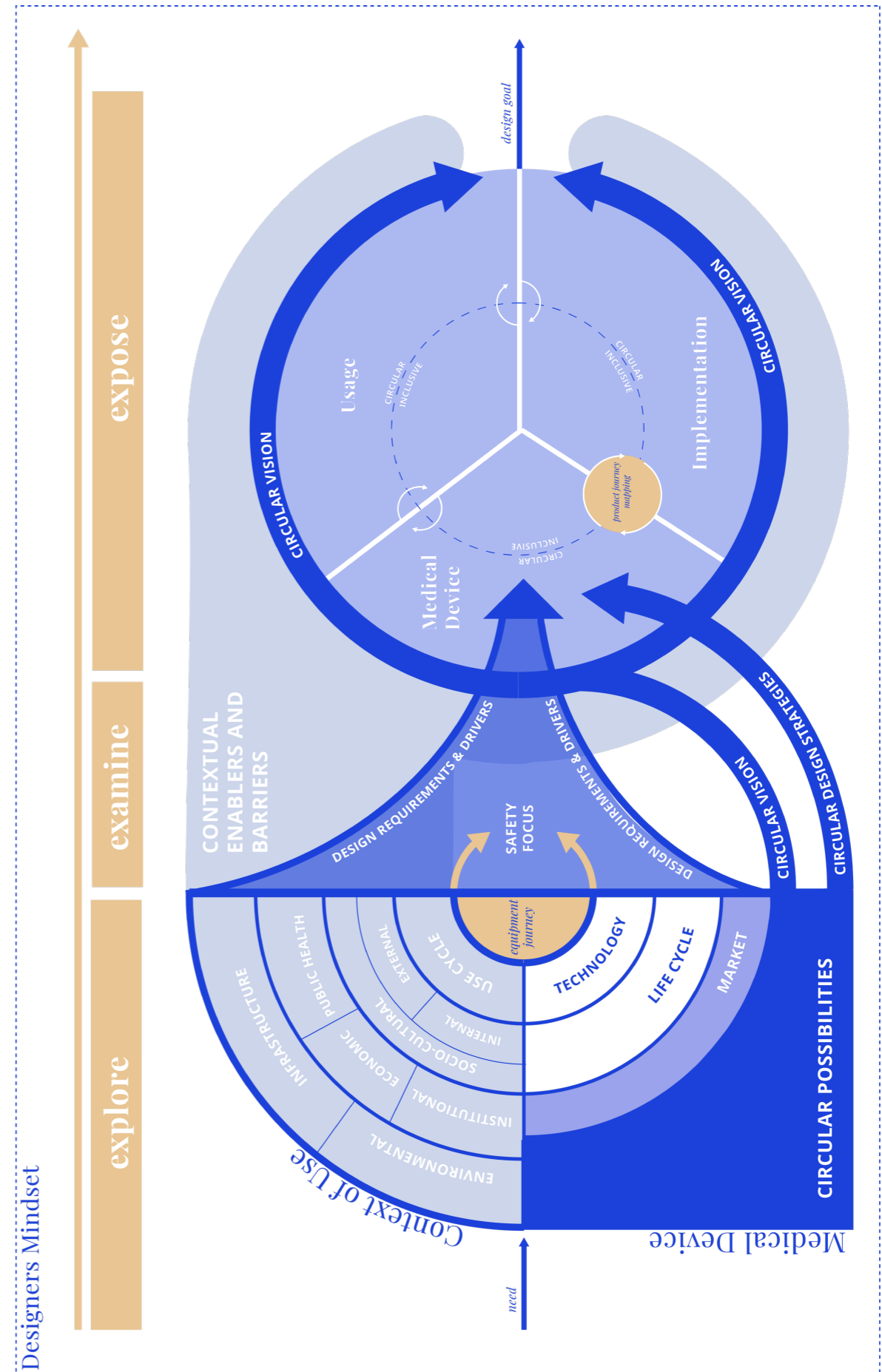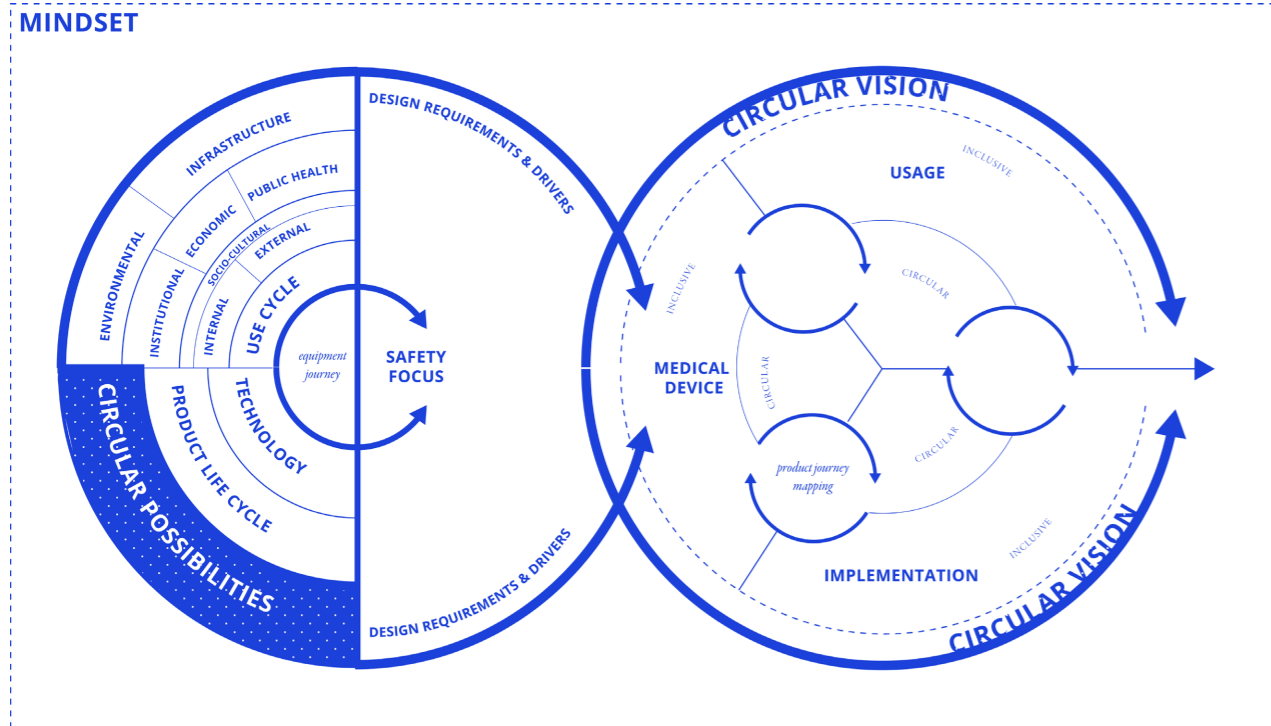
Appendix H: The method

Goal

to receive feedback on the sequence of the developed tool and its complexity and to determine possible changes to make the usage of the tool more comprehensible. The outcome of the sessions will be used to further develop the tool and its main function.

Procedure

The feedback sessions were executed with individual participants and were around 30 minutes each. Firstly, the goal of the tool (Inclusive Circular Medical Product Design) and its intended outcomes were shortly introduced by the designer to the participant. The participant is guided by the designer through each step of the tool by shortly explaining the goal and outcome. The participants were asked to think-out-loud and share their doubts and feedback while using the tool. This session is executed with three IDE master students, one of them graduating on a global project, the others less involved in such projects.

Key insights

- It is beneficial to state beforehand what the intended outcome of the session will be. However, not all steps should be shown in the beginning since this might be overwhelming for the user.
- It is unclear how important previous knowledge regarding the product, its use and life cycle, the context, etc. is. More knowledge and affinity with these subjects might influence the outcome for the better (more specific results)
- The questions need to fit the time & space the designer is working on, meaning: 'where will the product be used? vs where is the product used?'
- The context trigger cards work well
- To enhance the output of the tool, different methods or tools for each step can be recommended if the users would like to dive deeper into this subject.
- Creating the vision is a difficult step. Questions could be given, such as Why, How, and What.
- It might be beneficial for designers to know what aspects they have an influence on and what they can not change.
- For now, it is good that certifications/policy/regulations are taken out of the tool. However, this might be interesting to add depending on the time and people involved in the usage of the tool.
- The translation from design opportunities regarding risk (inclusiveness) and circularity to the vision might be abrupt and difficult. More facilitation might be needed to substantiate this decision because it also influences the end opportunity.
- The EXPOSE phase should provide the user with more grip. It might need more facilitation, to trigger discussion.
- The current and future scenario might not include the same life phases (NPD or donated), thus a new life cycle canvas might be necessary
- If the steps are not followed correctly, participants could have trouble losing track of the approach.
- The use of different coloured post-its for each aspect might contribute to the overview of the map.
- For non-designers, it might be difficult to include ideas on post-its. This is a skill that needs to be trained. Therefore, the approach as it is, is suitable for design students.
- An end-pitch might be beneficial for the participants to explain their final opportunity better. Furthermore, this will show the variety of opportunities to all participants.
- This tool could be the planning of a design sprint, which indicates the scope of the project.
- The tool should work motivational and inspiring, why is it so important that you are working on this subject.
- Could the end result be more SMART formulated?

Product analysis
Use the following questions:

- What is the products function?

- What are its main characteristics?

- What does the product consist of?

- What is necessary for the product to function?

- Are there multiple usecycles and/or multiple life phases?

- Where will the product be used?

Life-cycle analysis
If necessary, indicate the different life phases. Map the life-cycle of the product.
Use the following questions:

- What stages does the product go through in its pre- and post-use cycle(s)?

- Who are involved with the product?

- Are there any important connections or events?

- What product characteristics are of importance during its pre- and post-use cycle(s)?

Use cycle(s) analysis
If necessary, indicate the different life phases. Map the use-cycle(s) of the product.
Use the following questions:

- What stages does the product go through in its use cycle(s)?

- Who are involved with the product?

- Are there any important connections or events?

- What product characteristics are of importance during its use cycle(s)?

- What would a reason of obsolescence be?

Context of Use:
Map the context around the life cycle and find relevant connections and relationships.
Use the following questions:

- How will the skills and level of training of the people involved influence the products life cycle?

- How will (a difference of) language impact the products life cycle?

- Who pays for (what part) of the product and how will this influence the products life cycle?

- How will the location of the stakeholders influence the products life cycle?

- What if necessary cleaning supplies are unavailable?

How might we change this?
use the post its to pin point relevant (safety) risks of the usage of the product. How might we change these?

Define opportunities of product design.

VISION
What will the guiding vision statement be?

Circular Opportunities
Define the circular strategies possible for your product, how might this product become circular?
Does the product need any cleaning/desinfection/sterilization to recover and is this cost-beneficial?

You can use the following heuristics:
try to prolong the first use cycle
if the product includes electronics, make sure it is able to be repaired or maintained
try to limit the use of disposables
always take into account the closing loop, what happens to the product when it is not able to be recovered anymore? (design for dissassembly and technical & biological loops)

NEW PRODUCT LIFE CYCLE
divide in representatives (People & Business), and make sure both teams see the common goal (vision statement).
Use the product and barrirs&enabler cards to discuss the best solution.

If necessary, use another life cycle sheet.

-

We present to you the most promising inclusive circular ....

