D5.1 Assistive and Collaborative Designing Methods and Tools

Fraunhofer FIT

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Abstract	The report presents online collaboration tools. Those are tools for video conferencing, tools for asynchronous communication, like chat and file sharing, and online whiteboarding tools. Then the report discusses 24 methods and exercises useful to facilitate and support collaborative designing and prototyping practices. The first three exercises were applied during CBS workshops focusing on business modelling and supporting the CMDF establishment. The other 21 methods presented, are part of the Design Thinking Toolkit used with FIT. The last section of the report grants insights to Siemens practical experience when introducing DIY technologies and related collaborative methods to new and inexperienced participants.

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Executive Summary

Report D5.1 is the result of T5.1 Assistive and Collaborative Designing Methods and Tools. The task contributes primarily to part one of objective 4 of iPRODUCE project. It aims to develop and deploy a set of digital tools that will stimulate co-creation and open innovation in the consumer goods sectors.

The report consists of three parts.

Part 1 presents an extensive list of online collaboration tools (software applications). It first introduces tools for video conferencing, tools for asynchronous communication, like chat and file sharing, and finally online whiteboarding tools.

Part 2 discusses 24 methods and exercises that are useful to facilitate and support collaborative designing and prototyping practices. The first three exercises were applied during CBS workshops focusing on business modelling and supporting the CMDF establishment. The other 21 methods presented, are part of the Design Thinking Toolkit used with FIT. They have been adopted to the virtual setting and we discuss their implementation within the project.

The last part grants insights to Siemens practical experience when introducing DIY technologies and related collaborative methods to new and inexperienced participants. One group of students evaluated a visual scripting method for parametric 3D modelling (used in Siemens' platform) and rapid prototyping. Another group of students is analysing and prototyping the gamification concept for effective training on 3D printing.

This deliverable considers itself as complementary to the tools and methods already presented and discussed in D2.4. At the same time, we also want to emphasize our commitment to the following appeal:

"Even though the listings indicate the most popular tools and resources, thus indicating the most used and applied tools, the project partners should engage in the opportunity to explore the knowledge base herein presented as a way to expand their toolboxes, creating new standards for social manufacturing to be offered in the iPRODUCE platform."[1]

[1] Cited from D2.4 Report on Co-creation and Open Innovation Methods for social manufacturing page 31.

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List of Abbreviations

3D = 3 dimension (hight, width and depth)

CAD = computer-aided design

CBS =Copenhagen Business School

CMDF = Collaborative Manufacturing Demonstration Facility

DIY = Do It Yourself

FIT = **F**raunhofer Institute for Applied **I**nformation **T**echnology

MIRO = Online Whiteboard Application

MURAL = Online Whiteboard Application

SAG = Siemens AG

SME = Small Medium Enterprise

T = Task

TUM = Technical University Munich

WP = Work Package

1. Introduction

1.1. Scope and objectives of the deliverable

This deliverable reports the mid-term results from T5.1 of the iPRODUCE project. It presents Assistive and Collaborative Designing Methods and Tools. One of the iPRODUCE project objectives is the stimulation of the use of co-creation and open innovation in the consumer goods sectors. Next to WP5 also T4.5 is concerned towards this goal. The related report D4.9 Training Toolkit on Co-creation details on a set of tools for the co-creation process, developed and deployed for Face-to-Face settings. Thus it should be seen as a compliment to the presented methods in this report, with just a stronger focus on Face-to-Face settings.

1.2. Structure of the deliverable

Chapter 2 of this report presents **online collaboration tools**. The examined software is discussed based on their different purposes of use: Videoconferencing (section 2.1), Asynchronous Online Collaboration for Chat and File sharing and Synchronous Online Whiteboards. It builds on the list of communication tools presented in section 4.1.3 of D2.4 Report on Co-creation and Open Innovation Methods for social manufacturing.

Chapter 3 presents **design thinking methods** that have been applied and adapted during the iPRODUCE project. They have been found valuable in a social manufacturing context and proved a supportive function in collaborative design and prototyping. This chapter, like the previous, builds on D2.4 Report on Co-creation and Open Innovation Methods for social manufacturing. An initial list of Co-creation methods and tools had been presented there in section 4.1.2.

Chapter 4 reports experiences in the practical introduction of **some co-design and prototyping methods** and tools for inexperienced or less experienced participants. Siemens has checked the usability of collaborative visual scripting & prototyping with 3D printing and electronics and developed a gamification concept to improve the introduction of makers' technologies to new members (with an example of 3D printing). This was performed in cooperation with 2 Munich Universities.

Chapter 5 summarizes our conclusions and key takeaways and highlights the task related plans for the second half of the project.

Due to the pandemic situation in Europe during the last 14 months, the focus of the tasks shifted slightly. Previously planned activities like workshops were held online. Sharing tools, design thinking methods and the general knowledge exchange within the own CMDF, with other European CMDFs and other iPRODUCE partners happened 100% remote. The described work and results clearly reflect this shift.

2. Selected Methods 1 - Online Collaboration Tools

This chapter introduces a comprehensive overview of online collaboration tools. It builds on the list of communication tools presented in section 4.1.3 of D2.4 Report on Co-creation and Open Innovation Methods for social manufacturing. All of the tools introduced here, are considered to be usefull to facilitate remote collaboration, collaborative design and production processes and applied social manufacturing. D2.4 Report on Co-Creation and Open Innovation Methods for Social Manufacturing assessed and mapped communication tools used by iPRODUCE project members. The tools presented there were collected using a questionnaire distributed within iPRODUCE project partners. We used this input as a starting point for this report. The data gathered there was enriched with desk research and our own experiences during the pandemic extensive use of Online Collaboration Tools. We also collected feedback gathered though informal discussions and collaborative activities on iPRODUCE CMDF level and on their use during social manufacturing projects.

While D2.4 describes online tools in two sections: (section 4.1.1) Online resources for social manufacturing like Forums, wikis, bulletin boards and (section 4.1.3) (Online) Communication tools, this report focusses more on tools that are dedicated to help facilitating online collaboration. We therefore excluded “simple” online resources, like forums and bulletin boards. They usually do not include features for teamwork or collaboration in a private / non-public group.

Definition: What is an online collaboration tool?

Online collaboration tools are software, that allow teams to work on tasks together in a 100% digital / fully remote manner. A team can be a group of two or more inviduals that aim to accomplisch a common goal. Online collaboration tools are available 24/7 via the internet and therefore are flexible in terms of time and location. They enable sharing work and work results with team members or partners.

The following chapter compares functionalities and usefulness of selected online collaboration tools within social manufacturing. It reflects and answers the following key questions:

- Which recent tools for online collaboration are used by distributed remote working teams?
- How do these tools support remote working teams in the social manufacturing work processes?
- What are advantages and disadvantages of the tools compared to each other?

Based on key features, the tasks to be done and the main use purpose, we present the online collaboration tools in six groups: videoconferencing, chat/VoIP, conferencing with large audiences, file sharing, asynchronous knowledge sharing and online whiteboarding.

2.1. Videoconferencing – enable virtual meetings to share, discuss and take decisions

Facilitating social manufacturing and production activities, without physically being in the same location, requires being able to talk to each other in groups of two or more people. The opportunity to see the other meeting participants, compared to audio-only conversations via telephone, is a key advantage in

videoconferences. As non-verbal messages play an important role in human communication[2], videoconferencing enables to notice those non-verbal messages.

Therefore, we consider a stable audio- and video-transmission-quality being the most important feature of videoconferencing tools. Zoom is one of the most frequently used applications, due to offering an algorithm providing a widely stable audio- and video-transmission even without large bandwidth. In addition, the fact that a "free" account can be used after a one-step registration process for the organizer only, without any need to subscribe for participants, lead to it's wide acceptance.

Two features, that we considered important when choosing a videoconferencing application are the number of individuals that can participate and the price. Table 1shows a comparative overview of prices and number of participants, which of course can change at any time.[3]

Table 1. Videoconferencing Tools

Application	Participants	Price per month
Zoom	100, up to 40 minutes 100 500 1000	Free 46,00€ per room +46,50€ +83,70€
Google Meet	100 150 250	Free (participants need to register) or 5,20€ 10,40€ 15,60€
GoToMeeting (LogMeIn)	150 250	12,50€ 17,00€
Microsoft Teams	300	4,20€
Blizz by TeamViewer	5 50 100	Free 7,49€ 9,99€
Cisco Webex Meetings	50 100 200	12,85€ 17,30€ 26,65€
Facebook Messenger Rooms	50	Free (participants need to register)
Jitsi Meet	75	Free
Skype (Microsoft)	50	Free (participants need to register)
Discord / Discord Server	10 (up to 5000 audio only)	Free (participants need to register)

Other applications like Google Meet, Facebook Messenger Rooms, Jitsi and Skype can be used on free accounts too. But before being able to join a videoconference using those not only the organizer of the videoconference but also all participants need to register and create a private account. The related loss

[2] Depaulo, B. M., & Friedman, H. S. (1998). Nonverbal communication. In D. T. Gilbert, S. T. Fiske, & G. Lindzey (Eds.), The handbook of social psychology (p. 3–40). McGraw-Hill.
[3] The information in this table reflects the status quo at the moment of submitting this report.

of ownership on personal data is a risk, that from our point of view needs to be considered carefully and is a decision to be taken within the collaborative team itself. Other comparable tools like GoToMeeting, Webex or Microsoft Teams offer more data related control, but can be used on paid accounts only.

Tools like Discord can be an interesting alternative for small groups. It was originally developed for private usage in a gaming context. The tool is optimized for minimal latency and provides excellent transmission-quality. While previous updates allowed users to interact via voicechat only, the original picture videoconferencing-feature has been implemented during the pandemic. To use this tool, organizers and participants need to register and login with own credentials as well.

Teams facing a high need for data protection and privacy for videoconferencing, on premise solutions need to be considered. They do grant the full data control. For example the open source software Jitsi has delivered good results. Up to our experiences in iPRODUCE social manufacturing projects these tools are rarely implemented and used in the CMDFs. The reason for this is mostly claimed by the “ease of use” of the free tools on the market and the reduced cost.

All tools listed above possess an application for mobile devices or even allow to join conferences by using any common web browser. Videoconferencing participants are not required to install software on their devices. Zoom, Skype and Jitsi, can be used without having installed an application as long as a Web browser is installed.

When it comes to sharing information, increasing understanding and facilitating decision taking screen sharing to show presentations or records is an another frequently used feature. All providers listed do offer this.

When using videoconferencing as an educational tool, which in the social manufacturing setting is a frequent situation, “Breakout-Rooms” are a great feature to create subgroups. Breakout-Rooms allow a moderator or meeting host, to split the group into several separate virtual rooms. Participants can discuss and work in small groups and during the same meeting meet again with all team members. From our experience this kind of collaborative work needs teams that are either experienced in remote collaboration and the tasks related need to be well structured and prepared. Organizing collaboration meetings including educational sections requires strong effort in carefully planning and preparing materials and scheduling.

While videoconferencing offers synchronous collaboration and communication the tools presented next enable teams to work on shared tasks in an asynchronous mode. The opportunity to share information and work results during a collaborative production and design processes without a need of a personal handover is critical to the results and the timely interplay.

2.2. Asynchronous Online Collaboration Tools

2.2.1. Communication via Chat

All Videoconference-Tools listed in the previous section offer a chat feature. That means participants and organizers alike are enabled to communicate using text messaging while video conferencing at the same time within the same application. But regarding the complexity allowed, the tools show substantial differences. The tools listed here were the ones most frequently used within the CMDFs.

In social manufacturing a key feature has been found to allow to **create topic related groups** and / or separated channels. Microsoft Teams and Slack offer this feature. These channels or groups can be named by their organizers and therefore allow sorting and structure of the teams or task related groups. Tools like RocketChat or Mattermost offer similar chat features. RocketChat is an open source software that can be deployed on-premise and therefore enable remote collaboration in teams working with sensitive data and security needs.

Some tools also **display a status of presence**. Depending on the settings users can actively define their status and thus organize and structure collaboration. The status may vary to up to 6 different options: available, busy, do not disturb, be right back, away or offline. From our experiences actively negotiating how to apply those settings within the team offers more transparent communication rules and has proven useful for remote working teams in case of quick communication and decision taking needs.

Most chat applications offer free accounts upon registration, some expect payments for their service. Table 2 shows a comparative overview. Chat tools, just like videoconferencing tools, also differ in the maximum amount of participants allowed and pricing is often related to the number of users.

Table 2. Chat Tools

Application	Price per month
Microsoft Teams	12,80€ per user
Slack	Base-Version - free Standard-Version - 6,25€ Plus-Version - 11,75€
Rocket Chat	Community - free Pro - 3$
Mattermost	Base-Version - 3,25$ Premium-Version - 8,50$
Workplace by Facebook	2,70 €
Google Hangouts Chat	free

2.2.2. Online file sharing

Online file sharing is the alternative to using USB-Sticks or sending attachments via Email or Chat. Application providers offer access to online storage space. Users up- and download files and documents. Users may then share the data by using a link. The data recipient can access the files using

the link. The main focus here is the asynchronous service of avoiding to send large amounts of data and causing network issues.

