PROTOTYPES, UNCERTAINTY AND POLICYMAKERS' ENGAGEMENT IN DESIGN FOR POLICY

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Abstract

Policymakers demand alternative approaches to anticipate and deal with wicked problems, as well as effective and flexible means to interact with people and stakeholders (Kimbell & Bailey, 2017, p. 216). Design for policy takes novel approaches from the design discipline to enable exploration and co-creation through processes such as prototyping, which role has evolved due to changes of focus and field of action of the design discipline (Buchanan, 2001).

In policymaking, prototyping could allow better engagement of citizens in decision making and help policymakers to test and explore solutions at a smaller scale in real contexts, anticipating possible responses and outcomes. However, there are challenges for prototyping to be embedded in design for policy, such as dealing with uncertainty and fear of failure. Prototyping, as an explorative approach in which solutions remain open and indefinite for a longer period, might introduce a high degree of uncertainty preventing policymakers to apply prototypes as a policy design method.

This thesis explores the interaction of policymakers with the uncertainty of prototyping and its effects on their engagement in co-creation processes. A literature review about prototypes and policy design was carried out, followed by the comparative analysis of ten SISCODE co-creation laboratories in Europe and an in-depth qualitative analysis of three case studies. The results suggest that uncertainty can be a benefit or a threat depending on policymakers' role in the co-creation process and the phase of the policy cycle in which the prototype is developed.

Key words: prototyping, prototypes, design for policy, policy design, policymaking, uncertainty, policymakers, stakeholders, exploration, co-creation, design.

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INTRODUCTION

Changes in the production and economic paradigm have led to changes in organizations across different sectors and inside design discipline (Corsín, 2014, p. 382). The latter has evolved into an increasingly collaborative activity, focused more on the purpose of the design than on the objects designed, expanding from the *built world* of products to an intangible framework of *visions* and *strategies* (Buchanan, 2001). The need of changes in organizations and how they respond to the new paradigm has led public institutions into the search of different ways of tackling public issues, in which design and prototyping offer a possibility to optimize, explore and co-create solutions (van Buuren, Lewis, Peters, & Voorberg, 2020). The growing interest in creative and collaborative activities, together with the rising interest in *design thinking* (Sanders, 2013, p. 3) has enabled the union between areas that were once aloof, such as design and policymaking.

On the one hand, design has extended as a discipline from the production of material things, to focus on the purpose of design, of the intent, calling for a change of tools and methods, including prototyping; “There is the need for alternative forms of conceptualization and embodiment beyond stuff” (Sanders, 2013, p. 2). Prototypes and prototyping emerging values are no longer just a first version of a design solution, nor only a step of the design process, instead, prototyping can be by itself the final objective, as it has the potential to create cultural and organizational changes and drive to innovation processes.

On the other hand, other fields such as policymaking has faced a change in how organizations work (Kimbell & Bailey, 2017 , p. 216). The need to solve wicked problems and close the gap between policy design and its implementation is demanding public institutions to be more flexible and anticipate to possible and unknown outcomes (Corsín, 2014, p. 382) These conditions has enable new approaches for policy design to emerge, such as *design for policy*; where design thinking principles and design methodologies, such as prototypes, offer different alternatives to address public challenges.

However, design for policy and prototyping face different challenges when entering in the policymaking context; one of them is dealing with the uncertainty that prototyping with an exploration approach can bring and hence, the fear of failure, which could have a negative perception within policymakers, hindering their engagement in prototyping processes and making it difficult to be periodic and sustainable over time. This thesis aims to explore the interaction between the open nature of prototyping and the policymakers’ engagement during co-creation processes.

To implement this investigation, a research design has been developed composed by three phases; the first phase is composed by two literature reviews, one about prototypes' notions and changes in design discipline and a second one about prototypes in design for policy. At the end of this phase, a triangulation of the information was made from which two dimensions to compare prototyping approaches was defined, together with a list of challenges for prototypes in design for policy.