PEOPLE REPRESENTATIVE

Who are the people involved during each different life cycle?
What would the feasible costs be?
What would influence a feeling of trust, attachment, ownership (consumer attitude)?
What would potential (safety) risks be for each person involved?
HOW MIGHT WE EMPOWER PEOPLE?

BUSINESS REPRESENTATIVE

What could potential supply or value chain difficulties be?
What differs in the value proposition of each use cycle?
Which stakeholders are involved and what are their drivers & needs?
Is there adequate access to the tehcnology (capacity, skills & information)?
HOW MIGHT WE CREATE JOBS?

WHAT WOULD SUPPORT/ HINDER THE INCLUSIVITY OR CIRCULARITY OF

MATERIALS

WHAT WOULD SUPPORT/ HINDER THE INCLUSIVITY OR CIRCULARITY OF

DISPOSABLES

WHAT ABOUT..

TEMPERATURE

WHAT ABOUT..

THE ACCESSIBILITY OF TOOLS

EXAMINE EMERGING OPPORTUNITIES:
inclusivity
5. Pinpoint risks & define opportunities CONTEXT
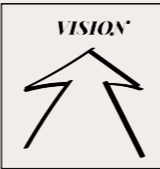
How might we change this (by product design)?
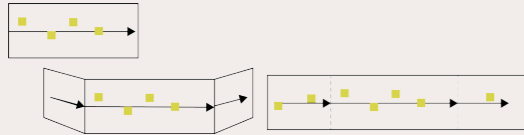
Circularity
6. Determine and discuss CE design strategies (given heuristics) TIMESPAN
7. Establish a CE vision (Why, How, What?) TIMESPAN

VISION
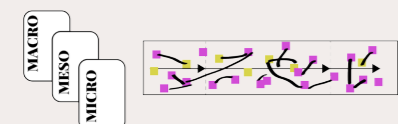
EXPLORE CURRENT COMPLEXITY:
med. device perspective
1. Product Analysis (structured questions)
2. Time-map: use cycle (life phases, structured questions) TIMESPAN
3. Time-map: life-cycle (structured questions) TIMESPAN
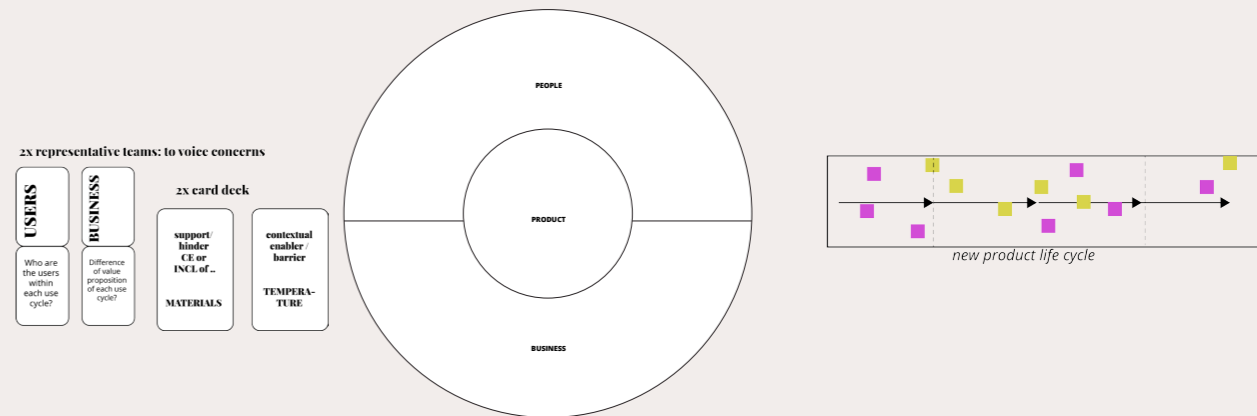
inclusivity
4. Map context of use (randomized card-deck; micro, meso, macro) CONTEXT

MACRO
MESO
MICRO

EXPOSE FUTURE UNCERTAINTIES:
8. find mutual understanding of (unintended) consequences (randomized card-deck) COMPONENT

2x representative teams: to voice concerns

USERS
Who are the users within each use cycle?

BUSINESS
Difference of value proposition of each use cycle?

2x card deck

support- hinder CE or INCL of ..
MATERIALS

contextual enabler / barrier
TEMPERA- TURE

PEOPLE
PRODUCT
BUSINESS

new product life cycle

9. Consensus: most promising inclusive circular ...

Appendix I: Workshop

The feedback sessions are based on the following questions:
Could you sketch how you perceive the model to look like?
How was the workshop for you?
What would you do to change/improve the workshop? Did you miss anything?
What would be a good model for you?
Do you think you can use any of the insights for your AED brief?
Anything else you would like to share?

TEAM 1

Workshop Evaluation by the designer (15/03/2021)

Overall:
- the term inclusivity might be confusing
- too little time (a bit rushed)

Phase 1: exploring current complexity
- -End result: chaotic map, but an understanding of the complexity
- State clearly that it is about their current product. Thus, what they expect it to be.
- We are working with assumptions, which might be hard
- context: individual, organization & institutional not clear in the beginning
- used the contextual factor cards as a discussion tool: interesting!
- Too little time to explore all the different cards

Phase 2: examine emerging opportunities
- difficult determination of (safety) risks. A more elaborate explanation is necessary.
- choosing 4 relevant factors was also difficult. A defined voting tool might be necessary
- State clearly when to work individually or as a team, to for example keep a clear overview when copying elements.
- Provide enough time to see each other's answers (maybe build onto each other's answers as well)
- The activity of finding inclusive opportunities needs a clear ending (summarize, or defining insights)
- The discussions are most valuable in this phase. New insights derived when discussing (out of the box) ideas.
- Circularity misses the business aspect (little discussion about service, pay-per-use etc)
- There has been little input about the End-of-Life.
- Defining a circular vision went surprisingly well and sparked discussion about the potential product

Phase 3: envision future balance
- Starting with the trade-offs to come to a future life cycle works well
- End-result includes less about inclusivity and the medical terms (might be interesting to loop back to this)
- Timeline might not be the best discussion tool (too little time to state everything again, because there is not a clear picture of the product yet).
- Feasibility, desirability, viability are well used for a discussion
- Responsible as well (good discussion)
- Their final proposal includes: next steps (product design, research on production), characteristics of the product, structure of the product (necessary communication), trade-offs

Workshop Feedback (16/03/2021)

Quotes:
"It gave me a new mindset to look for contradictions"
"I really liked the part of focussing on contradictions and making solutions for that"
"This method works to get people working in this direction"
"The main issue for me here is how I can reflect on this and how I can get the insights that I want and how I can implement them in my project"
"It made me realise that sometimes I have to think one step further than you originally would. For example, the availability of cleaning supplies, do they have these?"
[about the time-line activity] "Being forced to finish it without having the knowledge also made us aware of the assumptions and the thing that you really do not know yet [..] how often does it actually break?"
"I actually think that the short time of the workshop was beneficial to our outcome, we could not linger for too long on irrelevant subjects."

Overall:
- Focussing on tensions and trade-offs is received well
- Providing generalizing questions (examples of regular trade-offs) might help
- Working with assumptions is nice, to see what you do not know yet and see what you should validate
- Deliverables: a template might be nice, easy to follow; escape room box (more as a game);
- You will probably always need a facilitator or organizer to work with this model properly
- Use template or deliverable for a longer time (give option: pressure cooker, or two weeks, or half a year)
- Start of the project: compact version. If you go along with the project, a method or sensitizing activity that you can go back to each of those levels (go deeper, reflect more)
- More emphasis on the next step. It might be nice to offer a structure to execute these next steps. What happens next after you go through the approach?

Workshop Improvement:
- 3 hours: very exhausting (especially last part, which is the most important one)
- Provide more time to be aware of others answers & reflect on your own
- The workshop should visually be more structured to make it more clear (maybe use a step guide that shows how far you are one the way). However, this is something that not all participants agree on. When looking back at the canvas, it is quite disorienting. More structure is necessary to reflect on the workshop and insights.
- The use of break-out rooms is suggested (depending on the activity)
- There are differences in the opinion about the 'pressure cooker' variant. It is appreciated to move on quickly (and let some parts rest, do not linger too much) while others feel like they did not end up with valid information.
- Adjustment to workshop according to the feedback
- The miro board has been given more structure (lineair)
- A canvas (car-park) is added on top of the activities to save important insights and conclusions
- The three definitions of medical, inclusive and circular design have been shown multiple times along the board.
- Using different shaped and coloured post-its to create a more clear overview.
- The goal of each activity is clarified.
- According to the time available, and the level of the students, the questions asked are divided into relevant parts.
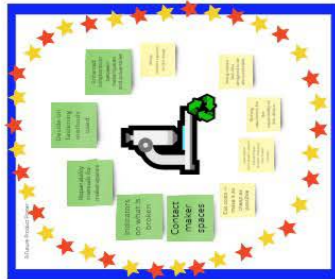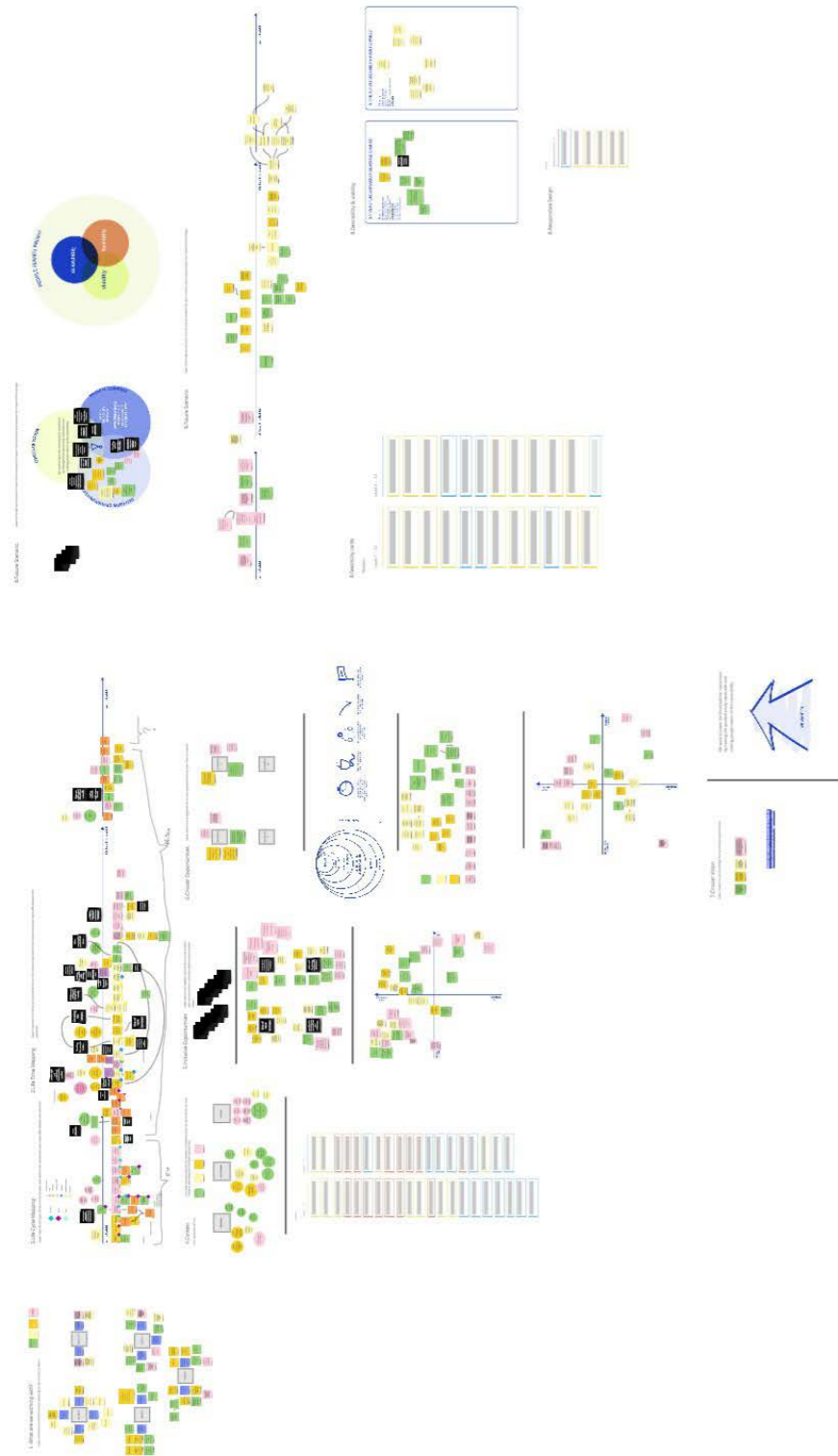
TEAM 2