Key features for selecting those file sharing tools are memory capacity and the related cost. Table 3 compares both features of some tools.

Table 3. Online File Sharing Tools

Application	Memory capacity	Price per month
Dropbox	2 GB 5 TB unlimited	free 12€ per user 18€ per user
Google Drive	15 GB 2TB 100 GB 200 GB	free 2€ 3€ 10€
OwnCloud	500 GB 1000 GB shared + 200 GB per user	15€ per user (1-4 users) 13€ per user (at least 5 users)
TeamDrive	2 GB 10 GB 100 GB	free 59.50€ per year 299,00€ per year

Regarding the protection of personal data and in terms of **data security** needs file sharing applications also show a large variation of options. While the free file sharing services offer vague guarantees to protect personal data, and in most cases European legislation recommendations are neglected, some providers explicitly add on this need. Applications providers like TeamDrive do actively promise to follow GDPR requirements and legal data security regulations. In general, from our expoeriences, as soon as personal data, like name, address or legal information is concerned a careful selection is recommended. The best protection are self hosted solutions. Those allow full data control but require dedicated facilities and skills on the other hand.

Next to the up- and download functionalities **remote collaborative editing** has shown to be an interesting feature as well. Upon our experience this is usable in very small groups up to a maximum of 4 participants only. The ability to edit documents online in a collaborative manner is also available as a real-time feature. Applications like Google Docs allow

2.3. Synchronous Online Whiteboards

Online whiteboards allow groups to synchronously, collaborate by editing and collaborating on a virtual online whiteboard. During the iPRODUCE project especially the design and ideation phases of social manufacturing projects were supported by those recently spread tools.

We explored the usage of online whiteboards in teams of varying sizes. Thereby we realized that the **team size** is crucial. Using Online Whiteboards with a group of more than 5 individuals can be challenging. As long as the group is working on a dedicated amount of ideas, participants can easily follow the process. Once the group is bigger, participants can get a feeling of being lost. The need for

detailed planning and moderation increases, with the amount of participants in a team collaborating at the same time.

The basic key feature offered by all online whiteboards presented here is to enable participants to **create virtual sticky notes** and move them on the shared virtual background. Teams use this during brainstorming exercises, to collect, sort and structure ideas. Examples of this will be shown in Chapter 3.2 and 3.3. Some online whiteboards do offer a significant number of additional features, that allow us to make a distinction between two categories: Simple Sticky Note Tools and so called Virtual Design Spaces.

2.3.1. Simple Sticky Note Tools

Simple Online Sticky Note Tools allow groups to collaborate synchronously and asynchronously using ideation techniques and design processes by writing, sorting and moving virtual sticky notes. Those virtual sticky notes can be moved by all participants and sorting is enabled by using different colors. Table 4 compares selected Online Sticky Note Tools in regard of their price.

Table 4. Online Sticky Note Tools

Application	Price per month
IDEA FLIP	free (3 Boards, share with 2 guests) 9$ per user (unlimited Boards and sharing with your Team) 12$ per user (unlimited Boards and sharing woth your Team and Guests)
Open Board	free
Excalidraw	free

All of those are available free of charge and for most of them are designed for a dedicated one-time use. This means the results of the online collaborative activity needs to be saved (Screenshot) when leaving the board. During iPRODUCE these tools have found their application while doing workshops with people external to the organizations or the CMDF. The shared board is accessible by using a link, with the only need of having a web browser installed.

2.3.2. Virtual Design Spaces

Virtual Design Spaces are tools developed for the exchange of visualized ideas and visually cooperating with a group. Table 4 compares a the most widely used Virtual Design Space applications and Visual Management Tools regarding their pricing structure.

Table 5. Virtual Design Spaces

Application	Price per month
MURAL	12$ per user (1-50 users, 1 Team) 20$ per user (10-50 users, multiple Teams)
Miro	free (1+ user, unlimited team members, 3 boards) 10$ per user (2+ users, free features, unlimited boards) 16$ per user (2+ users, all features)
Conceptboard	free (up to 100 Objects per board) 6,25€ 10€ (at least 10 users)

Mural and Miro are used with iPRODUCE CMDFs for collaborative (visual design) decision taking and brainstorming. Next to the sticky note related features described above, Miro offers a range of **wireframing** settings that have been applied by partners to visually share screen designs for Apps currently developed within the iPRODUCE platform. The comment feature has proven to help facilitate asynchronous information exchange between project partners inside the proposed design wireframes directly. Which saved time and resources, as feedbacks could be collected and documented in one step.

During the run of the projects data security had to be considered at several times. The application Conceptboard is a European provider hosting his facilities in Germany. It has been under discussion to move activities but the current lack of features (wireframing) kept the CMDF continuing to use Miro.

3. Selected Methods 2 - Adopted Design Thinking Tools

Social manufacturing projects often deal with wicked unstructured problems. Solving those in a collaborative manner with teams distributed in space and sometimes not knowing each other is a challenge. Often partners need to define new rules and collaborative working norms to support a team building process. Furthermore, educational activities and decision making, need to be organized as well.

Design Thinking has become an extremely fashionable method throughout the last decade[4] when it comes to working on wicked problems. It combines the human-centred problem-solving approach and the early prototyping methodology (embodiment) to test solutions and iteratively improve the results. Therefore, the related mindset can be accounted as being a common ground (common sense) for individuals involved in social manufacturing. Those individuals can be people associated with the maker community, entrepreneurs, small businesses, or the industry. Using Design Thinking Methods to tackle wicked problems proved to be a fruitful approach.

This chapter first describes our general approach to Design Thinking and the 5 phases process model. We then present selected Design Thinking methods and show how these have been adapted to the virtual setting. All methods were used with iPRODUCE partners and various CMDF members. The methods presented here are complementary to the 52 “Co-Creation methods and tools” presented in D2.4. The methods are summarized from a general point of view and their mode of application is described more in detail, as the aim is to enable the interested audience to replicate them.

3.1. The Design Thinking Process

The iterative Design Thinking Process with Fraunhofer combines Design Thinking with User-Centered Design and adjusts the focus of the individual steps to the particular objective and contains 5 phases. During phase one we dig deep into the problem by identifying user groups and empathizing with them, to find requirements. In Step two the identified requirements are defined in a technology and solution independent way. This is what we call problem space. Based on the problem definition, in phase three the solution space is entered by generating solution specific ideas to address those specified requirements. In order to make these ideas tangible, rapid prototypes are created during phase four. And finally in phase five, the prototype is evaluated as to whether it is heading towards the right direction or not. Detecting drawbacks of the prototypes is part of the process and improvements are made in multiple iteration cycles.

[4] Leifer L., Meinel C. (2019) Looking Further: Design Thinking Beyond Solution-Fixation. In: Meinel C., Leifer L. (eds) Design Thinking Research. Understanding Innovation. Springer, Cham. https://doi.org/10.1007/978-3-319-97082-0_1

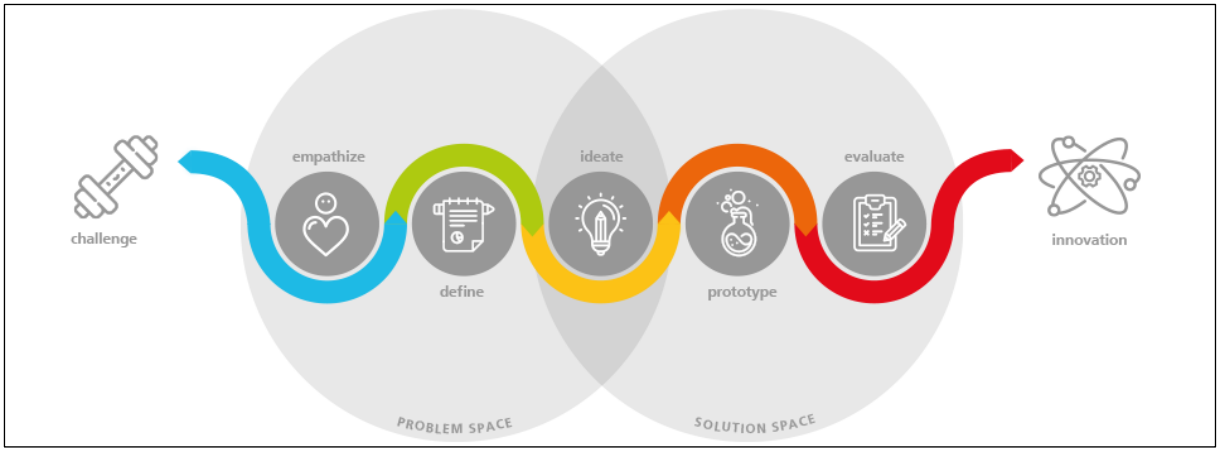

Figure 1. Fraunhofer Design Thinking

The five phases of the Design Thinking Process with Fraunhofer are visualized in Figure 1. Fraunhofer Design Thinking. The two underlying grey circles show the focus of activities during the phases. First the focus is on the problem and second it is on the solution.

The following section describes selected methods used during the iPRODUCE project. The exercises described here, have been adapted to the needs of the dedicated CMDF use cases. The first three tools were applied by the danish partner CBS during either business modelling activities within the consortium and activities within their own danish CMDF activities. The other exercises have been collected by FIT and were used during various workshops within the German CMDF and in collaboration with other CMDFs.

3.2. The Blue Sky Vision Exercise

The blue sky vision is an exercise to help identify a shared vision or goal among one or more teams. The exercise will also help identify the feasible expectations for collaboration among the teams and company members.

The method is introduced to the team of collaborators by emphasizing that anything goes and the exercise does not aim to criticize the results but more to navigate to a common ground of shared understanding. By applying the metaphor of “blue sky” most individuals can connect and find a certain freedom to bring words to their expectations and future vision of the business model, without being afraid of being pinned down to the explicit meaning. This freedom of expression leads to a relaxed conversation about what aspects of each other’s vision can become true and are realistic. Thus it helped to visually set some first “flags” of expectations and ideas, and initiate an open discussion on the shared vision.

In the example of iPRODUCE, this activity was used with the CMDFs in the activities of Task 7.2, dealing with the development of the CMDFs’ business models. It was applied to help the different partners discuss and find a common reachable vision as a group. This facilitates establishing the ground of collaboration and the most promising and viable service offerings they can provide.

As all iPRODUCE CMDFs ran through this exercise virtually we used Miro boards software to perform those collaborative sessions. One Blue Sky Vision Exercise took about 1 hour and was led by a trained moderator from CBS. The results of this process from the different CMDFs are shown in Figure 2 Blue Sky Vision example Miro Boards.