Dealing with uncertainty and fear of failure was the challenge selected to further develop the thesis research, that aims at exploring how policymakers interact with the uncertainty of prototyping in co-creation processes and if this uncertainty that belongs to prototypes is a barrier for policymakers' engagement.

The second phase of the design research was focused on means of verification of this research questions and to bring new insights into the discussion.This phase was composed by two means of verification: for the first part, the set of case studies selected for this dissertation were the ten labs included in the SISCODE project, an EU funded project aiming at stimulating co-creation in policy-design. These 10 cases have been selected because they represent a unique sample of co-creation labs currently engaged in applying co-design as a methodology to operationalize the engagement of policymakers in the development of prototypes as new solutions to local challenges across Europe. A general analysis of the 10 labs' prototyping approaches and their level of uncertainty was made and verified through a focus group with the lab members; as a result, a comparative analysis of the total sample of co-creation labs in SISCODE was carried out.

For the second means of verification, three co-creation labs were selected to deepen into their prototyping approaches and its interaction with policymakers. To do so, the lab members were interviewed, and additional documentation was reviewed to develop three qualitative case studies that show the interaction of policymakers with three different levels of uncertainty in three different policymaking contexts in the EU.

In the third phase, a triangulation of the information shows a relation between the moment in which the prototype is developed within the policy cycle and the level of uncertainty in the process. There are also different types of uncertainties percieved in relation with prototypes and the way policymakers interact with thAccording to the case studies, prototypes developed in early stages of the policy cycle tend to face higher levels of uncertainty and policymakers do not work together with co-creation labs in this phase, rather the co-creation labs have the role of influencers of the policy design and policymakers support or are informed by the prototyping process. In co-creation labs working in later stages of the policy design (implementation) the level of uncertainty is low, the prototyping request comes from policymakers and they act more as co-owners of the process. The role of policymakers in the process, the stage of the policy cycle and the position of the co-creation labs towards the policy context seems to determine the level of uncertainty allowed in prototyping.

1. Policy making and design for policy

The following chapter establishes the context in which this thesis is framed: design for policy, and how changes in policymaking has brought design into the scene together with the attributes of prototyping. First the changes in the policymaking landscape are presented, followed by de emergence policy design and design for policy, in which the theme of this thesis takes place.

1.1. Changes in policymaking landscape

"We must become able not only to transform our institutions, in response to changing situations and requirements; we must invent and develop institutions which are 'learning systems', systems capable of bringing about their own continuing transformation." (Schön D. , 1973, p. 30)

What Corsín (2014) refers to as a *new production paradigm* has changed the structures of production, distribution and consumption, not only in the production of goods, but also in the production of knowledge, demanding for organizations across different sectors to be flexible, provisional and anticipatory (Kimbell & Bailey, 2017 , p. 216) The complexity of wicked problems in which actors involved have different interests and motivations, requires a cultural change of public institutions, policymakers and public servants; policymakers demand alternative approaches to problem solving and interaction with other organizations and people, approaches that must be flexible and anticipate unknown possibilities.

> *"The idea that policies can be rationally driven from the identification of problems to their implementation has led to the strengthening of monitoring and evaluation frameworks and tools, with a focus on deviations that does not correspond to real reactivity and flexibility." (Rizzo, et al., 2020)*

There is also a change of hierarchy regarding the *expert role* and the need to involve people into collaborative processes is increasing; "In art, design, science, even entrepreneurial and political organizations, the languages of openness and open-endedness, of provisionality and experimentation, are thus taking hold as models for cultural practice." (Corsín, 2014, p. 382) This shift explains the growing interest in *design-thinking* "The extension of design thinking to policy – particularly participatory and co-design approaches – resonates with principles of network governance" (Lewis, McGann, & Blomkamp, 2020, p. 112) and is related to other changes in policymaking and public administration such as the emergence of bottom-up approaches, open government, the new public governance, and experimentation as a process for anticipation and learning.