Workshop Evaluation by the designer (22/03/2021)

Overall:
The 'car park', introduced to save insights and conclusions, is well used and highly appreciated.
The added definitions are of value.
There is still too little time (a bit rushed)

Phase 1: exploring current complexity
- End - result: chaotic map, but an understanding of the complexity
- Not everything from the product analysis is used in the life cycle mapping (missing stakeholders, times etc). It might be beneficial to have users look through the product analysis when working on the life cycle.
- New ideas are already added to the life cycle and the car park (is that a bad thing?)
- Many different perspectives used (different focus per student)
- Contextual factors are understood better (by using inclusivity definition)
- Some contextual factors are already included during life cycle mapping (bad thing?)
- Already providing different shapes for the steps provides a better overview.

Phase 2: examine emerging opportunities
- Dot voting did not work well for choosing risks (many with one vote, many similar ones)
- The inclusive opportunities are not very innovative/radical
- The inclusive opportunities are not well integrated in the proposal, so there is a need to end this activity better or to put more emphasis on these aspects during the trade-offs
- Circular opportunities stay quite general (e.g. prolong lifetime), but product redesign opportunities should be stated. So more specific brainstorm requirements.
- Seeing each other's circular statements might influence the outcome of the future vision.
- Combining the statement was quite difficult (because 1 was more different from the rest), but eventually the team managed to come up with an inspiring vision
- Little to no trade-offs stated between inclusive & circular (is this possible). Multiple general trade-off examples necessary.

Phase 3: envision future balance
- The end-result includes less about inclusivity and the medical terms (might be interesting to loop back to this). The reason for this will probably be the introduction of circularity in this final phase.
- More questions than solutions were stated in this phase (bad thing?)
- Circular business aspects are shortly introduced by a participant, but not discussed.
- Final proposal includes: Desirable, Viable, Feasible; mostly CE focussed (little said about dilemmas between medical and inclusive)

Workshop Feedback (29/03/2021)
Quotes:
'It made me think about factors I usually do not consider in my design process'
'It was nice and refreshing to think outside your box"
"the questions really helped"
"overwhelming to go from one big task to another big task, and you never know when will be the end"
"The lifecycle mapping and the life time mapping, could be interesting to make improvements to your product according to this method, because we found a lot of existing issues with the current microscope through this method"
"medical design is a great example to show the inclusiveness and sustainability issue, especially medical designs is very hard to make sustainable often"

Overall:
- There is a difference in car park: open questions & assumptions, insights & conclusions
- The facilitator quite important (guided workshop, kept asking deeper questions): if you do not have a facilitator, answers stay superficial (student might just keep it simple)
- Provide a booklet for a facilitator, or a facilitator within the team (per activity or so, roll switch) It might be difficult to always have access to a facilitator: provide the right (example) questions, activity cards to keep the workshop moving
- Provide booklet for the team
- Make the workshop/tool time-bound, do not spend too much time on it
- Add a wrap-up to a two weeks sprint (end up with what you did that day), important to have that to fall back on the next day (thus, adjust to the time that you have)
- Start doing the trade-offs between only one definition, and build onto that.
- SETTING IDEA:
  Design for sustainability: more project related, more practice. Two weeks of using the model might be interesting
  In AED project, already more about sustainability (no 2 week sprint necessary), the team already dived deep into the subject (so an afternoon of using the model is nice, to find new interesting topics to think about and research)
  PO4: conceptualisation, embodiment (early on in the process): start with a fresh idea to see how you split it up and research it (second part of PO4)

Workshop improvement:
- Workshop was long, too long for AED group, intensive in thought process (also a positive thing), yet enjoyable
- Car park was a really nice way to understand questions during thinking
- Questions of the facilitator during the workshop were really helpful, also made it more intensive (did you think about this..)
- Hard to remember previous insights, kept stacking up (chaotic to go back and forth)
- Add a wrap-up with each activity (take time for conclusion, reflection), a package that you can take with you to the next activity/phase, too much information to have an overview
- Information could get lost (provide set-conclusions)
- Add car-park for questions/assumption, and another one for conclusion (time for reflection)
- State beforehand that you end with a product poster: store information differently (know what is interesting to present, do not have to look back

RESULT QUESTIONNAIRE

The workshop showed me the urgency of designing circular medical products for the Sub-Saharan context: 5/7
The workshop inspired me to implement circularity more into my current or future projects: 5,6/7
The workshop inspired me to implement inclusivity more into my current or future projects: 5/7
I gained new insights into designing medical devices more circular: 5,3/7

New Insights in designing medical devices more circular:
- I learned more about the tradeoffs to be made between circularity and inclusiveness and medical design.
- For us, the repairability really stuck. How feasible this is has still need to be checked however
- I became more aware of the existing trade-offs
- how contradictions and trade-offs can be extracted from the data within the project
- That it might be nice to let Universities give feedback to the maker spaces/designers which can help upgrade and improve the design of the microscope
- There is often some sort of trade off that has to be made in order to make it more sustainable. Often it is a one time use product for hygiene reasons. So we have to make it more sustainable or made for more than one use while still keeping it hygenic.
- What happens to medical devices after its use

I gained new insights into designing medical devices more inclusive: 5,3/7

New Insights in designing medical devices more inclusive:
- Insights about how repairability could actually decrease inclusiveness
- Cheap was already a big aspect of our project but we can expand that to be even more inclusive
- I realised some things that I didn't think about before, like the different power outlets, or the (un)availability of cleaning supplies or tools to repair. It made me realise that you have to think one step further.
- To have some sort of online manual in the form of youtube videos etc so that not just a mechanic can use and repair it, but with the right tools, everyone could
- I guess most of it was about the price or availability of the devices. It is something we have to keep in mind, but that's what the goal of this project is as well. So not a lot of new stuff in that case.
- Inclusive design means to make medical devices more accessible (eg costs, logistics)
- Design for use broader than the specific use case, so that it can be used in a broader context later on.

I encountered interesting contradictions and trade-offs during the workshop: 6,1/7
Designing within the tension field gave me new innovative insights: 5,3/7
I feel empowered to embrace contradictions and trade-offs more easily in the future: 5,8/7
I agree with the final proposal of the workshop: 6,3/7

If I could change the future scenario and final proposal, this would be …:
- Maybe expand upon them as well and taking a broader perspective
- Include modularity more in the design. This was something that we were very enthusiastic about in our group, but that we did not really focus on during this workshop.
- There were many steps and it was quite long so coming towards the end, it was quite hard to remember all the insights we had gathered in the previous stages
- I think we came up with a nice proposal which we all agreed with in some form.

I am more aware of what happens with my designs in a different context: 5.5/7
I am more aware of what happens with my designs in the future: 5,5/7
I find it interesting to know more about the consequences and implications of my designs: 6,1/7

Other remarks:
- Was fun
- It was very interesting, and I am impressed by what we could achieve in three hours. I think it can be very valuable to our project. Nevertheless, it was going a bit too fast, so we did not have enough time for the last part of the workshop anymore.
- I liked the workshop. It stimulated creativity. Sometimes however, it went so quickly that I kind of lost the conclusions of the last part while it would be useful to bring it along to the next part. So it would be nice to make a part with main takeaways from every part and copy it to the next part as well to build on top of.
- I liked the workshop, we gained a lot of insights. However, it was a lot of information and there was not enough time to grasp and summarize everything. The final poster was nice to conclude but I feel like we forgot things we found in the first parts of the workshop.
- Great work you are doing in an important topic!
- Sorry for being late with the questionnaire! I thought it was a great workshop and it has a lot of potential to be a model to implement in education.
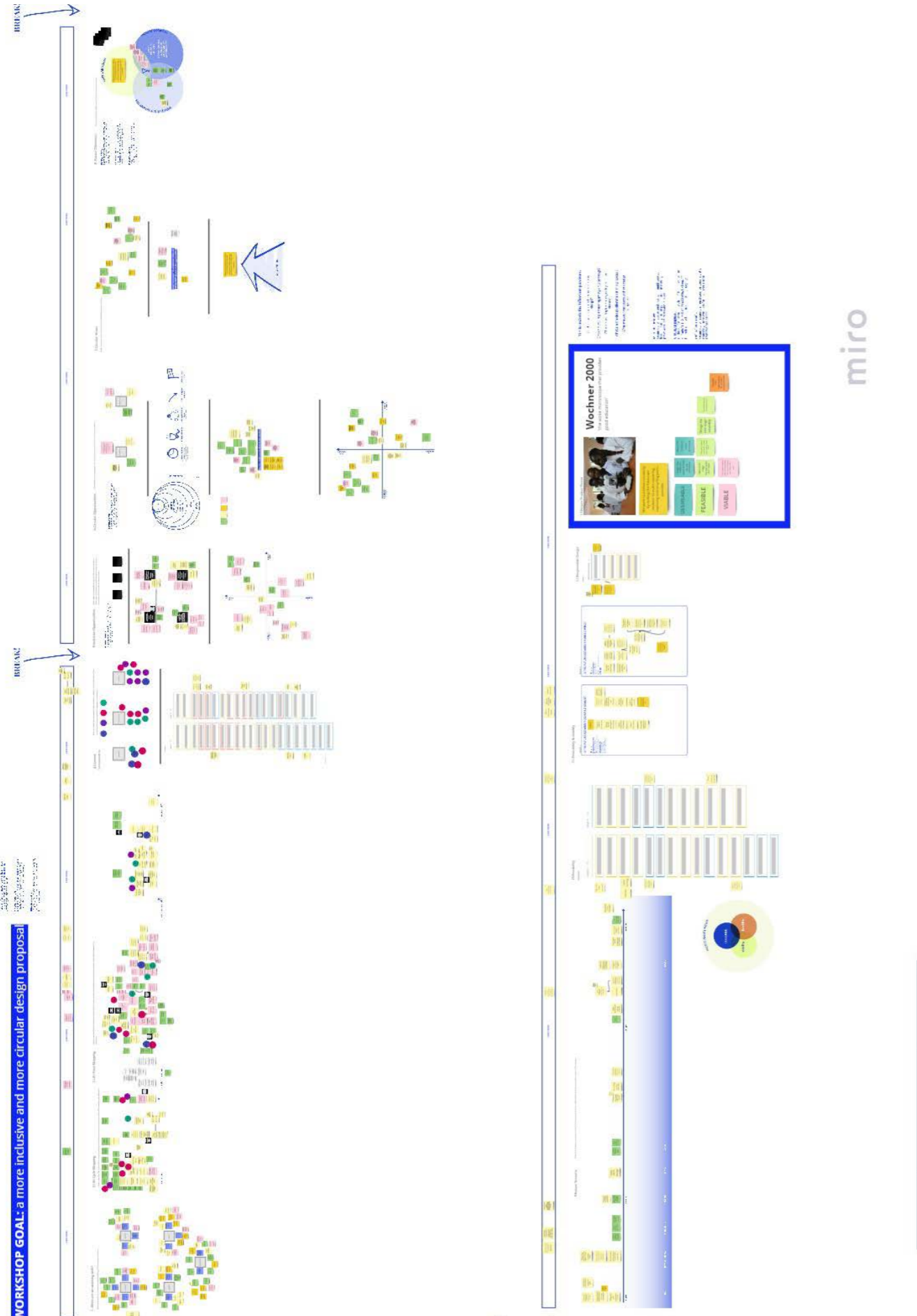
Appendix J: Workshop debrief