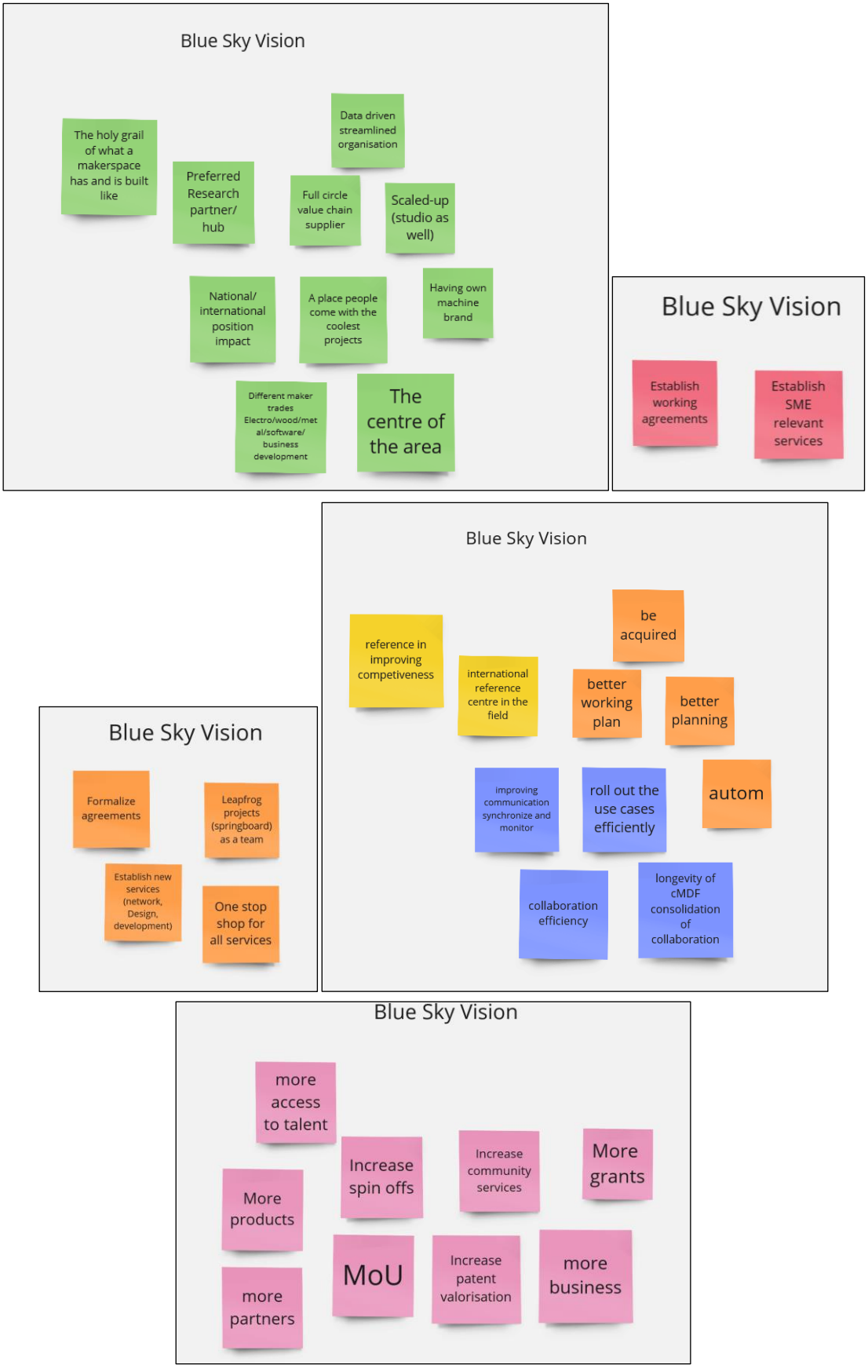

Figure 2. Blue Sky Vision example Miro Boards

3.3. Using Miro to Reverse Perspectives

The reverse perspective is an exercise to reframe how companies or organizations describe themselves. Instead of asking them what they are, as this is a common and expected question, asking them what they are not, helps them rethink their service offerings. It enables establishing new boundaries for their services and helps them identify core values and to focus on viable and tangible product and service offerings.

The method has been adapted from (business) coaching and consulting approaches. There the REframing of a perceived negative status is a standard exercise to on one side increase one's capability of reframing the problem itself and within solving it, and on the other side increasing self-awareness.

Figure 3. shows Reverse Perspectives example Miro Boards as they have been created during the iPRODUCE projects.

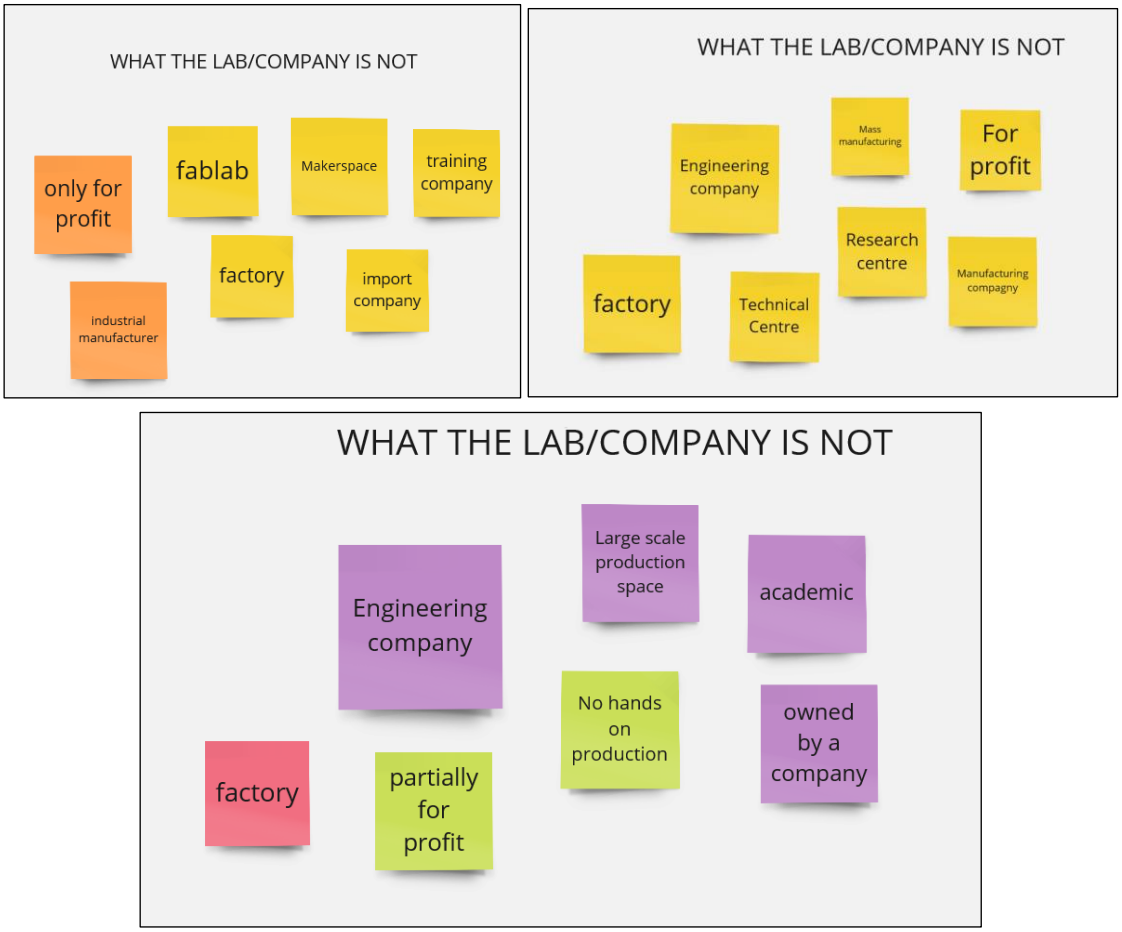

Figure 3. Reverse Perspectives example Miro Boards

The Reverse Perspective Method was used as a part of the Business model workshops held by CBS. The tool was used to spark the session by pushing the partners to look at their companies from a different angle, providing a reflexive response and framing their current competences and services.

3.4. Project Value Canvas

The Project Value Canvas (PVC) is an adaptation from the business model canvas. The PVC is a project tool, used to define the following key aspects of a project:

- mapping personnel, assets, challenges, goals and constraints
- helping make key assessments for the project success and
- framing the action plan that needs to be executed. Furthermore, the PVC assists in
- defining a set of expectations for the process and not only its outcome.

This tool was developed by CBS for the first stakeholder workshop with the Danish CMDF. One of the danish CMDF use cases focuses on providing local manufacturing resources through its mobile unit to schools as a way to facilitate the encounter of students with maker knowledge through planning, designing and experimenting with hands-on local manufacturing. Therefore, for the first workshop with schools in Denmark CBS felt it was relevant to understand the value of such proposition for this set of stakeholders. They adapted the business model canvas to best organise and identify the needs and define a plan that fulfils the schools expectations in regards to participating in such a project.

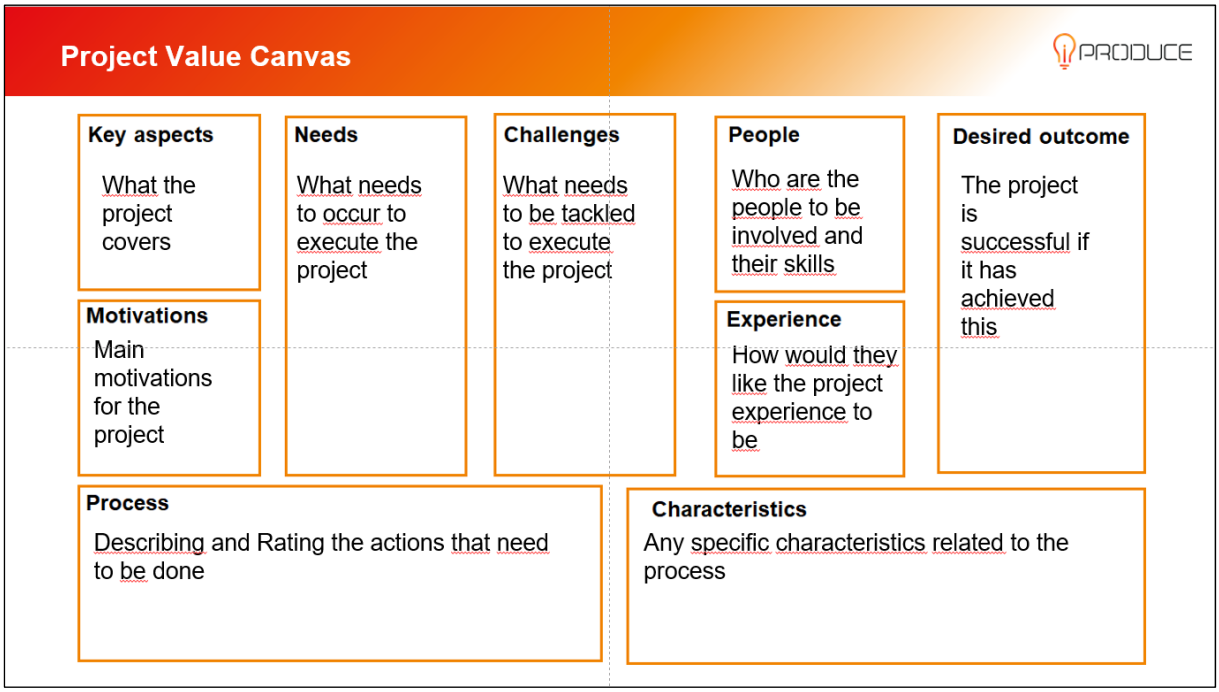

Figure 4. iPRODUCE Project Value Canvas

Figure 4. shows the original iPRODUCE Project Value Canvas. It was introduced to the school stakeholders during the first workshop held to plan and organize the project activities. The PVC structure was the red guiding line through the workshop discussions, and each field was filled after agreeing on a common goal and perspective. The PVC served to map specific needs, challenges and resources required to execute the project plan and for documentation purposes.

3.5. Design Thinking Methods adapted to the virtual setting

The following sections describe warm up methods, most of the time those are short games, frequently used in workshops and Co-Design activities. Warm up methods help team members to feel involved and to get a team together. They create a casual atmosphere by helping to get to know each other, breaking social barriers, facilitating communication and thus, creating a positive spirit. Commonly known warm up exercises have different additional purposes and are most of the time created for Face2Face settings. Most of the exercises selected here were used at different stages of iPRODUCE workshops. They have been adapted and all of those can be used in fully remote settings.

3.5.1. Warm Up Game: Keys

Anybody possesses a key or a bunch of keys. Even if the participants do not have it at hand, they remember it. This object is an excellent “reason to talk”, as it represents a person’s individuality and at the same time, if at hand, is something to adhere to. This usually helps participants relax and start a first conversation. This game aims at getting to know each other.

In order to perform this exercise virtually use a video conferencing software that allows separating in break out rooms. Ask all participants to get out their bunch of keys. Then introduce the method: Pair up in teams of two. One team member starts to explain each key to the other member. The listener can also ask questions. The key presenter and the listener swap roles after 3 minutes. Try to find interesting stories around the keys. If someone does not have a bunch of keys with them, they tell from memory. Once no more questions arise, send participants in teams of two into the breakout rooms. The method was applied during the early stages of Social Manufacturing projects.

3.5.2. Warm Up Game: Low-Tech Social Network

In order to apply this method in a virtual environment, use an online whiteboard. Ask participants to create a short social media profile on a large sticky note or provided template. Figure 5. Low-Tech Social Network Template shows an example template, as used in iPRODUCE project workshops.

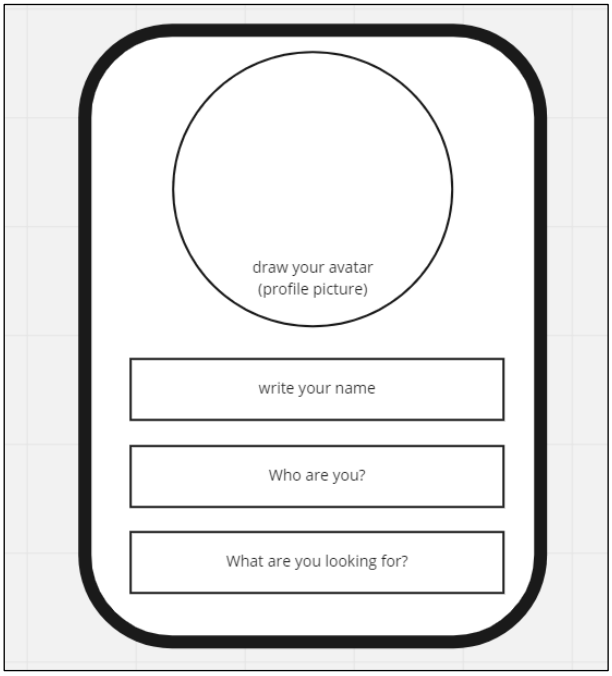

Figure 5. Low-Tech Social Network Template

The profiles include a drawn or improvised profile picture and a name, as well as 2 tags that tell who you are and why you are attending the workshop. These questions can be adapted to the concrete situation and needs. Create the profiles step by step. Once all participants are happy with their result, move the profiles to a dedicated space on the online whiteboard. Then ask participants to draw connecting lines to people thay are already connected. These lines should also be labeled with the type of connection, e.g. "have collaborated in project XY."