Top-down and Bottom-Up approaches

The gap between policy formulation and its implementation is in part a consequence of the disconnection between the actors in charge of each phase and their context ; "Policies are frequently designed without a clear knowledge of the mechanisms that reside in their concrete implementation, which often depend on the rules, procedures and capacities of local administrations or street-level bureaucrats." (Rizzo, et al., 2020) The relation between politicians, who formulate the policy, and civil servants or *street-level bureaucrats,* who implement it and the citizens that are affected by those policies can be addressed by two opposite approaches, from a top-*down* perspective or a *bottom-up* perspective.

From a *top-down* perspective, those in charge of implementation should be aligned with what high-level decision makers establish as policies, which requires an organizational management that addresses the complexity of actors involved. One of the main criticisms to this approach, is the fact that local administrators usually have direct and better knowledge about the problems that policies are addressing, nevertheless the tension between high level and local managers tends to be affected by the political context.

The bottom-up perspective suggests that the intention to align central and local administrators and formulation with implementation phase is impossible to achieve in practice from a top-down perspective, on the contrary, it should start from the point of view of the local administrators and citizens affected by the policy to increase the success of its implementation.

> *"Is thus the activity of reconnecting these actors and their goals with the overall policy framework and actors that operate at previous stages of the policy formation process: in this perspective, policies can be driven from the bottom to the top, assuming the attitude and the factors that are at play in the implementation phase as initial constraints" (Rizzo, et al., 2020, p. 22)*

One of the criticisms that this approach receives is the importance delegated to local administrators, who may not be aligned with the agenda of elected representatives in high-level positions. The tension between political decisions to be made and who determines it is a challenge that extends to collaborative approaches of policymaking, including design thinking and the role prototypes could play within this framework.

There are different models of governance that, from a bottom-up perspective, offer a structure for policymaking involving different actors from the beginning of the process. An example of this is the Open Government, that reflects a change of mindset in the public sector, a mindset that is aligned with what design and prototyping offers in terms of experimentation, anticipation and collaboration. "The 'Open Government' agenda pushes public servants to use new methods to engage stakeholders, gather data, and experiment before implementing policy" (Kimbell & Bailey, 2017 , p. 217) In 2011, the Open Government Partnership (OGP) was created uniting 8 funding governments from different continents to promote transparency and co-creation through partnership between different stakeholders from inside and outside public sector to "promote accountable, responsive and inclusive governance" (Open Government Partnership, 2020). Currently seventy-eight countries, and thousands of civil society organizations are part of the OGP. Open Government is a bottom-up approach in the sense that it puts citizens in the center of policymaking, in a more horizontal hierarchy structure.

Another example of emergent models of governance is the change of concepts like New Public Management (NPM) to concepts of New Public Governance (NPG) (Osborne, 2010). The first being a top-down approach to deliver services to citizens is being replaced for a more collaborative and horizontal relation with citizens, which are

seen as co-producers instead of just passive consumers of public goods "... the NPG paradigm is introducing *a more co-operative form of governing* that substitutes the focus on responsiveness to customers' needs with an emphasis on power-sharing and collaboration." (Sangiorgi, 2015, p. 334). Sangiorgi (2015) describes the differences of these two paradigms in the following table:

Table 1 Comparison between NPM and NPG

Table I Comparison between NPM and NPG paradigms

Paradigm	*Key quality*	*Value and values*	*Citizen*	*Service models*	*Innovation*
NPM	Efficiency, customer orientation, decentralisation	Individual and market value	Citizen as customer	Intra-organisational model that turns input into output	Innovation within organisations
NPG	Power sharing and collaboration	Focus on public value co-creation	Citizen as co-producer	Co-production; hybrid organisational forms	Innovation in partnerships and networks

NPG, Sangiorgi (2015)

Changes in the policymaking landscape have also led to discussions about *policy design* as part of public administration. The introduction of this *design science* (Hermus, van Buuren, & Bekkers, 2020, p. 22) into the policymaking scenario has open a space in which policymaking has the possibility to become more open, collaborative and experimental, in resonance with the Open Government and the NPG models. Below, a description of what policy design is and how design for policy has emerged as a new direction of it is explained.