A semi-structured interview has been conducted, three questions were prepared to structure the interviews:
What were you most proud of after the workshop?
What have you remembered most from the workshop?
How does the (outcome of) workshop reflect in your midterm design proposal?

TEAM 1

The follow-up with team1 has been conducted 5 weeks after the workshop.

The following insights are collected from this follow-up:
Most proud of
- The amount of work that has been done in the short time of the workshop, many things have been put on paper and discussed
- The extensive life cycle, it was of course incomplete but included a lot of material and assumptions
- The insight about repairability
- Thinking about the three definitions at the same time, usually we neglect one or two of them or do not work on them on the same day

Remembered most
- Having an overview of the life cycle, including the production and end-of-life
- The fact that medical design is by far not circular
- To go one step further if you want to be able to design inclusive: very specific insights such as different power outlets or the available cleaning supplies
- Working with the friction, tackle the things that are currently not right
- The black post-its to find opportunities
- The extensive life cycle was useful, but a challenging activity. Based on many assumptions that they could not research in between (provide grip to do so)
- The external facilitator made sure they continued pushing themselves, and not ponder too much on one detail
- The circular aspect of the workshop, how it works together with medical device

Reflect in midterm
- The focus on repairability, the workshop showed the importance of this aspect. However, now not focused on the students but more on the makerspaces
- Involving the stakeholders in context is still on the planning
- The life cycle map has been copied and adjusted to priority
- The workshop triggered them to focus on repairability and modularity

"In such a short period of time, we were able to retrieve many new insights and explore a lot of new information"
"I had a insights last week about the availability of power outlets for our microscope, it reminded me of the workshop, you need to think one step ahead to design inclusive"
"I am happy we took the time to make such an extensive life cycle map, it provided me with many new insights and made me aware of the assumptions"
"The life cycle might be incomplete, but it formed a great basis to start from!"
"The repairability aspect will definitely be implemented in our microscope"
"The workshop has been useful as a basis for the knowledge we have right now, to think about and consider many different aspects"
"I thought the repairability insights were cool!"
"I really liked the deeper questions you had in each activity, making us think a lot harder about our work'
"I can not really put my hands on one specific thing I remember best, I think it is an overall impression on how to look at such a challenge"

TEAM 2

The follow-up has been conducted 4 weeks after the workshop.

The following insights are collected from this follow-up:
Most proud of
- Go through the whole process and be able to answer all the questions
- The name of the poster
- How easy it turned out to be to map a life cycle (in such a short time so many different aspects). Mostly because it was online and within a well functioning team
- explored topics they had not yet tough of or would otherwise overlook
- The poster was useful, however it felt incomplete (due to lack of time)
- Being able to summarize our insights and thoughts into a poster

Remembered most
- The struggles between the three subjects (medical, inclusive & circular), instead of focussing on the issues with one of them. This was new and interesting.
- The car park, which was new and insightful, and has been used in the progress of the project
- The fact that they had been talking about hygiene for a long time, but did not link it to the materials that they were researching and the reusability of those
- The energizer (drawing your peers)
- The Venn-diagram to discuss the trade-offs, a visualization of the three subjects and how they overlap. It provoked to think harder and deeper.

Reflect in midterm
- All three subjects are implemented, but that was also already the direction of the project.
- during the workshop, some things they did not think of yet derived (mainly focus on repairability and maintenance). They still need to elaborate more on these insights.
- The circular visions were fruitful, and have been used for the further project
- The poster (and specifically the desirable, viable and feasible aspects) provided a good summary to work with
- The broad view on the life cycle will be used to write about the implementation strategy of the open source product
- The main focus is on producing locally.
- Some specific insights have been elaborated on, such as the sustainability of the usage of certain lamps

"The activities of the workshop were all doable, we were able to get content out of every one of them"
"The workshop introduced us to topics and aspects that we might have overlooked or just did not think about"
"Considering the whole life cycle around a product has been an eye-opener for our project and will definitely be put into practice for the implementation of the device"
"When we did the workshop, we did not have that much knowledge about our project yet, so there was so much to explore, learn and discuss!"
"The Venn diagram was a great way to go more into depth on the problems. Up until then we had a tunnel vision on just one of the subjects, instead of having an overview of the three"
"The car park was useful to store information. It provided an overview of all the necessary insights, and I only needed to dive deeper into our diagrams when I was trying to find a specific aspect"

Appendix K: Creative session

Goal
The goal of the session is to gain a new perspective on the problem and to generate numerous novel ideas.

Procedure
As a preparation for the session, the participants were asked to complete an association activity that could be shared in the beginning to kick-start the session. This creative session was hosted, making use of the online co-creation tool Miro. Meanwhile, Zoom was used as a communication tool. The sessions were 2 hours in total.
After an energizer, the participants shared their associations, and similar associations were clustered. The next step was to use this information to formulate a problem statement to solve. As a guiding tool, an introduction to this problem statement was provided, which included the solution space:
A solution can be found in providing teams of design students at the IDE faculty a helping hand, a tool that provides grip on the early phases of a design process to frame a complex problem into a logical, promising, and more holistic design proposal. Can we design a tool that provides the next generation of design students with a more holistic mindset?

The participants formulated the following problem statement:
Due to design briefs being broad and vague, design student groups at university often get a feeling of uncertainty during moments where decisions need to be made because they label too much information as important!

Based on this problem statement, the participants formulated 35 How-To questions (van Boeijen et al., 2020). The 5 most interesting or inspiring questions were chosen to elaborate on using brainwriting. This resulted in over 140 answers to the following questions:
How to filter the right information?
How to feel certain about decisions?
How to make a design brief concrete?
How to prioritize?
How to stop "solving the world"?

The answers to each question are clustered and named, and used as a source of inspiration to determine a use setting and to generate ideas.

CLUSTER

ASSOCIATIONS

PROBLEM STATEMENT

Who is involved? | What occurred? | Where did it happen? | Where did it happen? | Why did it occur? | How did it happen?

design student group | feeling of uncertainty | in the verge of a decision | Uni | broad and vague brief

problem statement
Due to design briefs being broad and vague, design student groups at uni often get a feeling of uncertainty during moments where decisions need to be made because they label too much information as important!

HOW TO'S ★★★★★

Due to design briefs being broad and vague, design student groups at uni often get a feeling of uncertainty during moments where decisions need to be made because they label too much information as important!

how to set boundaries

how to know when to stop

BRAINWRITING

INTUITION	DATA	METHODS	TEAM EFFORT	PRE-SET GOALS	INVOLVEMENT OF OTHERS

How to filter the right information

INTUITION
- Just trust your gut
- dont get carried away though

DATA
- order sources by relevance to a topic
- set a limit before deciding if info is valuable
- create a big database
- Highlight all the highlights

METHODS
- Create a word web
- Work in design sprints
- C-boxing all the time
- hit the dott method

TEAM EFFORT
- Let the whole team write down the highlights of the topic and see what is similar with the rest
- score relevance ofresearch topics within the team
- Find a discussion with the whole team about the information
- always make decisions in a collaborative way

PRE-SET GOALS
- Balance scoping and research
- Define clear sub questions and help them insights for relevance
- set boundaries from the beginning
- rate information on the relatedness to earlier created statement

INVOLVEMENT OF OTHERS
- Talk to professionals and help them decide with you
- Continuously try to get feedback from your homemercience coach
- Involve the stakeholders to decide which is the main focus
- Interview from the getgo

ITERATE	INVOLVEMENT	USE OF SOURCES	TEAM EFFORT	UNWIND	ARGUMENTATION	BEYOND CONTROL

How to feel certain about decisions?

ITERATE
- Test it
- TEST, TEST, TEST!!!!
- Iterate and test it again
- early prototyping
- just do it, then you'll see
- Know that you work in an iterative manner
- Iteration rounds

INVOLVEMENT
- when your teacher tells you it is the right one
- ask users involved
- Co-create the decision making process with client
- when your mum agrees

USE OF SOURCES
- use many sources
- use the multisource method... forgot the name
- back it up with numbers
- Base you decisions on facts, so you know it is not wrong
- numberize it

TEAM EFFORT
- team feedback sessions
- Discuss with peers
- vote them with the team

UNWIND
- sleep a night over it
- (self) reassurance
- have it grow on you
- self steem
- meditation
- balance work / free time

ARGUMENTATION
- Why, why, why, why
- write down your argument
- ask yourself: what is important?
- make other options feel ridicule

BEYOND CONTROL
- let faith decide
- throw a dice
- when time is up

Left board (page 46)

STATEMENT
- How to make design brief concrete
- Make sure you can write the essentials down in 1 or 2 sentences
- create a one sentence statement
- make a realistic planning

PLANNING
- Make a clear planning and try to fit all plans in
- make a realistic planning
- Set quantitative targets
- set milestones during the project

INVOLVEMENT
- Do a creative session with the stakeholders and agree on a common problem
- Discuss it with a professional
- set a common language with the client
- brainstorm sesh with the client
- let the client sketch possible outcomes
- combine the expectations of all the stakeholders

TOOLS
- the ultimate brief template
- explain it with storytelling
- use laddering technique
- hidden assumptions method
- make a collage representing the brief
- WWWWWH method
- Use a scenario in the brief
- Define one concrete scenario where your "problem" occurs

ELABORATION
- Write down all underlying decisions in the brief
- Write down what you are not going to do!!!
- sketch possible outcomes
- draw a cartoon
- Succes metrics for project
- pick a case study

SCORE (nr)
- How to prioritize?
- Harris profile
- harris profile
- Make a scoring system
- weighted objectives
- label the relevance

INVOLVEMENT
- ask other people to do it and compare outcomes
- ask users involved
- what do the people want
- Use feedback form coach
- Interview stakeholder(s)

SCORE (abstract)
- on realisticness (is that a word?)
- C-box
- Easy – hard
- cheap – expensive
- Create a best and worst-case scenario.
- List
- Converging techniques

NEEDS
- always ask what is important
- what fulfils most fundamental needs of a user (see Pieter Desmet)
- Prioritize based on your mission/vision and ambitions

PRIOR STATEMENT
- Define clear ambitions
- what answers your question best

INTERNAL FACTORS
- Just go random
- what makes you most happy at the moment

EXTERNAL FACTORS
- time management
- Discussions

CREATE FOCUS
- how to stop "solving the world"
- Work like a start-up, focus on one problem at a time
- go step by step
- experience that, that works
- Focus on 1 specific context first

SCOPE REALISTIC
- realize this is only a uni project so will almost never be produced
- Have someone with the design to think of realistic scenarios
- know your one person out of 6 mil people
- Scope down further than comfortable
- try to solve it, but not get overwhelmed

PLANNING
- make it a to do after creating a design to think of the impact you want to think of
- manage time you want to work on a project.