This exercise aims at getting to know each other and understanding the type of connections already existing in the group. If the social network remains visible throughout the whole workshop or even during the collaboration process, newly discovered connections can be continuously added and visualized.

1.2.1. Warm Up Game: Squiggle Birds

This exercise has proven to be an excellent ice breaker for activating participants for rapid prototyping activities. We used it during virtual workshops within the German CMDF with group sizes of up to 12 participants. Although the exercise is more effective in a real-world setting, it also proved to help participants in remote workshops to getting started and feel confident in bringing something to paper. It prepares participants for drawing challenges, e.g., paper prototyping and teaches that everyone can draw with simple basic things.

Make sure to use an online whiteboarding software that offers a simple pencil functionality and that participants use larger screen sizes (tablet or PC), in order to allow the “virtual painting” experience to unfold. Each participant draws whorls into a dedicated space. After a few seconds of drawing, participants pass to the next space containing other participants whorls. They shall now transform the whorls into birds. For that, they shall add elements to each whorl: eyes, beaks, feet or tails.

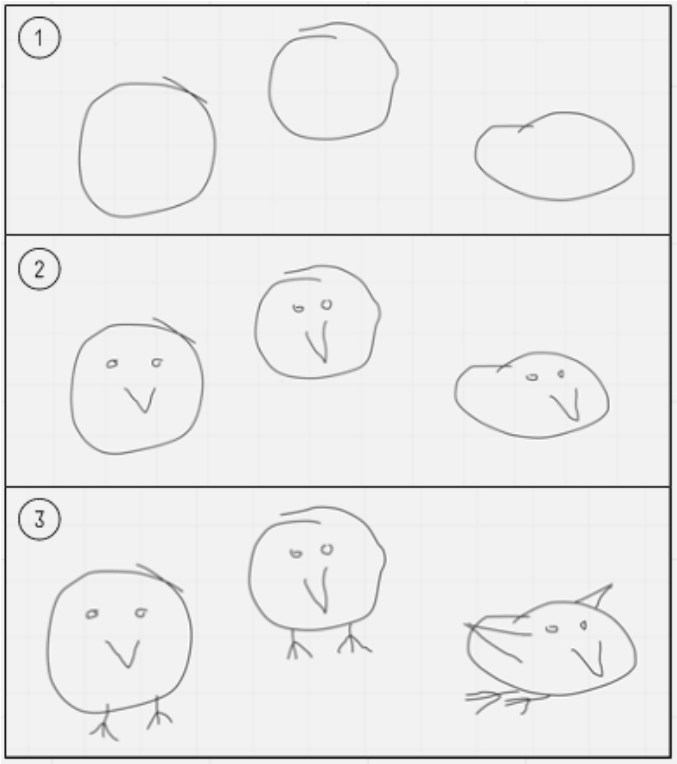

Figure 6. Squiggly Birds example steps

Figure 6. Squiggly Birds example steps shows what this exercise looks like.

3.5.3. Warm Up Game: Draw an Apple

Similar to the previously presented exercise this warm up game builds on painting experiences. In order to perform this method in a virtual setting the use of an online whiteboarding software and a larger screen size are mandatory for all participants.

Participants are asked to draw 20 apples in 5-10 minutes. Every apple must be different and the participants are not allowed to talk. After this exercise, let participants discuss their experiences. This game prepares participants for reaching for quantity and building on top of others' ideas.

The main purpose of this exercise is opening the participants' mindset for collaborative work and wild ideas. Nevertheless for the virtual setting, we recommend this method for groups from 3 to 8 people, not more. This method takes round about 15 minutes.

In the initial phase of the design thinking process, we aim to empathize with the people we are designing for. A common goal in social manufacturing projects is to understand the needs of the people while facing the problem to be addressed. One needs to learn about their tasks, tools, expertise, processes and their physical environment and keep records of everything found out. As a result of the empathizing phase, a varied set of information is collected, which then serves as the basic input for the second *Define* phase.

3.5.4. Empathize Exercise: Break Up Letter / Love Letter

This exercise was used to understand what makes certain products or services stand out from the market. It has been used to shape CMDFs business models and product vision. In our virtual setting, we used this tool in an asynchronous mode. First the team members wrote the texts on their own, and then a moderator extracted common “features” from all the inputs. In a virtual meeting with all team members the common facts were shared and discussed.

In order to perform this exercise, tell participants they fell in love with a product or brand and let them write a Love Letter to that product/brand. Of course, you write to your beloved ones **why** you love them so much. In an synchronous setting the moderator reads out all Love Letters to the group and the group collects overlaps.

The exercise requires 3-6 participants and results in a common understanding of the problem to be addressed and possible “desired features”. The team can use this exercise as a starting point to understand who are stakeholders involved in the problem situation and reasons why the problem occurs.

This method also works with Break Up Letters to products/brands, which participants do not like anymore (or hate).

3.5.5. Empathize Exercise: Newspaper Headlines of the Future

The exercise can be used in a virtual setting but needs careful instruction and preparation. Use an Online Whiteboard to apply this team exercise. Limit the team size to 3-5 participants. The exercise usually does not take longer than round about 5 minutes.

Let participants imagine Newspaper Headlines of future articles about the company, product or service they envision. Define the year of the imaginary newspaper. Prepare a newspaper template in the virtual whiteboard with free space for headlines or prepare pictures to paste in for making it more lively.

This exercise helps team members to concisely focus on the main impact they are trying to achieve. It therefore is a fast way to understand the focus of the team and their approach toward the problem under way.

3.5.6. Empathize Exercise: Semi-Structured Interview

Interviewing is one of the key methods in understanding a problem context. Semi-structured interviews are the fastest and most direct way of gathering information on the problem to be tackled. At first the team members need to identify stakeholders, that are willing to share their insights and can contribute to the topic or field of study. Team members then need to create a list of questions that will guide the interviewer through the interview process. Questions should start with easy openers. Make sure to ask open, non-suggestive questions. In general, the conversation should drive the flow, not the questions. The interviewer gets back to the question list when the conversation cools down or to check that all aspects were covered. Mainly the interviewee should speak.

This exercise focusses on the discovery of the overall context of a problem. At least 3-6 interview participants are required and one interview will take 30-90 minutes. Make sure to carefully collect and note down the answers and information provided by interview partners.

Interviews have been most easily be transferred in the virtual setting. We realized that in our iPRODUCE related project contexts, interviewees were much more willing to agree on a remote interview appointment, than to a face2face interview. Nevertheless, we recommend sharing the interviewing tasks with a team members, as to have one person running the conversation, while the second person acts as a note taker and reminder, in case key topics are missed.

3.5.7. Empathize Exercise: Diary Study

Diary Studies are useful if team members are unable to participate and observe actively in activities related to a problem. Sometimes problems occur regularly, but hard to be observed, sometimes team members themselves underly time restrictions or their presence would bias the people's behavior.

To overcome this, ask participants to take notes about a certain aspect in their daily routines for a defined time period. These routines should be related to the situation when, the team members expect a problem to occur. Prepare a form to make reporting easy and clear for the participants. Consider using forms to be filled from smartphones. This also allows participants to augment their log entries with audio or video material.

This method can also be used to evaluate a prototype and collect user feedback as part of the *Evaluate* phase. It requires 5-10 participants, that are willing to contribute for a certain period of time, as it can take days to months. The duration of data collection should be chosen carefully, considering the frequency of the problem occurrence and the willingness and availability of participants to contribute.

The information gathered during the *Empathize* phase of social manufacturing projects needs to be structured and analyzed. This aims to *Define* the core problem(s) documented in the observational records. D2.4 report lists numerous methods related to the define phase, like Persona, Storyboard, Customer Journey or Affinity Mapping. The exercises presented next, therefore focus on phase three of the design thinking process: *Ideation*.

Based on previously identified problems, team members tackling social manufacturing challenges need to start generating ideas for potential solutions at a certain point. Thinking out-of-the-box helps them to create innovative, enjoyable, inspiring, fitting and relevant answers and solutions.

3.5.8. Ideate Exercise: Group Passing

To understand the basic idea of this method, we will present the instructions provided for a Face2Face setting first, and then explain the adapted version for an online setting.

In a Face2Face setting the method requires at least 5 participants and takes round about 20 minutes. The exercise starts with all participants seated around a table. They are equipped with an empty sheet of lined paper and a pencil. The moderator presents the problem statement and focuses on finding different solutions collaboratively. Each participant writes down one short idea to solve the given problem on the sheet of paper. Once written, the sheet of paper is passed on to the participant right next on the table. He/She builds on top of this first idea and adds another sentence explaining the improved idea. When done, the paper is passed on to the neighbor again, and so on. The process continues until everyone gets their original idea back. Then all participants skim through their elaborated idea individually and finally present a summary of their solution to the group.

To use this method in a virtual setting we went through two iterations. For the first iteration, we started by literally transferring the table to the virtual whiteboard. Figure 7. Group Passing Template - first iteration shows the result.

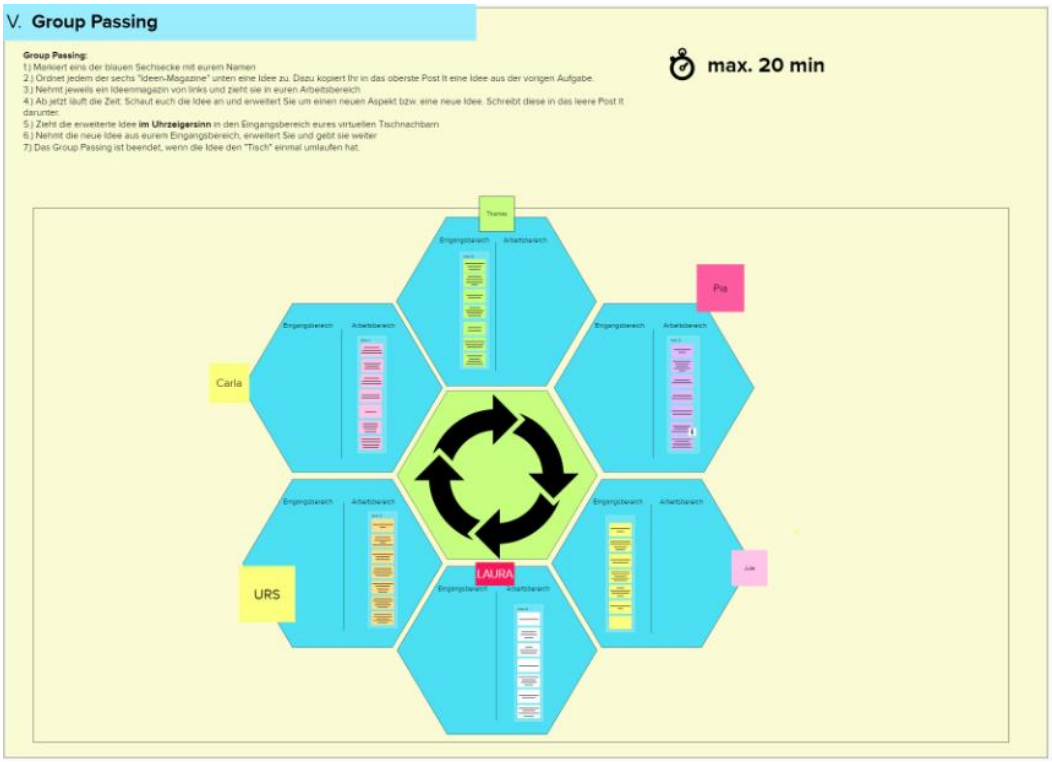

Figure 7. Group Passing Template – first iteration

Participants had difficulties to move the “set of virtual Post-its”. They moved single Post-Its instead and were struggling to understand where to start working.

Though we iterated on the template and changed to a color sorted staircase arrangement. The final template is shown in Figure 8. Group Passing Template – second iteration. We used the colors for guiding participants through their steps for improving their “virtual neighbors idea”. Participants were instructed to note down their idea in the first line. We set the timer for each round, increasing the time allowed, as participants needed more time to read and understand the initial idea and their collaborators improving comments and added ideas. In order to gain rich insight we understood the importance, to make clear that participants shall individually react on the presented idea instead of putting their same thoughts to every column.