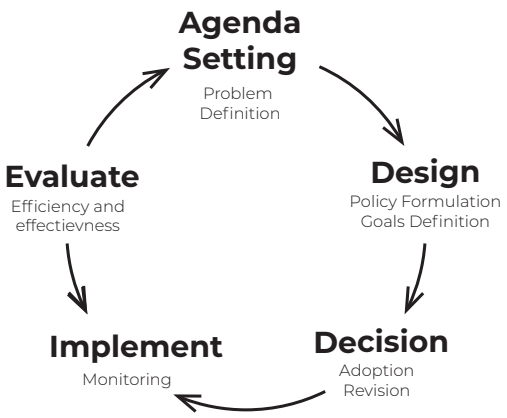
1.2. Policy Design and Design for policy

"The problem of government as a learning system may be stated simply in these terms: how can we, as a society or nation, learn to identify, analyze and solve our problems?"(Schön D. , 1973)

Policy design aims at solving problems through policy programmes "... is the deliberate attempt to define policy goals and consciously connect them to policy instruments intended to reach those goals" (Clarke & Craft, 2018, p. 6). Policy design emerge from *policy analysis* (Colebatch, 2018, p. 366), a wider field of professional practice and academic study. It began with a top-down approach, where decision makers and leaders make use of policies as artifacts to pursue their agendas, and the policies are implemented by local administrators or *street-level bureaucrats*.

The commonly known policy cycle starts with the agenda setting, where the emerging issues are identified, and the problem is defined. After the agenda setting comes the design or *policy formulation* where the goals of the policy are settled along with the impacts and implications expected. Then, the decision to approve the policy is made and the policy is adopted followed by the implementation of the policy, which should be constantly monitored to ensure its correct implementation. Finally, the implementation is usually assessed in terms of efficiency and effectiveness (Hill & Hupe, 2002, p. 95)

Figure 1 The traditional Policy Cycle

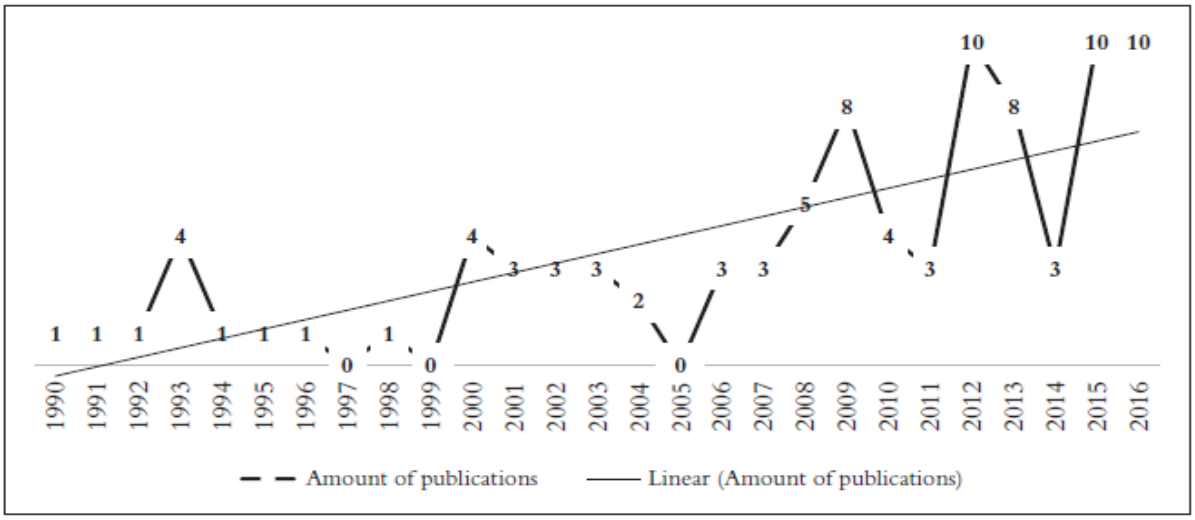


Based on the ROAMEF policy cycle and Grazzini (2015)