INVOLVEMENT
- talking to stakeholders involved
- have professors tell them experience what their impact was within a project
- ask for what's expected from you

SELF-REFLECTION
- reflect on the impact you can have at the beginning of the project
- critical reflection
- meditate

METHODS
- compare work with other projects
- watch youtube videos about specific projects
- 80/20 rule: where can the design have the biggest impact
- use metaphors to understand the situation

Appendix L: IDE global health students session (page 47)

The IDE Global Health Students were asked to respond to the following questions:
What is a good definition of Medical Design?
In what setting and shape can the tool be used?
What would be important characteristics/requirements for the tool?

A next generation medical device approach:
a design journey towards a more inclusive and more circular life

IDE Global Health Session – Jard van Lent 30 03 2021

WHAT IS A GOOD DEFINITION FOR MEDICAL DESIGN?

Current definition:
'designing efficient and reliable medical devices which increase safety for the patient and the user by preventing infections and injuries'

Proposed additions/adjustments:
General:
- Medical Design: Medical equipment/device design or medical products

'Efficient':
- Effective instead of efficient
- What does efficient exactly mean (cost, material, time, resource, omni)

'The patient and the user':
- (Interactive) Include their environment as well (eg. hospital)

'Preventing':
- Not only preventing, but also diagnosing
- Medical devices help solve injuries and infections

'Medical devices':
- Does this term also include treatment of any medical condition (eg. prosthetics), if we talk about the prevention of infections and injuries?

Other:
- Definition: Designing product and services that facilitate safe and effective medical processes
- Feeling of control for the user

IN WHAT SETTING AND SHAPE CAN THE TOOL BE USED?

Setting ideas:
- IDE Academy (one day workshop)
- Elective Course, such as Creative Facilitation
- Advanced Concept Design (a week long process, involvement of client/stakeholders)
- Bachelor Ending Project
- Preparation before going on a field trip (IMP, Graduation)

Shape ideas:
- (Interactive) website: which could also collect the feedback for the tool itself
- Digital tool: easy to connect stakeholders
- Physical: puzzle, building blocks

Other:
- 1-2 day workshop to get started
- 3-day pressure cooker
- Embedded in the design process, such as a double diamond (for Msc and Bsc)
- Choose a specific moment in during the project (do not focus on the full project)
- Team effort (people from the field, or multidisciplinary team)
- Introduce during bachelor and use in master (eg. VIP)

WHAT WOULD BE IMPORTANT CHARACTERISTICS/REQUIREMENTS FOR THE TOOL?

Users:
- Users have experience with the involvement of multiple stakeholders
- Users have experience with creative sessions

Tool:
- Tangible, Physical
- Avoid too much terminology, and explain the used terminology
- Expectation management: share specific outcome for the team
- Include depth and details (eg. a cookbook)
- Elaborate on why this approach should be implemented (how is this beneficial for the client as well as the designer?)

Appendix M: Second ideation phase

A medical touch
The first part of this ideation phase was to ideate on creating a medical experience of using the model. The reason to start with this was the fact that the model is specifically developed to be used for medical devices/services, but does not emphasise this. Multiple methods, such as HOW TO's and SCAMPER are used to retrieve new ideas. These ideas, however, were not in the intended direction of the designer.
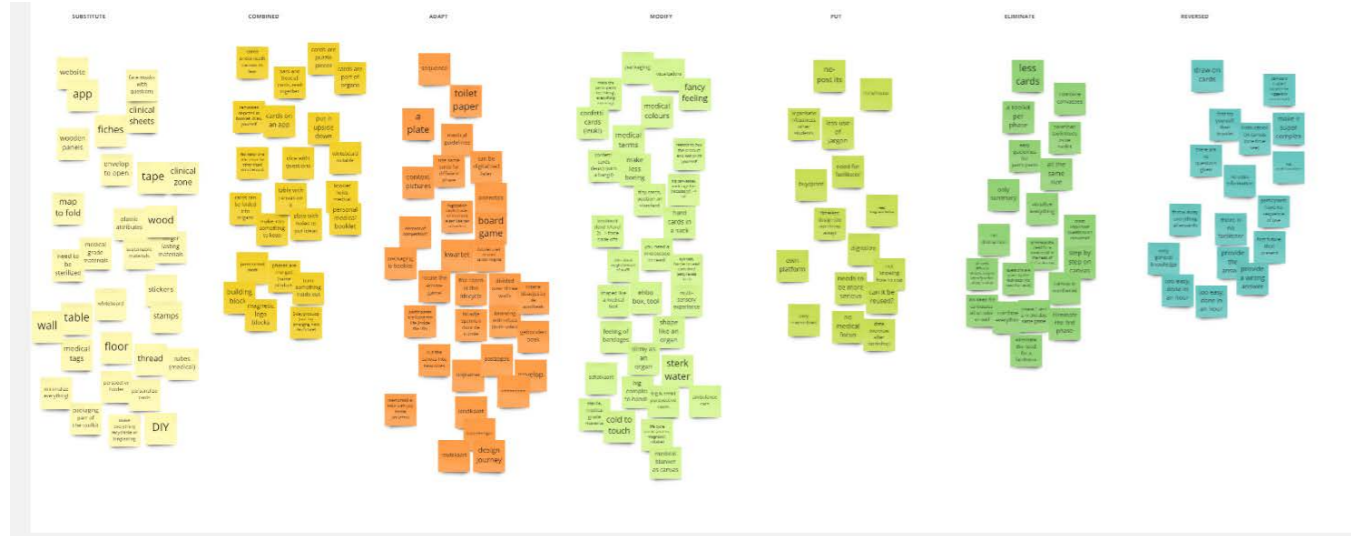
Memorable interventions
The decision was to find interventions in the model to make it most memorable. Two directions derived, which are based on multiple HOW TO's, sketches, and ideas (see right page).

One of the directions was to use an individual journey guide for each student, in which individual insights could be gathered and used as a prompt to retrieve memories later on.
The second direction was to intervene at the end of a workshop with a fun game, which would probably be the trade-off activity, which is also a new activity for most of the students.
These ideas, however, were not the intended direction for the designer as well as the supervisory team. Therefore, another direction has been explored, a memorable encounter with the model.

CONCEPT DIRECTION 1

TRADE-OFFS (process)
trade-off activiteit faciliteren
(participatie van iedereen, discussie, out-of-the-box, balans vinden)

weinig eigen "tools"

memorabel: eind van de dag + unieke ervaring

bijv: verschillende spel mogelijkheden

CONCEPT DIRECTION 2

WRAP-UP (strategy)
ademruimte tussen grote opdrachten
gericht op het individu en eigen moreel (mindset)

self-persuasion (inzichten & waarom belangrijk)

memorabel: iets wat je maakt & houdt, een 'prompt

bijv: een uniek design paspoort, verzamelen van eigen inzichten en ideeën (naslagwerk)
Kan gefaciliteerd worden met een extra object

Appendix N: Iterative process Circled Map

First iteration

The first iteration has been tested by four IDE master students, of which two as a team and two individuals. These tests provided enough insights for the designer to continue with the next iteration of the map.

Goal

The goal of this test is to find out how students use the map, if and when it is comprehensible and how they would like to use such a map.

Procedure

Each test has been around 15 to 20 minutes and is based on a semi-structured interview.
The participants are handed the map and asked to use it as they would while asked to think aloud and take the designer through their thoughts.
With only the map provided they are asked the following questions:
What is the first thing that comes to mind when looking at the map?
How do you think the map should be used?

Afterward, the participants are given a description of how the model should be interpreted, i.e. what the structure of the model is and how the elements of the model are connected, and a simplified visualisation of the model.

With the new materials provided, the participants are asked the following questions:
When going through the materials, are you able to pinpoint the elements stated in the map?
What would you state about the comprehensibility of the model?
What words would you use to describe the visualisations?

Outcome

The participants have given feedback on the phrasing and the graphic design of the tool to make it more comprehensible, e.g. the need for consistency, changing of colours, use of icons, the need for extra information, and the rotation and emphasis of certain text including the three definitions. Furthermore, the start and end (or next steps) of using the model need to be emphasized more. All participants have used the map first as a booklet, to go through the first layers. To find the start of the model has been difficult. Multiple participants have mentioned their difficulty with the wording of the different levels.
The usage of the map, to stand on the inside and read it from the inside out, has not always been interpreted like that. Therefore it is of importance to state this when starting to use the map.
The extra information provided on how to interpret the model has been useful in understanding how to work with the model, and therefore a combination of visualization and explanation is required. The possibility of putting the facilitator in the middle of the map has been mentioned.

The map has been stated 'novel, inviting, engaging, playfull, interactive, dynamic and complex'. The simplified model has been stated 'clear, not stand-alone, process-based, roadmap and layered'. The difference between the thoughts of each visualisation shows the added value of the interactive circled map.

'I would really need another person to join me to work with this tool and understand this model' - Participant (individual)
'I think we should just put it onto the floor'! - Participants (team of two)
'The map is an interesting tool, I would really like to know exactly what it is for and how to use it' - Participant (individual)
'Now that I have experienced the map, the other visualization is boring to use..' - Participant (individual)
'It feels like you are using something, not just a method from a book" - Participant (individual)
'I enjoy the physical aspect of this model, to not be behind my computer for once' - Participant (Individual)
'The visualisation represents the need for good communication" - Participants (team of two)
"It kind of gives me the feeling of a game' - Participant (individual)
"The more elements and lines join in, the more difficult this model gets to understand it' - Participant (individual)

Second iteration

The second iteration has been tested by four different IDE master students, in two teams. A high-fidelity prototype has been made, including a hard cover, foldable paper and new dimensions that allow better movement within the map. This iteration also includes a new visualisation, as was discussed with an expert (Appendix B: Interview 11) These tests provided the designer the insights to finalize the circled map and booklet.

Goal

The goal of this test is to find out how students interpret the map themselves and its understandability when explanation is provided.

Procedure

Each test has been around 30 minutes and is based on a semi-structured interview.
The participants are handed the map and asked to use it as they would while asked to think aloud and take the designer through their thoughts.

Afterwards, the participants are given an explanation of the model, as has been stated in the booklet 'How do I interpret the model?'. With this new information provided, the participants are asked the following questions:
What information is new to you?
What information is necessary to understand the map?
What information is lacking?