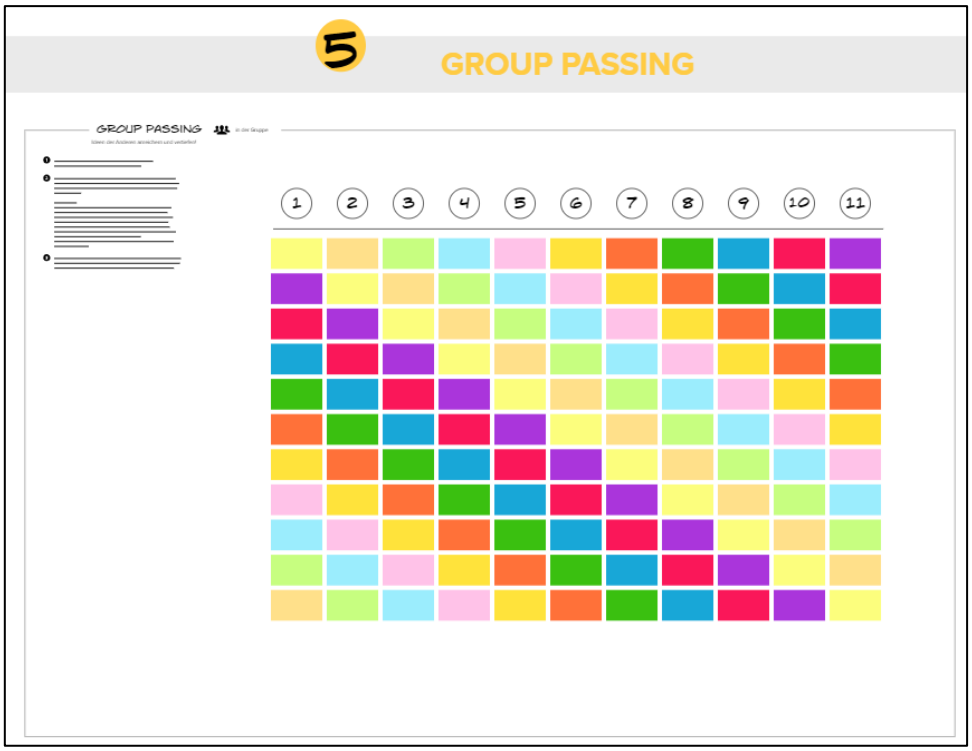

Figure 8. Group Passing Template – second iteration

The second iteration template proved to be more useful and was easily understood by team members and project partners involved in iPRODUCE. Colour coding helped participants to understand where they are expected to write down their input next. Avoiding that participants have to move the virtual sticky notes reduced the mental load immediately and though enabled participants to concentrate on reading and writing down their inputs.

3.5.9. Ideate Exercise: Round Robin

This is a variation of the previously presented Group Passing Exercise. It works best in small teams of three and focuses on finding and elaborating different solutions collaboratively.

As a starting point the moderator presents a “How might we” statement as initial challenge. The all participants write down an **unconventional solution idea** to the presented challenge on a sticky-note in line 1 of the staircase arranged sticky-notes. Then, participants move on to the next column on their right, read the solution idea, written by their “virtual neighbor” in line 1 and then add **why they believe this solution will fail** to the sticky note below in line 2. Finally a third turn is introduced. All participants move on to the next column and add on the sticky in line 3, **how one could to overcome the previous critique**.

This method is a great tool to elaborate on ideas, check their feasibility and reflect on possible objections.

3.5.10. Ideate Exercise: Collage

This exercise can also be used as part of the *Empathize* phase to learn something about the peoples’ or users' perspective on a topic or problem. The central idea is to get inspired by a collection of pictures.

In order to provoke creative problem solving a collection of pictures as diverse as possible is provided to the participants. While in a Face2Face setting this exercise requires a large collection of material, e.g. from magazines, usually provided by a moderator, online whiteboarding tools like Miro and Mural offer an integrated image search functionality. In order to perform the exercise in a virtual setting, given the use of a respective online whiteboarding tool, simply ask participants to answer a given "How might we..." question by selecting images and in a second step letting them elaborate verbally how to relate these images to the question and their solution idea.

This method requires at least 1 participant and takes at least 10 minutes. The method is even more easy to be done in the virtual setting. Collages help to initiate discussions and collaborative inspiration, as different team members may interpret image content in various ways and therefore enrich each others' ideas.

3.5.11. Ideate Exercise: Questorming

Questorming is an exercise that builds on the standard brainstorming technique. The only difference ist that participants are asked to find questions instead of answers. Use Questorming to get a group of at least 3 participants to come up with questions about a predefined problem statement. Every participant generates as many questions as possible in a brainwriting session. Each question is noted down on a separate virtual sticky note. Time boxing is highly recommended for this exercise and a maximum of 5 minutes for writing down the questions is our recommendation. Afterwards, the questions should be sorted and grouped based on their content. This can happen during a group discussion or by a moderator. Those question clusters then define various angles to target the problem.

This exercise produces a lot of output that usually needs to be properly distilled, and therefore is one of the more time-consuming exercises. But the perspectives identified often provided helpful steps towards identifying priorities and select ideas to be later on transferred into tangible prototypes.

3.5.12. Ideate Exercise: Pessimist vs. Optimist

Use this method to promote analyzing ideas from two perspectives: pessimistic and optimistic. Divide the participants into two groups. One is responsible for presenting a positive and the other for a critical point of view of the solution proposed. Expressing critiques impersonally and constructively lets ideas evolve.

Figure 9. shows an example of how we used the Pessimist vs. Optimist exercise during workshops with the iPRODUCE CMDF members.

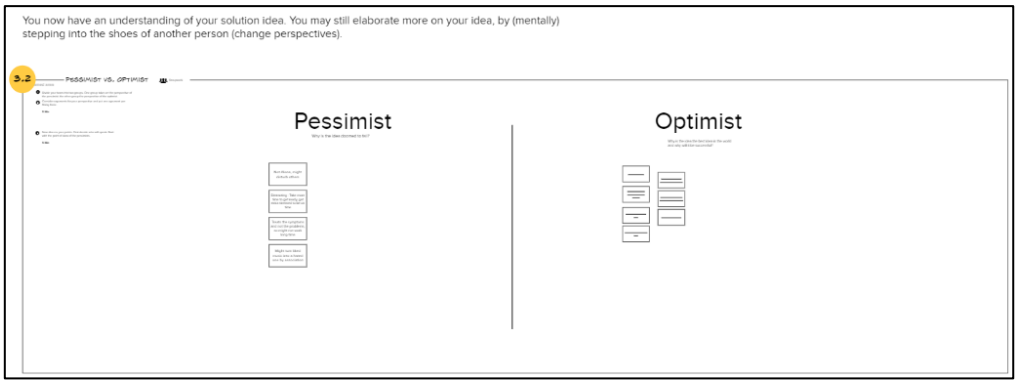

Figure 9. Pessimist vs. Optimist Mural example

Performing the exercise in a virtual setting requires the ability to split the group in two and send both groups to separate break out rooms. It requires at least 6 participants, to have 3 per group. It takes round about 10 minutes for the two groups to collect arguments. The moderator should make sure to have each group agree on who will be the speaker during the discussion session. Then all participants get together, and the two defined speakers have a discussion exchanging their arguments.

Depending on the group, a moderator is needed to make sure that critique stays constructive. It is helpful, if during the discussion all pro and con arguments are noted down on dedicated sticky notes, as they may later on be consulted for reference.

3.5.13. Ideate Exercise: Innovation Portfolio

We used the Innovation Portfolio Exercise as distillation method to prioritize and select ideas out of a set of generated proposals. Each idea is written on a separate sticky note. The group discusses where to put each idea, based on a mix of quantified numbers, analyses and gut feeling. Each sticky note is placed on a 2-dimensional diagram. The axes are typically „effort“ and „impact“. Figure 10. Innovation Portfolio - example 1 shows the basic layout. By tagging the possible options with emblematic words like “Big Bets”, moderators can help participants to get an idea quickly of how to sort the collected ideas and at the same time rank and discuss their opinion on expected effort and impact by each team member.

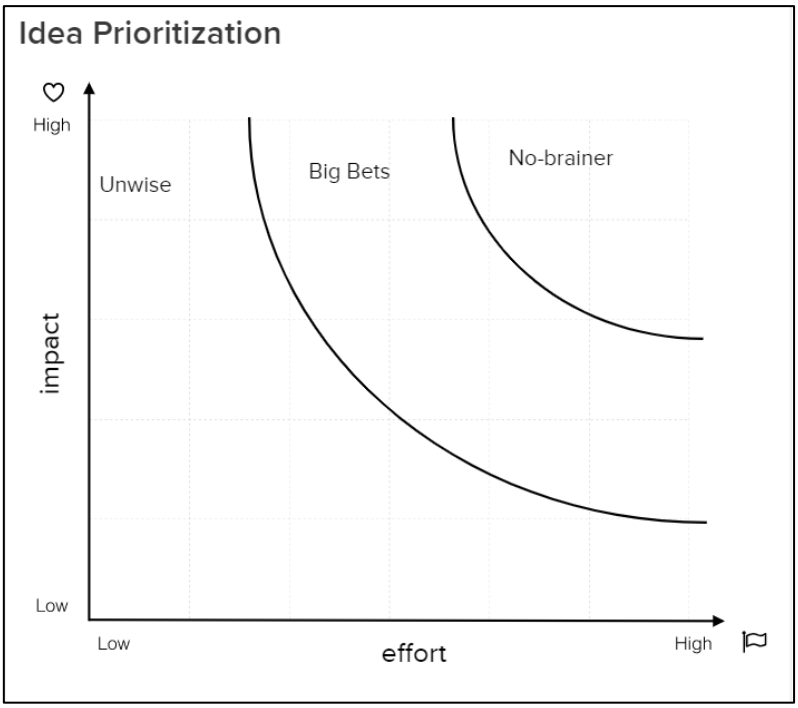

Figure 10. Innovation Portfolio - example 1

The Innovation Portfolio is a very flexible method. It can be adapted easily. To use this method at least 3 participants are required. It can easily be used in a virtual setting using basic whiteboarding software.

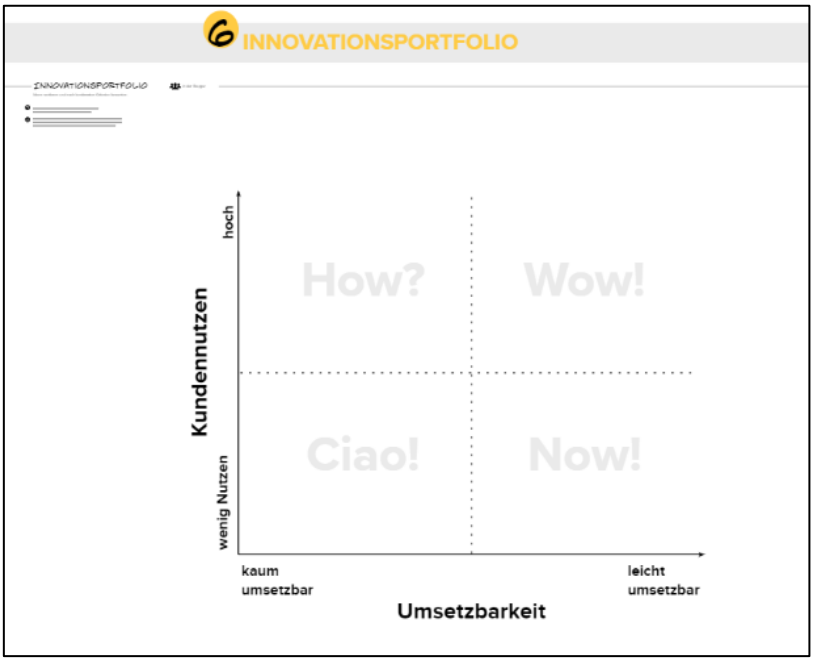

Figure 11. Innovation Portfolio - example 2 german

Figure 11. Innovation Portfolio - example 2 shows a modified version of the Exercise, that we used during workshops within the German CMDF.

In the next phase *Prototype*, the most promising ideas generated in the *Ideate* phase are transformed into tangible prototypes. The general recommendation is to start with cheap, easy and fast tools, such as paper prototyping, to not lose time. Those early prototypes are of low fidelity, or low-fi prototypes. The major goal is having a testable artefact that serves to demonstrate the idea/concept. It will be improved and be subject to further iterations until the concept is worth being put to a higher fidelity level. Thus more extensively developed prototypes of each fidelity can be shared and tested. Prototyping methods presented here focus on the early stage prototyping.

3.5.14. Prototyping Exercise: 2 Minutes Madness

The 2 Minutes Madness exercise is best used for 2D screen design prototypes. While the exercises' principal idea to use pen and paper and draw a simple draft within the 2 minutes timeframe is very easy to use in a Face2Face setting, we had several trials on how to transfer this method to a virtual setting.