The first connection between design and public administration emerged from the Minnowbrook Conference in 1968, where Herbert Simon talked about *design sciences*, "These sciences focus on the artificial– the manmade – as opposed to the natural sciences. Artificial sciences therefore incorporate design, which is 'concerned with how things ought to be, with devising artefacts to attain goals". (Hermus, van Buuren, & Bekkers, 2020, p. 22) Shangraw and Crow (1989) would associate this concept directly with public administration. According to a literature review conducted by Hermus, Buuren & Bekkers (2020) since this event until 2016, "... there is an increase and prolif-

eration in design-oriented studies reported in Public Administration journals... mostly oriented towards delivering concrete policies and services." (Hermus, van Buuren, & Bekkers, 2020, p. 35) Which can be observed in the following graphic:

Figure 2 Yearly amount of publications of Design Oriented Studies in Public Administration



(Hermus, van Buuren, & Bekkers, 2020, p. 27)

The first design approaches in *policy design* were instrumental "In the context of policy design, design is seen as instrumental in the sense that it links problems to solutions and rational in the sense that the process should be knowledge and logic driven." (Hermus, van Buuren, & Bekkers, 2020, p. 23) It was also idealistic, as it aimed at finding an unique solution or answer to public problems; "the goal of design should be to develop mechanisms or algorithms that would produce clear and usable answers for the policy designer" (van Buuren, Lewis, Peters, & Voorberg, 2020, p. 6) Later, it started focusing on tools and mechanisms that could bring these answers, without focusing in problem structuring or evaluation: "much of the approach based on instruments still assumed a capacity for experts and analysts to develop the correct answers for policy problems" (van Buuren, Lewis, Peters, & Voorberg, 2020, p. 6)

These approaches along with modern structures to produce knowledge and solutions has changed. A new design orientation in policy design emerged acknowledging the contextual factors that affect how problems are defined and influence or constrain how policy instruments operate. (Clarke & Craft, 2018, p. 7) The appearance of concepts such as New Public Governance also influenced the new design orientation in policy design, focusing attention in the actors involved, and rethinking the role of the state in these processes; "the new design orientation has since revived the policy design tradition by embracing the diversity of potential designers and design inputs and spaces that now exist inside and outside of government proper" (Clarke & Craft, 2018, p. 8)

Unlike *policy design, design for policy* refers to design coming from design thinking literature, which has a different logic in comparison with the first one. *Design for policy* emerges within the new design orientation and aims at a collaborative approach

to policymaking, diverging the range of possible solutions instead of aiming for a one single right answer to public issues. The collaborative aspect of this process makes it a process of co-design; “The underlying assumption is that such an inclusive approach may increase the satisfaction of the end-users and their appreciation of public policy actions.” (van Buuren, Lewis, Peters, & Voorberg, 2020, p. 7). Below a comparison between policy design and design for policy can be found with its main differences:

Table 2 Comparison between Policy Design and Design for Policy

Policy Design	Design for Policy
Convergent thinking	Divergent thiking
Expert-driven	Collaborative process ***Co-design***
Rationality	Empathy
One final solution	Provisional ideas ***Prototyping***

Based on literature from van Buuren, Lewis, Guy Peters, & Voorberg (2020)

In design for policy, prototypes might contribute to close the gap between policy design and its implementation from a citizen-driven approach “In public administrations, the focus on materializing concepts, especially the interactions that people have with systems, enables participants in prototyping to understand and assess how a policy might be experienced and implications of policy delivery.” (Kimbell & Bailey, 2017) Prototypes can also be part of processes of experimentation, which is a growing interest in governments from different countries. Next, an overview of experimentation in the public administration is presented, together with the spaces in which these experiments are meant to be systemic, which are what we will call in this research, innovation units.