Outcome

The outcome of this research is quite clear. Information is missing regarding the field of friction and field of knowledge, on the sequence of the steps (which are included on the part), the key factors and on the iterative process within part 7. This can be adjusted in the booklet. The map, and the color indications of the definitions, is clear to participants, especially when provided with the explanation. An extra indication needs to be added on the map where to start.
Next to this, the research shows a collaborative approach within the teams, communicating what they see from their perspective, and actively changing positions within and outside of the circle. The new dimensions of the map have a similar effect on the participants.

"It looks good with this cover, a real product."
"Oh wow, the map is round, that is funny!"
"I think we need to position ourselves within the map? Should we then put it on the ground? Are we allowed to do that?"
"So the colours indicate the three definitions, that is quite clear."
"The explanation is necessary to really understand the model."
"I might need some more indication on where to start within this visualisation."
"I am a slow reader, this might take me a while.."

Appendix O: Cost price estimation

Tools			5 toolkits	50 toolkits
Circled Map	*Front & Back*	350 g/m2 gelamineerd mat https://www.printerpro.nl/producten/affiches/	13,54	63,4
	Inside	90 g/m2 84,1x150 https://www.printerpro.nl/producten/bouwtekeningen/	€33,39	€203,65
Design Guide		135 g/m2 gesatineerd https://www.printerpro.nl/producten/brochures-magazines-geniet/	49,53	341,28
Card deck	*Inclusivity & Circularity*	400 g/m2 9,8 x 9,8 https://www.printerpro.nl/producten/kaarten/	€103,76	900,5
Canvases	*2x Life Cycle (A0)*	A0, 120g/m2 https://www.printerpro.nl/producten/bouwtekeningen/	40	229
	Trade-off (A0)	A0, 120g/m2 https://www.printerpro.nl/producten/bouwtekeningen/	25	139
	Assumptions & questions (A1)	A1, 120 g/m2 https://www.printerpro.nl/producten/bouwtekeningen/	18,2	86,6
	Conclusions & insights (A1)	A1, 120g/m2 https://www.printerpro.nl/producten/bouwtekeningen/	18,2	86,6
Packaging	*A4 box*	(packaging can be bought by 50, for 5 this is divided by 10)https://www.rajapack.nl/kartonnen-dozen-verzenddozen-exportcontainers/dozen-drukwerk/a4-postdoos-rajapost-beschermende-zijflappen-sluitklep-bruin-of-wit-micro-golfkarton_OFF_BE_0526.html	5,8	58
	tube	packaging can be bought by 50, for 5 this is divided by 10 https://www.rajapack.nl/kartonnen-dozen-verzenddozen-exportcontainers/postdozen-verzenddozen/verzendkoker_PDT05623.html?testclick=T2S	9,55	95,50€
		Total Price (EXCL VAT)	316,97	2203,53
		Total Price (INC VAT 21%)	383,54	2666,27
		Total Price per unit	76,71	53,33

Appendix P: Timetable scenarios

A proposed time indication of the 2-day session

This includes introduction and wrap-up within each part and allows for some air in between. Besides, it provides the time for an introduction to the model.

1st day (in total 6,3 hours)

Phase 1:
Medical Design
    Part 1: 60 min
        Step 1: 30 min
        step 2: 30 min
    Part 2: 60 min
        Step 1: 30 min
        Step 2: 30 min

BREAK
Inclusive Design
    Part 3: 45 min
        Step 1: 45 min

Phase 2:
Inclusive Design
    Part 4: 60 min
        Step 1: 20 min
        Step 2: 25 min
        Step 3: 15 min

BREAK
Circular Design
    Part 5: 95 min
        Step 1: 20 min
        Step 2: 25 min
        Step 3: 15 min
Step 4: 15 min
        Step 5: 20 min

BREAK
All
    Part 6: 60 min
        Step 1: 15 min
        Step 2: 25 min
        Step 3: 20 min

2nd day (in total 5 hours)
Phase 3:
All
    Part 7: 105 min (iterative process, preferred a cycle of 2, thus 210 min)
        Step 1: 45 min
        Step 2: 30 min
        Step 3: 30 min
BREAK AFTER EACH ITERATION

    Part 8: 90 min
        Step 1: 30 min
        Step 2: 30 min
        Step 3: 30 min

A proposed time indication of the 1-day session

It provides the time for an introduction to the model.

1st day (in total 5,9 hours (extended version, including Circular Vision step)
Phase 1:
Medical Design
        Part 1: 45 min
                Step 1: 30 min
                step 2: 15 min
        Part 2: 45 min
                Step 1: 25 min
                Step 2: 20 min
BREAK
Inclusive Design
        Part 3: 30 min
                Step 1: 30 min

Phase 2:
Inclusive Design
        Part 4: 45 min
                Step 1: 10 min
                Step 2: 20 min
                Step 3: 15 min
BREAK

Circular Design
        Part 5: 70 min (or 45 min if part 4 & 5 excluded)
                Step 1: 10 min
                Step 2: 20 min
                Step 3: 15 min
                (Step 4: 10 min
                Step 5: 15 min)

BREAK
All
        Part 6: 45 min
                Step 1: 10 min
                Step 2: 20 min
                Step 3: 15 min

BREAK
Phase 3:
All
        Part 7: 45 min
                Step 1: 15 min
                Step 2: 15 min
                Step 3: 15 min

        Part 8: 30 min
                Step 1: 10 min
                Step 2: 10 min
                Step 3: 10 min

Appendix Q: Evaluation workshop

Workshop observations by designer

Overall:
- Throughout the full workshop, questions were derived regarding the current Schistoscope. This implies that more time is necessary for a thorough understanding of the current medical device/service, or enough time within activities to discuss. E.g. an extensive discussion has been part of Phase 2, in which the components of the product are clearly described to get more concrete ideas.
- The 'problem owner' tried to answer the questions that were asked. Therefore, the 'problem owner' could be perceived as the expert.
- The 'problem owner', and the other participant with knowledge regarding the subject, cut off ideas of the other two participants multiple times. It seems it resulted in fewer 'out-of-the-box' ideas, or bold statements.
- In general, all participants were able to join the dialogue and discussion concerning the three definitions, despite their knowledge and skills.
- All participants were able to take part in all Levels of Difficulty. This means that it has less to do with specific knowledge, but more with the ability to make connections and the availability of time to go through the levels.
- The team did not use the Assumptions & Questions and Conclusions & Insights canvas.

Phase 1:
- The Medical device/service analysis took longer than expected. This was mainly due to the discussions and the questions concerning the device and its usage. The participants were able to get a common understanding of the Schistoscope.
- During Lifetime mapping, the Lifecycle was already discussed. The participants were able to correct this themselves, making a distinction between the definitions.
- The Lifecycle canvas or the used post-its need to be scaled in order to fit properly.
- Both card-decks have sparked new ideas, or provided ideas that were built onto already existing ideas.

Phase 2:
- The focus of the team was on the device itself, but a sample preparation is necessary beforehand. They saw opportunities of combining both while working on Inclusive design.
- Many of the factors within the Inclusive ideation point to the same direction. This sparked the interest of the team to have a bigger view on a full toolkit necessary, instead of just the medical device.
- The Trade-off activity should have a distinction between negative and positive influence of key factors on each other. The Key factors that complement each other might have a higher priority to solve.
- The team was able to think in the 'big picture', e.g. considering the importance of funding in this project and how this influences design decisions and the implementation.
- This team did not need the probability matrix to prioritize the inclusive and circular ideation to key factors. They were able to state Key factors through discussion, in which the 'problem owner' was involved.

Workshop feedback

"I think it is really well-designed. I can see the whole process getting narrowed down. [..] We produced a lot of data, and then we condensed the data, that is really good"

"I really like the three circles that you did in the end"

"The cards that you made are really nice, because first you think of all random things that come to mind but then you also have some questions that make you think about it a little deeper. So you can sort of check if you did not miss anything."

"It is nice to see that all of the work we did is coming together in one spot"

"I like how it looks at the end!"

"I suppose that it is the next step to see where the priority lies"

"Would it not be possible to stretch the whole thing? Because a lot of interesting discussions, which might not directly be related to the product, could lead somewhere but we had to end these discussions to move to the next step. So, maybe just have extra time"

"It is a really good model, I can see this being used in the analysis phase as well as the evaluation phase of the design process."

"What if you took out components of this model, and use it a few times to gather data, and then go back to the full model" (talking about modular usage of the model)

"It looks very sleek, I am impressed"

- Life Cycle canvas: might need some more space, focus points (e.g. location), and a legend of post-its shapes and colours. This depends on how much the user needs or wants to be steered.
- It needs to be emphasized that this life cycle canvas will be used multiple times throughout the model, and it will extend.
- Trade-Off canvas: might need a coloured distinction between positive and negative influences, or stated within the overlap where to place post-its.
- The need for more time, and thus longer discussions, is stated by multiple participants. Instead of 3 hours, they would have liked working on it for a longer time.
- The suggestion is given to have a usage that is tailored to different needs, thus using certain elements of the model multiple times or choosing which ones are relevant.

Workshop questionnaire

+ previous knowledge
- no or little previous knowledge

How did you experience the workshop?
- It was fun. We were properly guided throughout the process. It was a little high paced for me though, which is understandable for a pressure cooker session. Furthermore as it was online, it was a little chaotic sometimes with everyone just putting up notes, especially phase 2.
- Great
+ I liked it! The instructions were clear and the miro board helped to structure all our thoughts.
+ Really well done! I liked how it was structured, and the volume of information generated given the time.

How do you feel after tackling such a complex challenge?
- I feel like we have touched many of the bases of the complex environment, and were able to relate them to one another. We ended up with an overview of which we could draw some conclusions for further development.
- It was fun to break down the complex problem into smaller parts
+ A bit tired. This, partially due to the impact of working with multiple participants. But also fact that we had to think about a widespread selection of aspects in a fairly limited time.
+ That the right solution to the project is present in the data collected. All I have to do now is sift through it and combine the right bits.

What would you take with you from this workshop? Try to formulate at least two answers
- Responsible design is not that easy and I do not think there are products that are ideal from all perspectives. However it is important to take them all into account and make well informed decisions. Be aware of the sacrifices you make to achieve a certain value in a different department. There are many factors in different steps of the life cycle that can influence the impact of your product on society. Decide on each step wisely.

- Firstly, my own thesis will be a medical project so I would be willing to try using a tool like this to help me scope out problems. Secondly, I knew I design tools but I don't think I've seen it being done, so now that opens new possibilities for me!
+ (1) The use of miro for creative sessions. The (some well-known) methods were easy to access for all participants and the visual representation of the questions and final summary really helped to get to a useful outcome. Also the order in which the questions appeared made sense: allowing us to discuss without guidance first, continued with guiding questions for more inspiration (2) I struggled during my own graduation project with how to visualize the trade-offs that occured. Using a creative session like this one could have been useful. I might try this in the future.
+ 1. The structure -> gather everything you know in one place -> figure out how they relate to each other -> what combinations produce what results. 2. That there is so much that I did not consider while working on the schistoscope previously. Circularity and inclusivity are much larger topics that I previously thought.