Instructions for the Face2Face setting are as follows: Iteratively build a cheap and easy-to-throw-away paper version of the system or interface you want to develop. Use a thin and a thick black pen plus a highlighting colour. Do not erase lines, do not correct mistakes, just throw the whole paper away. Scribble your interface or system as simple as possible but as detailed as necessary to convey your idea. Use as many iterations as you need and spend max. 2 minutes per iteration. More is better! Start from basic ideas and become more detailed with each iteration.

To transfer this method to a virtual setting, we realized that the diverse teams using this method on a virtual whiteboard were facing various difficulties. Participants had very diverse technical equipment and based on their affinity to design and painting delivered very different results, which to some extent resulted in an inhibiting effect of other team members. We have come over to introduce the exercise in a virtual setting to be done in two ways:

1. Either alone on each individuals' desk using pen and paper at hand. And then shared with teammates using the video conferencing camera, or by scanning it or taking a smartphone picture and uploading it, to share and discuss the result with the group.
2. Using Miro Online Whiteboarding software, that contains a set of wireframing templates. Participants would be introduced to the available templates and should try to puzzle their ideas quickly and improving them by each round.

We understood from the team members that participated in our workshops, that using the pen and paper version feels much more natural and easy to do.

3.5.15. Prototyping Exercise: Wireframes

As described previously Miro Online Whiteboarding Software contains a set of wireframing templates. Depending on the scope and maturity of the prototype, those first drafts can be a starting point for more elaborated Wireframes.

A Wireframe is a non-interactive prototype and thus a common tool at the beginning of the *Prototype* phase. With its help, the structure and spacing of the view (e.g., web page, application) is visualized without graphic design, e.g. colors. The advantage is that it is easy and cheap to adjust the idea based on stakeholders' feedback. Furthermore, the feedback is more focused on the structure and general

idea and less in content and details. The time spent to create a wireframe can take from 10 minutes to hours. This method requires at least 1 participant.

It is important to mention that dedicated wireframing Tools like Figma, Sketch or Adobe XD and many others are available and offer collaborative services and features. Nevertheless, reflecting those would by far exceed the scope of this method collection, and therefore is not carried out further.

3.5.16. Prototyping Exercise: 3D-Prop

Building a 3D model of the envisioned product is a logic next step towards bringing social manufacturing project ideas to life. In order to understand and test haptics and form tangible, other tools are necessary than for a digital product. The 3D-prototype can be made of paper, building blocks, dough, wood or whatever is at disposal. It can also be a 3D print. Suitable materials should be used depending on the type of prototype and area of application addressed. As with all prototypes, the major aim is to fail early and cheap and iterate a lot. Duration depends on the scope and maturity of the prototype.

Transferring the production of creating 3D-Props to a virtual setting proved to be a severe challenge during the CMDF workshops. In key, the setup was organized to meet the pandemic restrictions. Therefore, a setup was chosen, to primarily share tasks within team members to build more prototypes. Though one could be present in the Makerspace, where 3D-printers and all material and tooling is available, while other team members were connected virtually via Video Conferencing. While one could prepare 3D-files to be printed, the other one launched the machine and prepared other material. Final 3D-Props were then tested, by sending them to stakeholders and virtually moderating a user test.

Figure 12. 3D-Prop example

To illustrate what this could look like, Figure 12 shows examples of 3D-prop-prtotypes that were produced during Face2Face-Design Thinking workshops within FIT.

In the *Evaluate* phase, previously built prototypes are being tested. There is a broad variety of testing methods which involve end-users, design experts, stakeholders, or other people. However, the target is to find out if the previous work - starting with empathizing - was correct and complete or if important aspects were missed.

3.5.17. Evaluation Method: Think-Aloud Test[5]

Conducting a user test using the Think-Aloud Method to gain insights on what prospective users intend and expect, is a broadly known method within the software development communities. For individuals feeling related to the maker and/or entrepreneur community this is not necessarily true.

To perform a Think-Aloud Test prospective users are asked to verbalize everything they see, think, expect and experience while using the prototype. In the meantime, the test moderator notes down what users like or dislike, what confuses them and what works well. Some users require being reminded of expressing their thoughts verbally from time to time. Usually test participants will not express the root causes of issues in the first place, so the test moderator may try to ask why the participant shows a certain behaviour.

Think Aloud test can be done remotely by using shared screen functionalities of video conferencing tools, if the prototype is suitable for the remote setting. Any testing of 3D-prototpes or Wizard-of-Oz-prototypes is required to be done in Face2Face settings.

3.5.18. Evaluation Method: Heuristic Evaluation

A Heuristic Evaluation is usually conducted by experts of the domain of usability, UX, etc. Heuristics are a list of rules one evaluates an interface against while performing tasks. If the interface violates one or multiple of the heuristics and the task completion is negatively affected, the expert notes that down as a critical incident or violation. Heuristics can be various, some of the most know are Nielsen ‘s 10 golden rules[6] or the 7 dialogue principles documented in ISO 9241:210[7].

While usability engineers are educated and trained to perform this kind of analysis, we learned during iPRODUCE Workshops that also Non-Experts do gain valuable insights when confronted with Heuristics approaches and best practice examples. Melting down the Heuristic Evaluation method to a “review-exercise” helped to shape products that follow basic usability rules and thus increased the chance for social manufacturing projects to succeed.

[5] Charters, Elizabeth. "The use of think-aloud methods in qualitative research an introduction to think-aloud methods." Brock Education: A Journal of Educational Research and Practice 12.2 (2003).
[6] Jakob Nielsen. 1992. Finding usability problems through heuristic evaluation. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '92). Association for Computing Machinery, New York, NY, USA, 373–380. DOI: https://doi.org/10.1145/142750.142834
[7] Bevan, Nigel, James Carter, and Susan Harker. "ISO 9241-11 revised: What have we learnt about usability since 1998?." International Conference on Human-Computer Interaction. Springer, Cham, 2015.

1.2.2. Evaluation Method: I like, I wish, What if

The “I like, I wish, What if”-Method is a tool that easy to use in a virtual setting and has been applied in various variants during iPRODUCE workshops.

The method is based on trigger questions, used for collecting qualitative feedback. The questions placed to dedicated frames on the virtual whiteboard, and participants or users note down their answers on separate sticky notes. We use the method as part of other methods to ask for open feedback, e.g., from users who tested a prototype:

- I like… (asking for aspects users liked about the prototype)
- I wish… (prompting users to share subjective improvements or changes of the prototype)
- What if… (addressing new suggestions about not yet existing functions from users)

This method requires a group of 3-7 participants and in a virtual setting takes not more than 10 minutes. Not all three questions must be used each time.

Figure 13 shows an example of the method applied to collect feedback on a collaborative team process itself. The question “I wish...” in this context prompts critique and negative feedback, but at the same time requires the author to focus of what should be improved and providing actionable feedback.

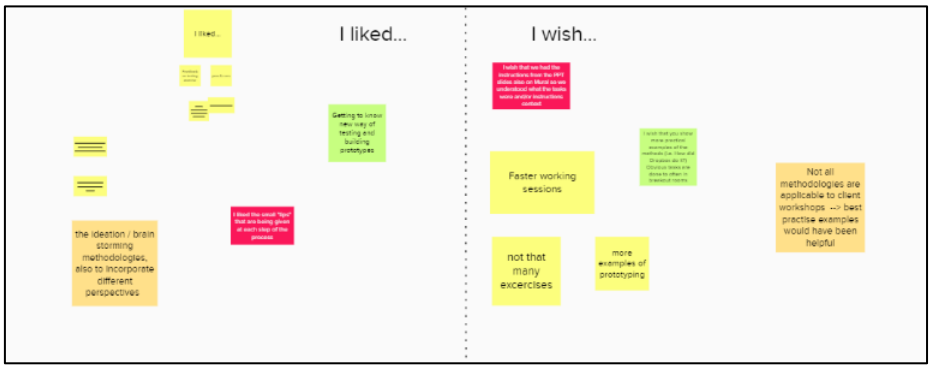

Figure 13. I like..., I wish ... Mural example

1.2.3. Evaluation Method: Focus Group

As social manufacturing projects are team exercises, a method to test and collect feedback in groups is of big help. The Focus Group concept is widely known in social sciences and is applied in various group settings to collect insights and opinions about artefacts and products.[8]

The simple principle is: to bring together a group of participants whom the team members expect to bring valuable inputs about the prototype. Every participant tests the prototype and then participants are asked to discuss their experience. It can be helpful to guide the discussion by open questions and moderate the process actively.

This method can also be used to examine the current situation as part of the *Empathize* phase early in the discovery of the problem itself.

[8] Carey, Martha Ann, and Jo-Ellen Asbury. Focus group research. Vol. 9. Routledge, 2016.

We recommend organizing Focus Groups with 5-10 participants and scheduling 60-90 minutes for the discussion. Additional time for testing the prototype should be scheduled.

In a virtual setting smaller focus groups seem to work better. From an organizational point of view the testing of the prototype should be scheduled separately, but maximum one week in advance to the focus group session. In a virtual setting, two moderators are recommended, as to have one moderator leading the discussion and the second moderator taking notes and documenting the feedback collected.

The next chapter presents the results of a workshop done by iPRODUCE partner Siemens (SAG). The workshop explored dedicated evaluation methods that are usable in a generative design context.

4. Selected Methods 3 – Usability Assessment for Some Co-Design and Prototyping Methods

Siemens (SAG) works closely with many universities and research institutions around the world. Technical University of Munich (TUM)[9], Germany, is one of the partners for scientific collaboration at Siemens. In September 2020, SAG launched a one-week Summer School for TUM students with different topics around digital twins. One challenge within this school was dedicated to a collaborative creation of a digital 3D representation of one iPRODUCE use case and its connection to an electronic prototype. Our aim was to evaluate the learning curve for methods and tools that can be used in the context of Generative Design Platform developed during iPRODUCE.

The current two-semester Siemens master class 2020-2021 allows a team of five students from the Strascheg Center for Entrepreneurship at Munich University of Applied Sciences (SCE)[10] to study social manufacturing concepts from iPRODUCE. The team task focuses on the prototyping of a gamification concept, proposed by SAG colleagues. The students shall also investigate the business potential and learning potential of online gamified training before and during the development of a prototype.

Section 4.1 explains the criteria for the evaluation of methods and tools performed during the two cooperations. Section 4.2 discusses the general approach to the evaluation and shows the results of the cooperations.

4.1. Purpose of the Assessment (Evaluation Criteria)

During the collaboration with students from German universities, we evaluated tools, to be used in iPRODUCE social manufacturing projects for collaborative design activities. For the tools and methods to be optimal for the usage within our Generative Design Platform - developed aligned with iPRODUCE objectives - they shall address or be suitable for the following modern paradigms:

- Visual Scripting
- Parametric modelling
- 3D model visualization
- Cloud applications
- Gamification
- Easy Accessibility
- Rapid prototyping
- User Experience (UX), different aspects

We decided on these needs in a brainstorming session with Siemens domain experts. The paradigms listed above are considered important for collaborative design processes, because they aim to ease mutual understanding at different steps of co-design, and exchange of the knowledge and design results. The agreement to develop the generative design platform, with having those premises to follow,

[9] https://www.tum.de/
[10] https://www.sce.de/

was an initial step for our development process. The paradigms are used as a basis for evaluation at any time during the iterative product development cycle.

For a more detailed presentation of technologies underlying the generative design platform and the related collaborative design process refer to section 2.1 of the iPRODUCE Deliverable 5.3 – Generative Design Platform as Social Community.

4.2. Approach to the evaluation

We have evaluated tools and methods supporting the paradigms mentioned above within the following two cooperation with upper-graduate students in Germany:

4.2.1. Summer school challenge “Digital Twin meets UX”

In September 2020 Siemens organized a Summer school “Digital Twins" at Siemens in Munich. We set a challenge called “Digital Twin meets UX”, that was dedicated to the experiments with the iPRODUCE use case from Spanish CMDF “Smart Gaming Chair”. Figure 14. shows the initial settings discussed at the beginning of the challenge and used for parameterization with visual scripting. The main objective of the challenge was smart product development with parametric design for optimal user experience. The students were all new to parametric design and visual scripting. To learn this, they considered Grasshopper[11] plugin of Rhino 7[12], 3D modeling tool. They were introduced to Grasshopper within one afternoon session. After that the students proceeded with learning by doing while they created a parametric model for a smart chair.

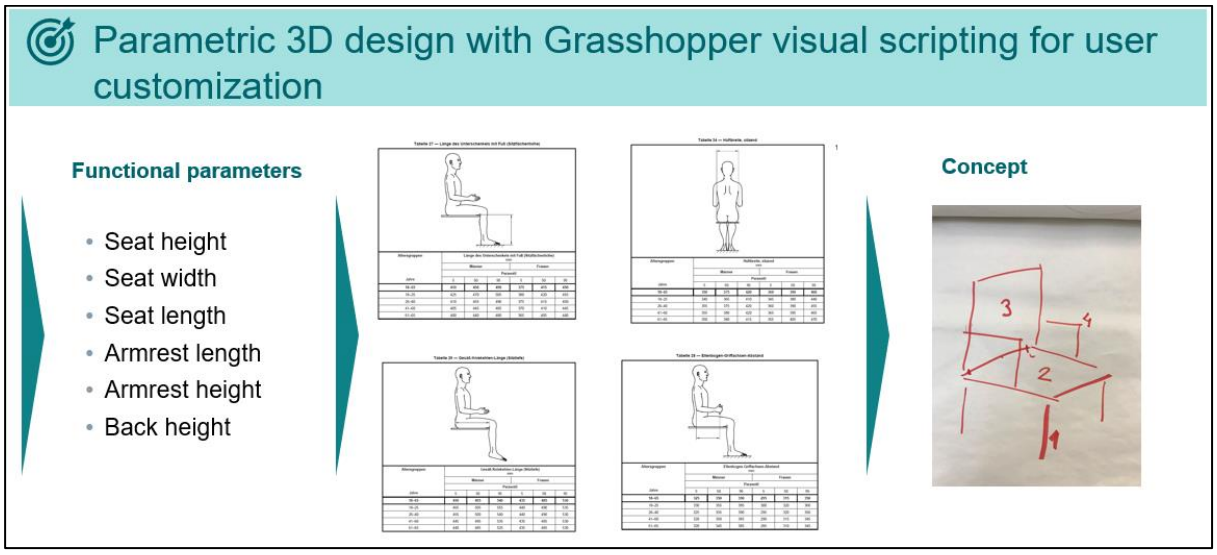

Figure 14. Initial settings for the challenge

The students' training was done in three steps. They first needed to distribute design tasks among 4 participants. In order to do this the Chair Concept was split into 4 areas, legs, seat, back and arm rests.

The following two figures illustrate two examples of how the partial digital prototypes (separated parametric models) can be customized with end user wishes.

[11] https://www.grasshopper3d.com/
[12] https://www.rhino3d.com/

The first one, in Figure 15. shows an example of possible parametrization for legs and armrests.

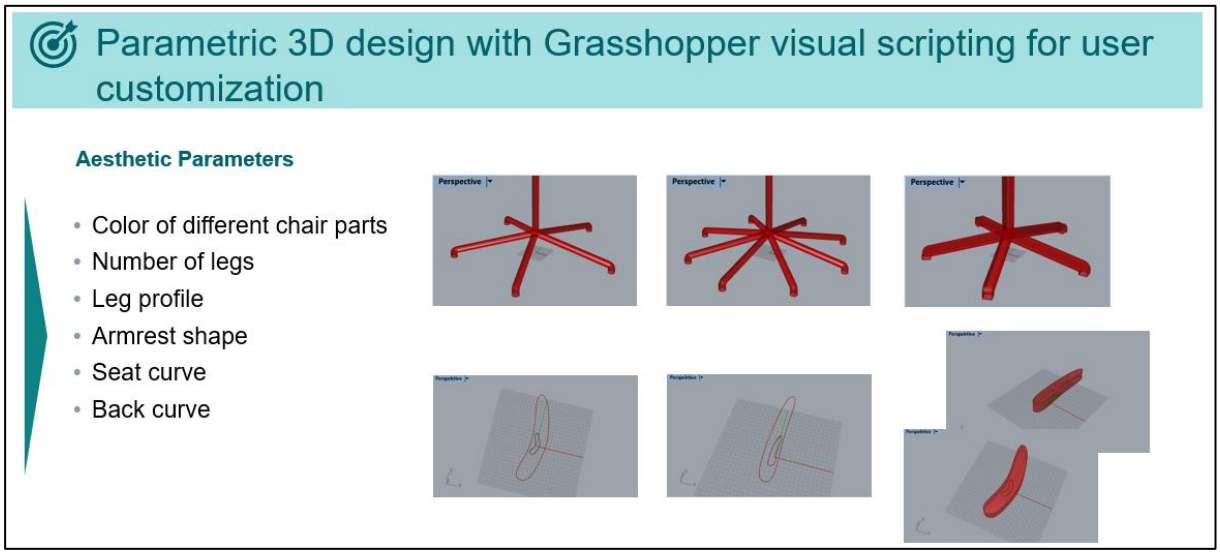

Figure 15. Example of possible parametrization (for legs and armrests)

The second example in Figure 16. illustrates the possible weight optimization with an evolutionary solver Galapagos13, an optimization plugin for Grasshopper.

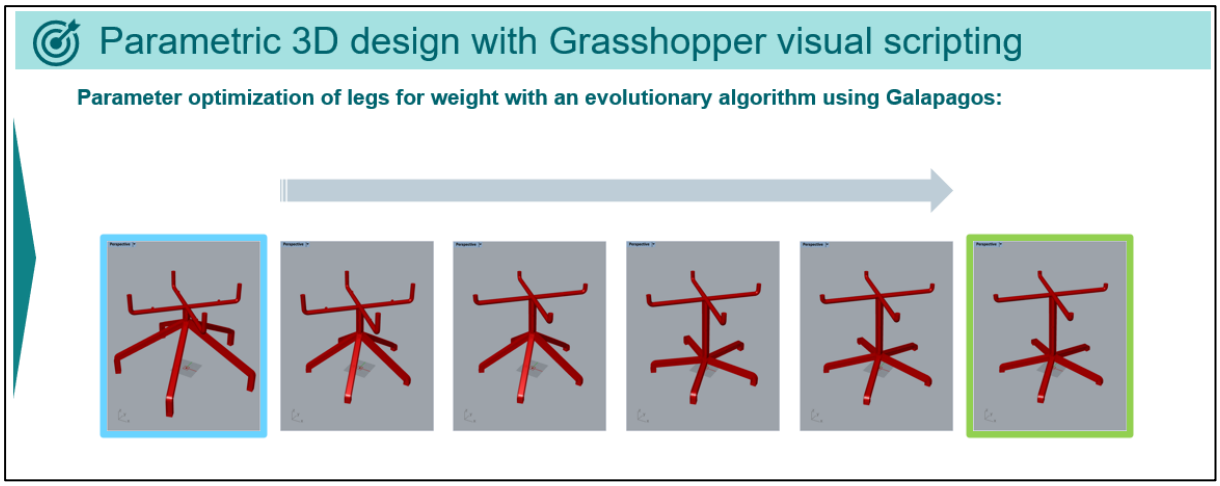

Figure 16. Example of possible weight optimization with an evolutionary algorithm

As the second step of the students' training, the selected design files needed to be combined into one entire design and finally the physical prototype was created. This was done in two steps. First, one model, selected out of many possibilities of parameter settings, was created with 2 different technologies for 3D printing– FDM and SLA, as shown in Figure 17.

[13] https://www.grasshopper3d.com/group/galapagos

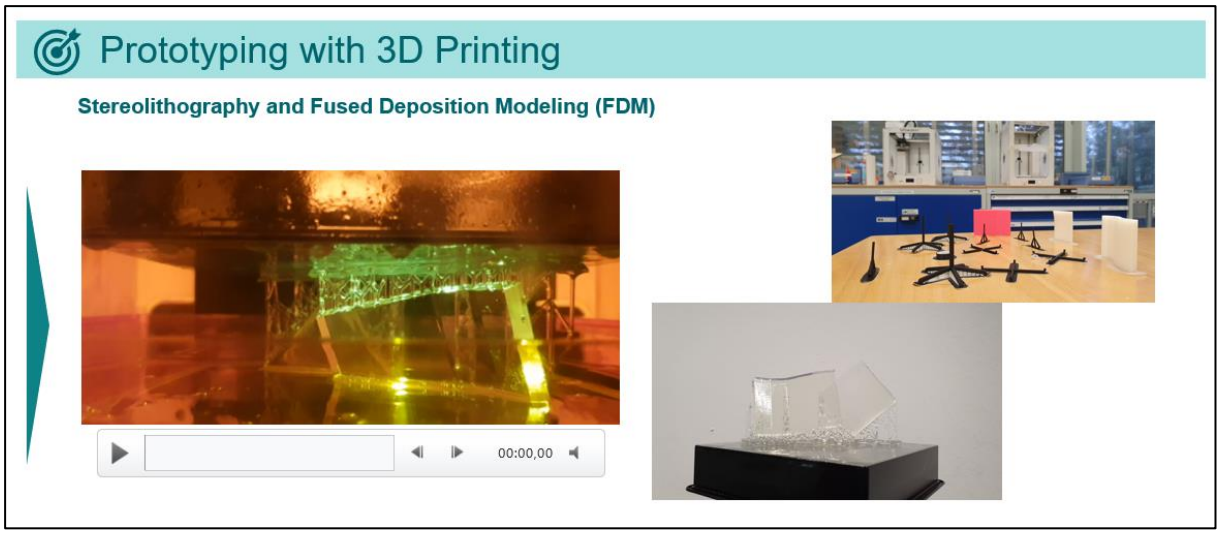

Figure 17. Prototyping with 3D printing

Next, the tangible prototype was connected to a basic electronics interface to show interconnection between digital representation and the physical world. This was realized using Arduino[14], as illustrated in Figure 18. The reaction on the sensor values, obtained from Arduino, and control of actuators, connected to the Arduino board, were defined in the Grasshopper visual script, which also controls the parametric 3D design of the chair. So, the behaviour of the electronic prototype was synchronized with its 3D digital twin in Rhino. This provides the opportunity to calibrate the parametric model with reasonable parameter constraints or to check, which 3D model better corresponds to the physical world.

The final prototyping result was presented during a project pitch session within Siemens' iPRODUCE partners at the end of the summer school week.

The parametric model created by the students during this challenge is now used within T5.2 "Generative Design Platform".

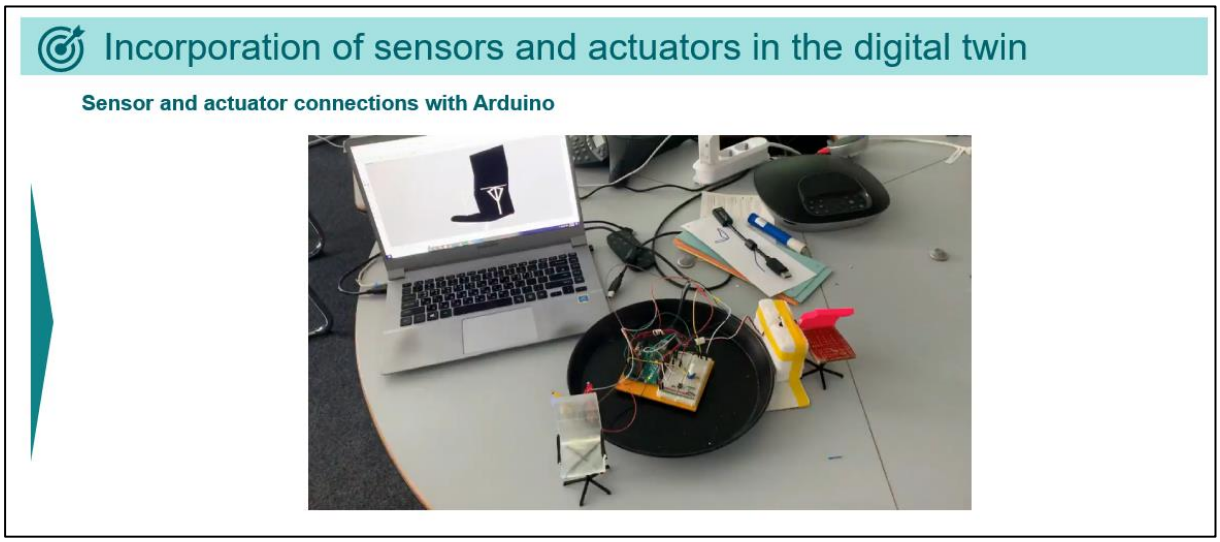

Figure 18. Prototyping with Arduino electronics: connecting physical prototype with digital design

[14] https://www.arduino.cc/

Overall, the following tasks were performed by the students during the 5 days challenge:

- Parametric 3D design with Grasshopper visual scripting: define as many parameters as possible to cover multiple design options
- Define output values for optimization
- Perform design optimization with an evolutionary solver
- Decide how to model sensors and actuators in the digital representation
- Apply 3D printing prototyping for visualization of a selected design
- Connect to Arduino board to access sensor values and control actuators within the digital design for creating a digital twin

An evaluation survey for user satisfaction with the visual scripting paradigm is available after this collaboration. The critical issues with the tool supporting parametric design and visual scripting will be addressed within our Generative Design Platform. Although Grasshopper was rated rather as a suitable tool for parametric design with a good user interface, there is still a challenge to use it within a group of designers, because it still lacks features supporting multiple collaborators working on one product design.