How do you see yourself using this model, without a facilitator, if a guidebook and the necessary materials (such as the card decks) are available?
- For personal use, I would like it to be a book that describes the method and helps you through it. Where there are images of the canvases and perhaps an example of how it could be used.
I would use it first in the analysis phase, in order to map out the current circularity, inclusivity and medical perspective of the product/service. Use the achieved knowledge in ideation and redesign. And then use the model again to see if the redesign has improved opposed to the original. For companies it would be nice to have more of a toolkit to guide your team through the steps to evaluate the path the company is currently on and to see what are opportunities for improvement.
- I would need a flowchart to better help me with the flow. I doubt we could've been able to go through this without your aid at this moment.
+ I think online would be best. For instance the guiding card questions would take time to spread out, whereas now there was a clear overview. The more general phases could be presented in a booklet I guess, allowing the creative facilitator to print them on A3 or simply copy the questions by hand.
+ In theory, I would use this model for every project.

How did collaboration contribute to the outcome of the workshop?
- All other team members were already acquainted with the subject of the workshop. They are either going to work on it or have already worked on the schistosomiasis device. You can see that everyone has a different view on where the problem of the device lies. Personally I think it is not in the current version of the device, but in the whole process surrounding the device. I think the model allows for service/process design as well, but the focus now was a bit more on the product design part. Due to these different perspectives, we came up with a broad evaluation of the problems.
- I think collaboration was a great tool to help build on each other's points and brainstorm.
+ By discussing each other's ideas, though I think most were based on everyone's initial idea. Sometimes there was not enough time to read what everyone wrote.
+ A lot of the information was generated because of the discussion between the group members. I doubt if the same quality and quantity of information would have been generated if all four members did this workshop individually.

As a designer, you are responsible for your design decisions. In what manner has this workshop contributed to your awareness towards responsibility?
- I think by going to the phases you sketch ideal situations for the three 'responsibilities' (Medical, Environmental and Inclusivity). And in the last phase you bring them all together and by putting them into perspective you can prioritise the three responsibilities. By identifying the sometimes opposing characters of these responsibilities you are aware of the shortcomings in the other areas when making your decisions.
- I realize the consequences of the decisions we take instantly within the next step. Very few times, we had to go back and choose a different topic to be able to proceed forward (example funding).
+ Increased value of other designer's opinions. I don't usually use creative sessions.
+ This workshop has changed my thoughts. I was of the impression circularity and inclusiveness would not be a part of medical equipment as safety comes first. But it is possible to be both, and this method can also add financial value to the projects.

What could have been better? Try to formulate at least two answers.
- Phase 2 has ended up into a bit of an enormous chaos. It is a quite excessive canvas that envelops many different things of the product life. I also noticed that here you asked several times: Have you thought about ...., Can we say

something of... Hereby guiding our thinking process. Perhaps the canvas itself could help with that as well. Who What Where for example. It is also a little indistinctive what is the use cycle and what is the life time of the product. It also seems to me that in different parts of the life cycle different responsibilities might take the overhand. So it would be nice if this would be visual somewhere.
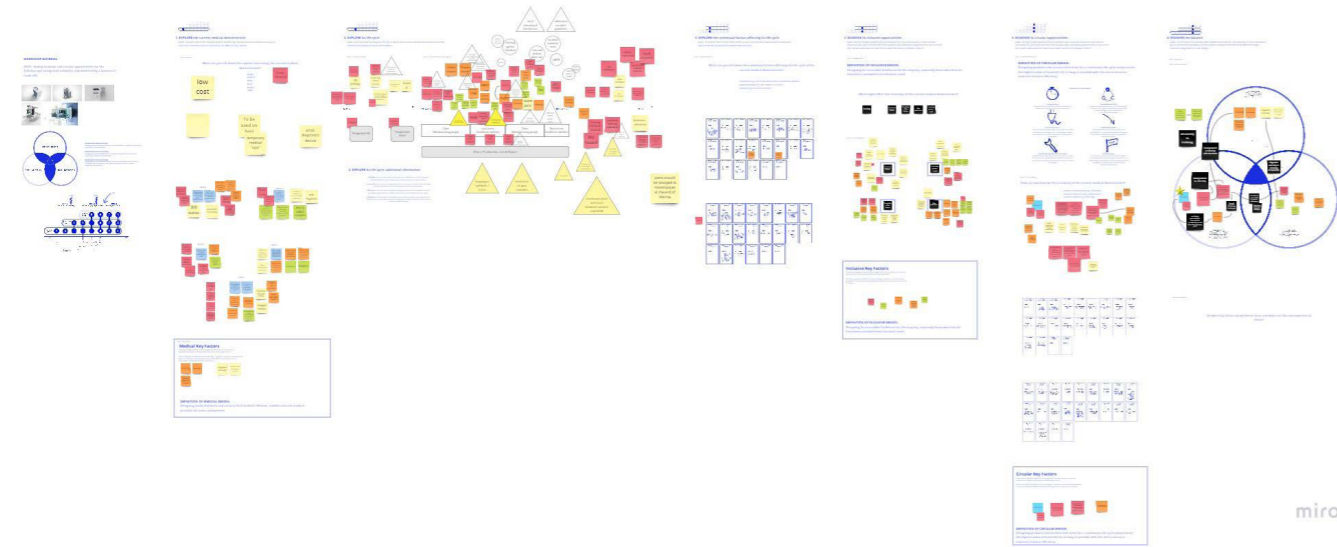- The timeline of the entire workshop could've been better. The life cycle part could be more structured. More sub categories would make it better to read and analyze.
+ I'm also wondering why the focus is only on circular design. Circular design, as it is about a responsibility to the environment right? Indy her idea about biodegradable slides are very interesting, however they do not really go about circular design. Still in the current case where they dispose of the (cleanable & reusable slides) anyways it could be an interesting solution. It is indeed the question whether you design optimal for the current situation, or for how you want the situation to be.
+ (1) Legend for the post-its. (2) More guiding lines to easily place the post its more structurally. (3) e.g. the why/what/how questions were silently and individually answered by rotating. There will be more to read the further you get in this round, so the time provided should also increase.

Did you miss anything during the workshop, and if so, what?
- I think we could have taken a bit more time to draw a conclusion at the end of each phase. Now they are just key factors, but perhaps there should also be something of a design goal or clear opportunity.
- I think the workshop covered all the points that I can think of!
+ Maybe a timer of some sort, as to give us an idea how long we will stay on one question.
+ combining different aspects in the three circle model to come up with ideas that include multiple advantages

Would you like to share any other (positive/negative) remarks?
- The canvases are clear and insightful. They have a good balance between bits of information and reminders of things to think about, but also allow you to think widely and a bit outside of the box.It is nice to start with a really open question and then use the cards to ensure that you have touched bases and go more into the depth.
- Only time, otherwise it was a fun experience.
+ In the explanation given beforehand you mentioned "Level Basic" and others, I did not understand what you were referring to.

SCHISTOSCOPE 3B

Background

Schistosomiasis is a Neglected Tropical Disease (NTD) that affects over 200 million people worldwide. 90% of these cases are in Africa. The disease is usually found in backward regions, and is transmitted when people relieve themselves in nearby lakes and rivers. The parasites in the excreta find new hosts (people washing clothes/ children playing) and burrow through their skins. The symptoms range from stomach aches to cancer. The people of the affected regions depend on organizations such as WHO, local government bodies and NGOs to diagnose and treat them. Every year, healthcare workers travel to schools, collect samples of excreta from children of 5 - 15 years, analyze them under a microscope, and provide praziquantel, a drug used to treat the disease. As the process is very labor intensive and dependent on the analyzer's competence, there is a need to automate the process. Using AI to recognize eggs not only reduces manual effort, but it also improves the speed and accuracy of the tests. The healthcare worker also has additional time to prepare samples and interact with the patients. Below is a visualization of an ideal scenario using such an automated device. :
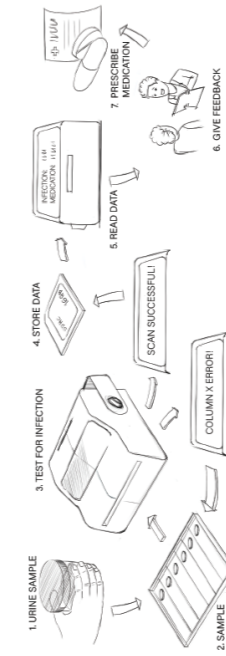
How it works

There are three main functions of the device 1. Correctly position each sample below an optical lens to capture a picture. 2. Use an optical system to capture the picture. 3. Process the image to recognize eggs and display results
A Raspberry Pi 4 is used to control the system. All movements in the X, Y and Z directions are done by motors and gears. The X movement moves the samples, the Y movement moves the lens along each sample, and the Z movement controls the focus of the lens.
Multiple pictures must be taken and put together in order to capture the entire sample, so analyzing all six slides will take about 35 minutes. Depending on the number of eggs found, an intensity level is displayed on the screen, according to which the correct dose of medicine is prescribed.

Manufacturing

A lot of medical equipment is donated/ imported to Africa, but because there are no spare parts to repair/ maintain this equipment, most of it is dumped in 'medical graveyards', after a malfunction. This calls for the search of a way to manufacture the equipment locally, as they can then be repaired. The recent drive to improve education in the continent saw the rise of makerspaces, where students learn to make things using 3D printing and hobby electronics, making 3D printing a promising way to manufacture medical equipment and spare parts. Hence all components of this device can either be bought at a local hobby electronics store or can be 3D printed. PET-G filament was chosen for its properties and availability.
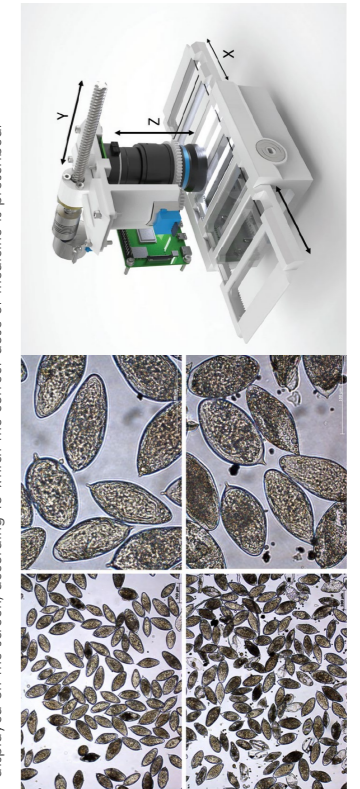
This device uses urine samples to detect schistosomiasis haemotobium. The intended device (the object of this workshop), however, is used to detect schistosomiasis mansoni, a different species. Stool samples are used in this case. The way the device functions is the same. It is just the sample that is different

Introduction

Currently, there is a lack of functional medical devices and services in low- and middle income countries as well as a need for circular medical devices and services worldwide. Considering the fact that the majority of the world's population resides in these low- and middle where this acute shortage of functional medical devices and social and ecological impacts are experienced the most, it is a challenge that is inevitable and too gruesome to not address.

Therefore, there is an urgent need for a next generation of medical practices, innovations targeting the large global need for healthcare, in which the social and environmental challenges are addressed simultaneously.

This booklet presents you a model that is able to help you to come to more inclusive and more circular medical devices/services in the early phases of your design process. It introduces medical, circular and inclusive design to each other simultaneously for the first time!

This model aids you in becoming aware of the life cycle of a medical device/service, of the opportunities that emerge to improve the medical device/service and what trade-offs are necessary to find a promising more inclusive and more circular medical device/service, specific for your context of use.

By using the model, you are going to discover new insights, set priorities and catalyse a new mindset useful for tackling these important and inevitable challenges. The model will guide you through a field of knowledge regarding medical, inclusive and circular design, and through a field of friction, balancing the three definitions.