4.2.2. Master class "Online Escape Room Experience in the Context of Social Manufacturing "

The aim of the SAG second cooperation was to investigate how to increase the effectiveness of online trainings. Individuals new to the maker scene and interested in relevant technologies, like 3D printing, laser Cutting, CNC routing and electronics were in focus. The students should decide how to best develop an online training to ease and speed up their learning.

For this purpose, we decided to apply a gamification paradigm. We expected that effective online training attracts more different people to the maker movement and simultaneously boost its own creative power.

We also assumed that such online training could be used to manage critical skills of employees. Therefore, the students were also asked to create and assess such kind of existing training for professional purposes too. Managing critical skills of employees becomes important, once people need to learn safety critical rules to operate potentially hazardous equipment, like drilling machines, laser cutter, soldering, etc. People operating such equipment shall remember instructions for a longer time and also shall be keen on updating and learning more. That is why we decided to apply gamification to online training for such critical skills.

During the Master Class the following methods were applied:

- Primary and secondary desk research
- Qualitative research with stakeholders interviews
- Quantitative research of the iPRODUCE deliverables
- Prototyping and obtaining early feedback during the development

Figure 19. shows how much of the material obtained by the participants during a training will stay persistent in the long term memory (measured 2 weeks after trainings), depending on the channels

delivering the new information to the students.[15] This study justifies our motivation for active learning as the basis for gamification approach during trainings.

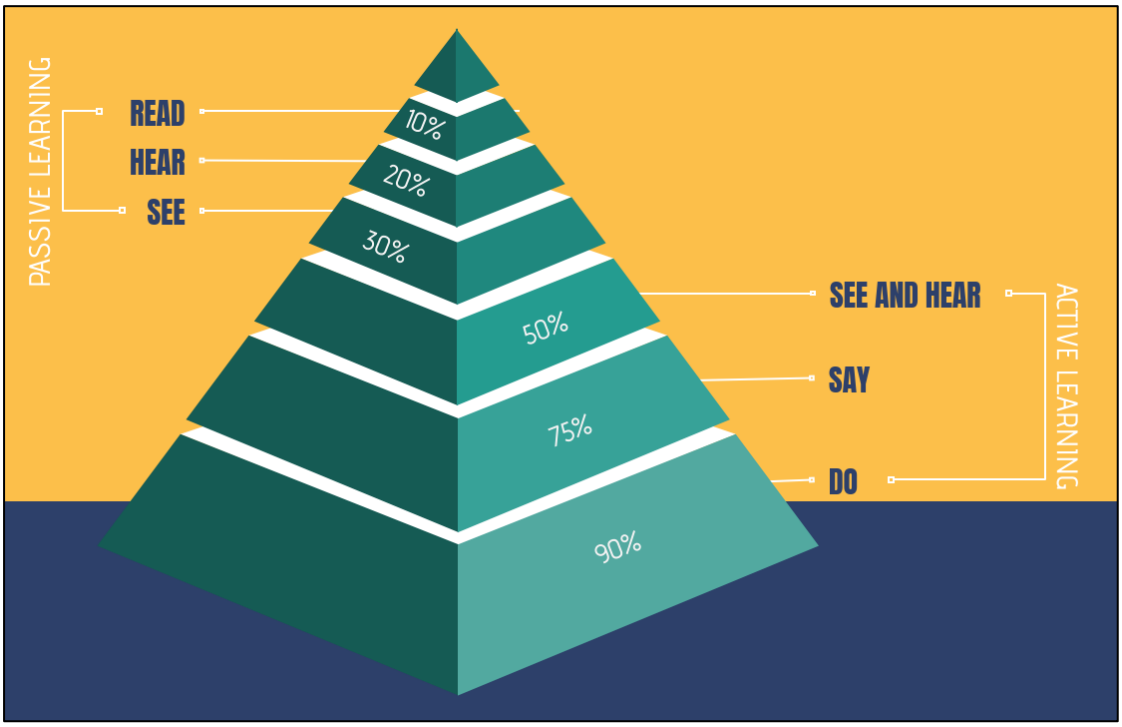

Figure 19. Motivation for active learning as basis for gamification approach during training

During this cooperation, the students performed and analysed 15 interviews in 2020 with Siemens current and former employees about their experience with different types of trainings, focusing on the Siemens internal trainings, both offline and online. Figure 20 shows the findings of this research. About 90% of the interviewees were not satisfied with the current company's internal online trainings and wished for a more collaborative / group based learning experience. The average feeling for memory retention was about 40% self-assessed.

[15] https://elearningindustry.com/cone-of-experience-what-really-is

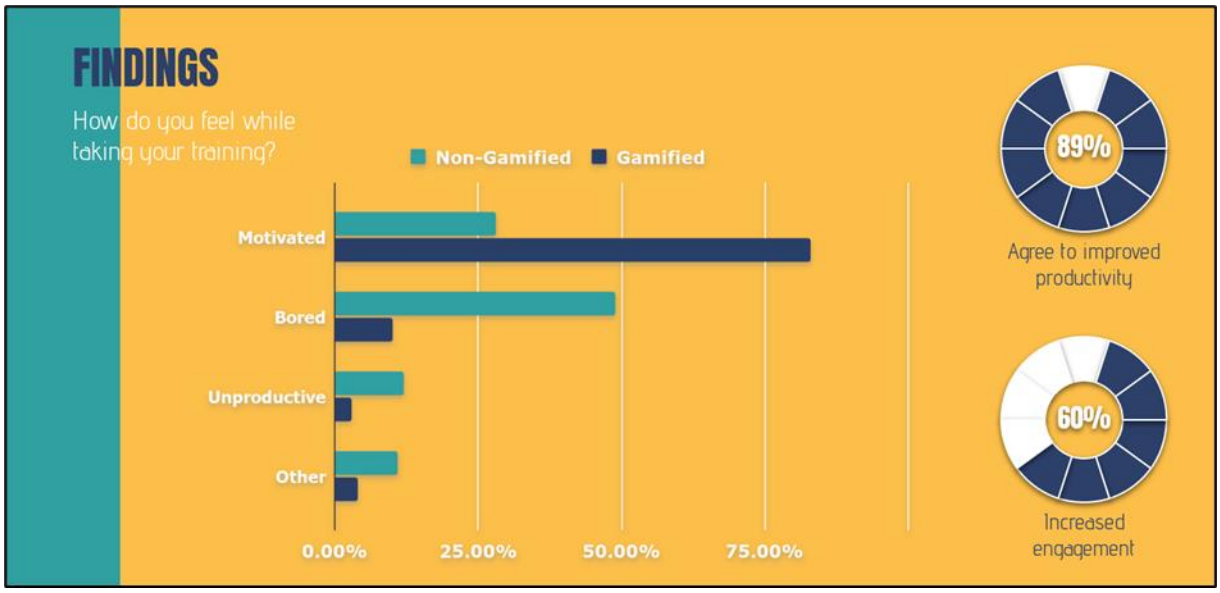

Figure 20. Research Findings

The master class results in an MVP for an online training on 3D printing in the Escape Game style, developed with Unity[16], a game development platform, and will be available online by the end of the second semester of this collaboration. Besides the MVP, the students will deliver business potential investigation, learning potential research, user journey, and other documentation as the result of the collaboration. The main strong points of the proposed concept are identified and shown in Figure 21.

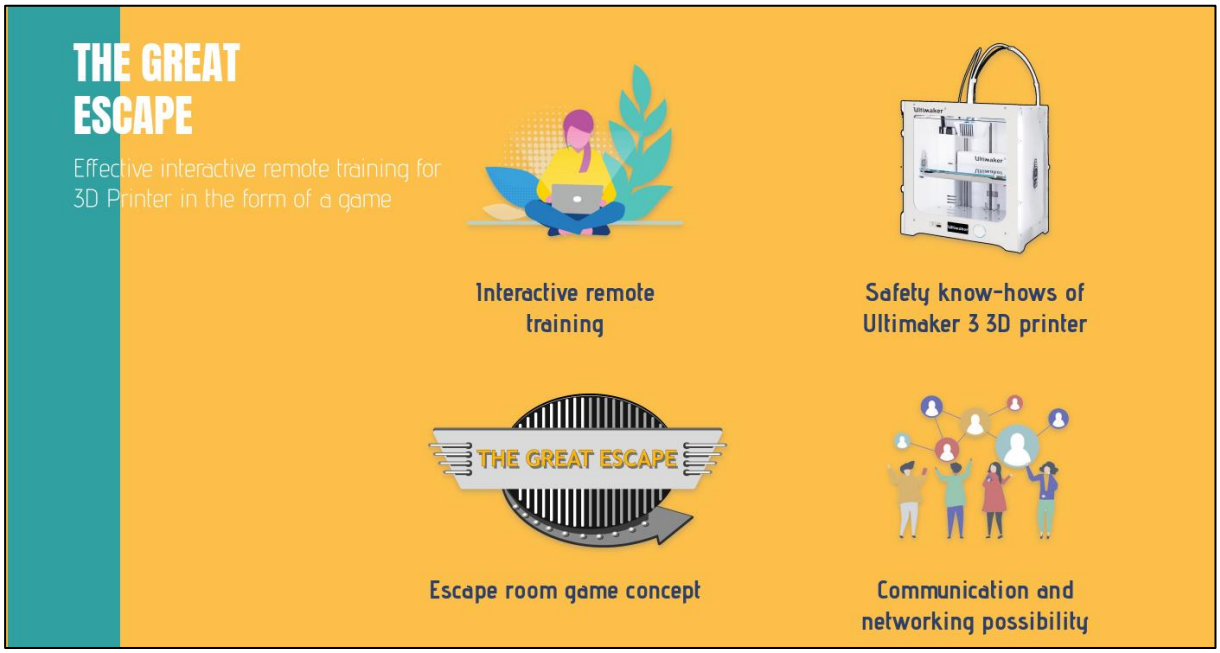

Figure 21. Proposal for effective training with a first pilot for 3D printing

Overall, the following tasks were performed by the students during the master class:

- Siemens employees interviews with analysis, included different types of stakeholders and makers
- Solution proposal, collaborative, emotion based

[16] https://unity.com/

- User journey defined
- A high-fidelity prototype developed with Figma[17] and assessed by potential users
- Initial MVP of the online game implemented, and early feedback acquired
- Business potential identified: initially for Siemens, but can be extended to iPRODUCE partners and other maker communities

Because of the COVID situation, the whole collaboration was arranged purely virtually, from the beginning to the end. Within this master class, the following tools were applied to make this remote collaboration possible and effective:

- Zoom & MS Teams for video conferences, in particular for virtual round tour at Siemens' maker space and safety instructions for its equipment
- Slack for asynchronous communication
- Figma for remote collaborative prototyping
- Mural[18], digital workplace for visual collaboration (online whiteboard)
- Unity for 3D game development
- Simmer[19] for game deployment and early remote evaluation of the current development state

By the end of the collaboration, Siemens plans to present its results to iPRODUCE partners, providing online access to MVP implementation. We can also elaborate on the proposed business model for such type of training to fit iPRODUCE objectives.

[17]https://www.figma.com/
[18] https://www.mural.co/
[19] https://simmer.io/

5. Conclusions

The present report first introduces online collaboration tools, for video conferencing, asynchronous communication, like chat and file sharing, and tools for online whiteboarding. Then the report discusses 24 methods and exercises coming from a design Thinking approach and found useful to facilitate and support collaborative designing and prototyping practices. The last section of the report grants insights to Siemens practical experience when introducing DIY technologies and related collaborative methods to new and inexperienced participants.

While completing this first part of T5.1 during the last 12 months, we successfully built on the knowledge collected in D2.4. We learned that a plenty of methods and tools already exists, and that most are ready to be used for the various types of social manufacturing projects. Much of the existing tools can be seen the fields of education, innovation and collaboration in general.

Due to the pandemic situation the direction of our research shifted towards adopting methods to the virtual setting. We challenged our skillset to create the required virtual setting and integrated tools such as video conferencing and online whiteboards into our workshop activities within a very short time. We found that the existing tools, especially whiteboarding tolls are highly functional and could most often be used even by remote workshop newbies very easily.

We also learned that adapted workshop facilitation methods resulted in excellent results. Adoption most of the time happened through revised timing and written task instructions. The experiences we made during these exceptional circumstances helped us to expand, improve and adapt our toolset incredibly. At the same time getting in touch with industry partners and small SMEs was difficult.

For the remaining 18 months of T5.1 we are looking forward to further elaborate the tools and methods available for social manufacturing together with the other CMDFs. We plan to expand our learnings to the other CMDFs and want to investigate how the tools and methods presented have come to work and have been applied in their context. The respective Deliverable D5.2, due in M36, will add findings from all other CMDFs.

PRODUCE

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