This booklet enables you to implement the model into your own project by following the steps provided.
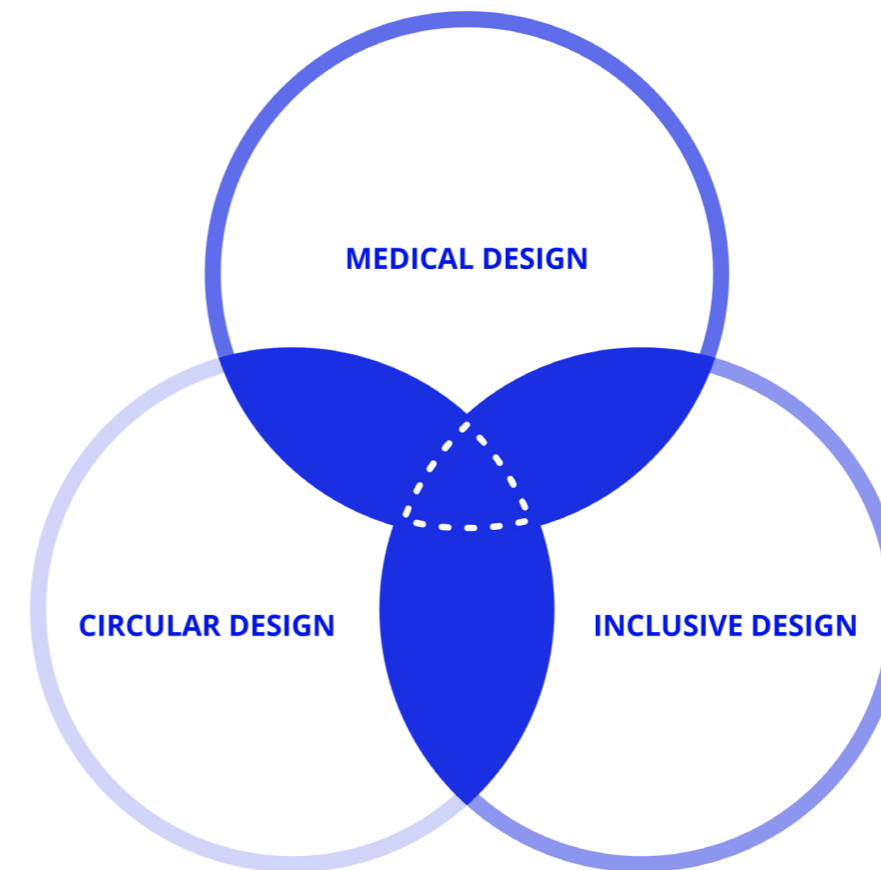
This model introduces you to three definitions:

MEDICAL DESIGN
Designing medical devices and services that facilitate effective, reliable and safe medical practices for users and patients

INCLUSIVE DESIGN
Designing for accessible healthcare for the majority, especially those who thus far have been excluded from this basic need

CIRCULAR DESIGN
Designing products and services that strive for a continuous life cycle and preserve the highest value of materials for as long as possible with the aim to increase material resource efficiency

PHASE 1:
Explore current complexity

PHASE 2:
Examine emerging opportunities

PHASE 3:
Envision future balance

CIRCULAR DESIGN — 5 6 7 8

INCLUSIVE DESIGN — 3 4 6 7 8

MEDICAL DESIGN — 1 2 6 7 8

start — end

Circular Key Factors

Inclusive Key Factors

Medical Key Factors

How do I interpret the model?

The left model is a simplification of the complexity you will encounter.

The three definitions will be explored when using the model, introduced one-by-one, and combined to come to more inclusive and more circular medical devices/services.

The model starts by exploring your current medical device/service, expands on this knowledge and takes a broad view, to eventually come back to a future medical device/service.

To do so, this model consists of three phases: EXPLORE current complexity, EXAMINE emerging opportunities and ENVISION future balance.

Each phase consists of parts, of which there are eight in total. These eight parts need to be executed in sequence, yet it is encouraged to go back to previous parts if necessary.

The model includes the following parts:
1. EXPLORE the current medical device/service
2. EXPLORE its life cycle
3. EXPLORE the contextual factors affecting its life cycle
4. EXAMINE its inclusive opportunities
5. EXAMINE its circular opportunities
6. EXAMINE the balance
7. ENVISION its future life cycle
8. ENVISION the more inclusive and more circular medical device/service

Each part includes Level Basic, so this level will always be achieved. When executing Part 1, 2, 3 or 5 and wanting to dive deeper in the subject you can enter Level Intermediate and Level In-Depth. This can depend on the time and current knowledge and skills. Within one team you might vary between levels. Be aware to execute Level Intermediate before going to Level In-Depth.

Part 1 until Part 5 is used to retrieve new information and knowledge. The key factors you will find in Phase 1 and Phase 2 are necessary to end Phase 2 and start Phase 3. From Part 6 onwards, the retrieved information will be used to find balance between the three definitions of Medical, Inclusive and Circular Design.
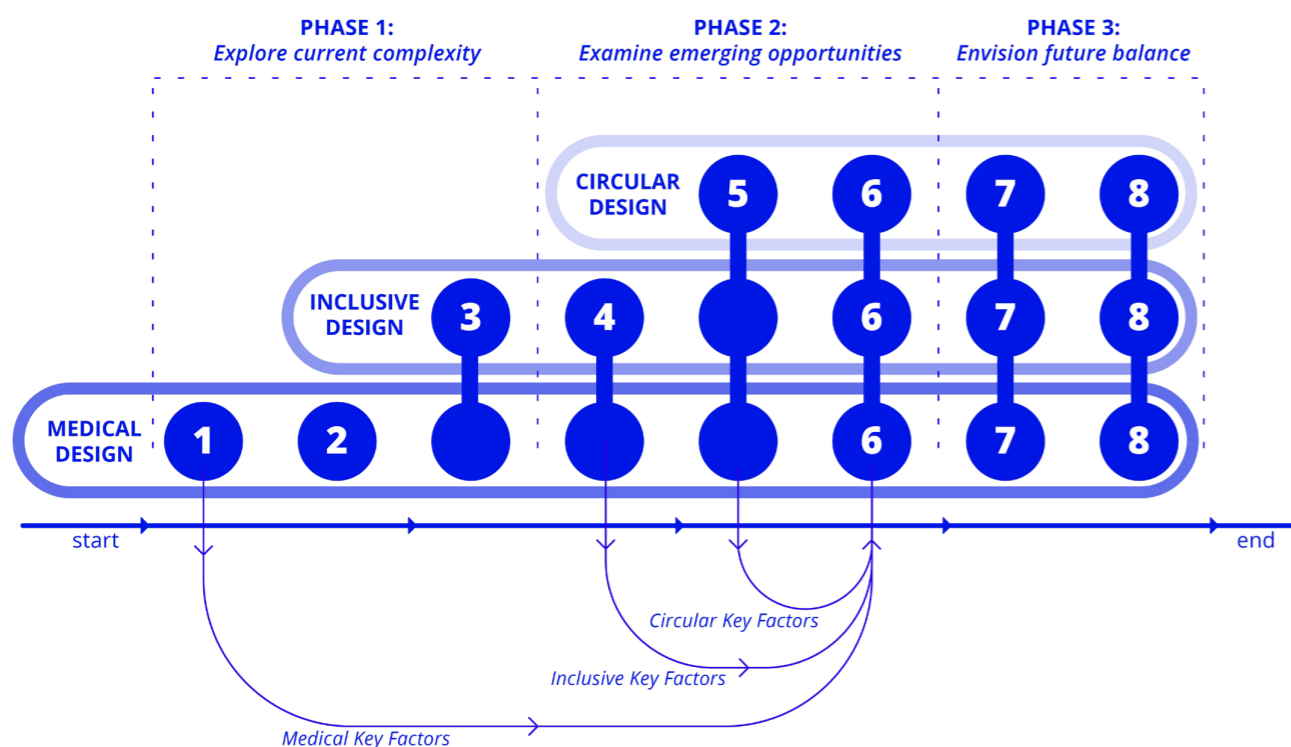
Appendix R: Expert evaluation

List of experts is anonymized for publication and available upon request.

List of experts is anonymized for publication and available upon request.

Appendix S: Card decks

INCLUSIVITY CARD DECK

Level questions:
Individual (micro focus)
What about the (un)availability of cleaning supplies (e.g. the use of heavy chemicals instead)?
What about financial barriers for the patient?
What about the skills/level of training of the user?
What about potential concerns of the patient/user?
What about reusing due to cost?
What about parts or components getting lost?

Organizational (meso focus)
What about the skills/level of training of the people involved?
What about the supply chain for the necessary consumables, disposables or parts?
What about the (un)availability of technicians?
What about storage?
What about the (un)availability of spare parts?
What about the (un)availability of tools for repair and maintenance?
What about (eruptive) power supply?

Societal (macro focus)
What about humidity?
What about dust?
What about temperature?
What about external stakeholders?
What about transport conditions?
What about the location of stakeholders?
What about import costs?

Level 3 questions:
Individual (micro)
What about patient privacy?
What about cultural barriers for the patient/users?
What about the usage of a different cleaning/disinfection/sterilization technique (e.g. boiling water)?
What about the (un)availability of water?
What about the (un)availability of a manual?
What about reporting a device/service failure?

Organizational (meso)
What about the breaking and damaging of accessories?
What about the awareness of cleaning and sterilization protocols?
What about contact with the medical device/service company (e.g. for technical assistance)?
What about the total cost of ownership (i.e. direct and indirect costs of the device/service)?
What about the budget of the location of use?
What about hospital waste management?

Societal (macro)
What about shame (e.g. shame around the usage of a certain medical device/service)?
What about literacy?
What about service contracts?
What about language?
What about country-specific medical regulations and policies?
What about public mobility?
What about different power outlets?
What about altitude?

CIRCULARITY CARD DECK

Level 2 questions:
Component (micro)
What about hardware failure?
What about recyclable/recycled materials?
What about generic/off-the-shelf parts and components?
What about reducing material usage?
What about the lifetime of the device/service?
What about reducing weight and volume?
What about connections?
What about the difficulty to clean/disinfect/sterilize?

Structure (meso)
What about production waste?
What about other production techniques?
What about cleaner energy resources?
What about minimizing consumables/disposables?
What about a mobile platform?
What about reverse logistics?
What about difficult maintenance and repair?

System (macro)
What about the product-service-system?
What about service contracts?
What about refurbishment or remanufacturing?
What about modularity?
What about recycling of materials?

Level 3 questions:
Component (micro)
What about software failure?
What about the (un)availability of components/materials in the context of use?
What about using only one material?
What about the device/service being outdated?
What about the introduction of more efficient technologies?
What about integrating functions?
What about additives and surface treatments?
What about printing and labeling?
What about hazardous components?
What about hybrid devices(e.g. critical & non-critical)?

Structure (meso)
What about minimizing energy consumption during production, transport, and logistics?
What about the costs of recovering the device/service?
What about the packaging?
What about the infrastructure to recover resources?
What about the circular awareness of stakeholders?
What about difficulties in communication or relationships between stakeholders?

System (macro)
What about (the dangers of) incineration?
What about life cycle service?
What about sharing the use?
What about a fixed number of use cycles?

COEVOLVE: a design journey towards more inclusive and circular medical practices
Jard van Lent