Innovation Units and Experimentation

Experimentation is a word that has become relevant in the public sector as terms such as *innovation* rises within public institutions; this can be seen in the increasingly creation of innovation labs in multiple countries’ governments, that aim at experimenting using a design thinking approach. (Lewis, McGann, & Blomkamp, 2020) Moreover, the establishment of international organizations dedicated to support these labs, such as the Observatory of Public Sector Innovation, founded in 2014, demonstrates an interest on building an ecosystem for innovation, in which systemic experimentation is important: “If we want effective public services, we need an experimental,

learning government robustly and systematically testing things out, measuring them and growing what works." (Breckon, 2015, p. 6) Other units across Europe such as Living Labs and Fab Labs have emerged as catalyzers and nodes withing the ecosystem to tackle innovation from a co-creation perspective. The first ones work as "transition arenas", which means they enable spaces for stakeholders to dialogue and experiment in real life contexts before scaling up solutions (Schaffers & Turkama, 2012, p. 26) Fab Labs started in 2006 in the MIT Center for Bits and Atoms as platforms for technical prototyping, however its scope has changed over time, focusing more on its value to connect communities, researchers, makers and innovators supported by technology (Fiaidhi & Mohammed, 2018, p. 83) What innovation labs, living labs and fab labs have in common as innovation units is their willing to experiment through collaboration and co-creation in a systematic way.

The concept of experimentation itself has changed, within the change of production of knowledge paradigm, experimentation has shift from a *closed to experts* domain to a *collaborative* process "if the experiment was once thought-of as a closed system against which scientists sought a theory's justification, it would seem that today the experimental is conceived rather as a design project" (Corsín, 2014, p. 385) Similar to what has happened with prototyping, experimenting has evolved into a collaborative activity that defies modern organizational structures, such as the ones established in the public sector. "The growing emphasis on experimentation prefigures and carves out a space for prototyping in policy development as a particular mode of enacting organizational flexibility, provisionality and anticipation." (Kimbell & Bailey, 2017 , p. 218)

One of the key aspects of experimenting and prototyping is learning and iterating from failure, otherwise the value of these practices is not sufficient; "governments experiment all the time – rolling out new policies on the populace, but without really learning if they are doing any good" (Breckon, 2015, p. 6) However, experimenting means dealing with a high level of uncertainty and the possibility to fail, which demands a big effort to change traditional structures and mindsets within public institutions.

> *"Applying design (as the design thinking literature refers to it) to policymaking and service delivery also raises serious questions about the applicability of these design methods – which are mostly derived from industrial and product design. Moreover, it raises serious dilemmas when it comes to typical public administration values, such as accountability, legal certainty and predictability" (van Buuren, Lewis, Peters, & Voorberg, 2020, p. 4)*

It is also important to understand the limits of what design thinking approach can address to in policy design; Clarke and Craft (2018) point an innocence of the political context in some issues that require political and normative decisions from elected politics, "Design thinking falls short, then, in providing guidance or methods by which politically contentious policy making activities should and are undertaken in practice" (Clarke & Craft, 2018, p. 14) which relegates most design thinking cases to the imple-

mentation and service delivery of political decisions that have already been made. “In some circumstances, policy decisions are highly contingent and ‘irrational’, and driven by purely situational logics and opportunism” (Rizzo, et al., 2020, p. 28) and not by the logic of design thinking approaches, that are considered “naïve” by some authors such as Clarke and Craft (2018).

There are also constrains regarding the time and resources that a collaborative process requires, which limits this approach to specific contexts where system-thinking and networked activities are feasible and required. Howlett (2020) highlights the importance of specifying when and why an approach such as design thinking in policy design is adequate in order to be able to measure and assess its implementation and role within specific policymaking contexts. There are ways in which design can contribute into a new public administration mindset, in which prototyping is key part of its benefits; however, there are also limits and challenges to make it possible. This thesis will explore one of those challenges and verify it through qualitative case studies across the European Union following the methodology explained in the chapter below.

2. The design of the research

2.1. Aim

This thesis aims to investigate the interaction between the process of prototyping and the engagement of policy makers in co-creation. The thesis focuses on the notion of uncertainty, which is inherent to prototypes' attributes, and how it affects the incorporation of prototyping in contexts outside the design discipline, specifically in policymaking. To do so, a qualitative research was carried out within the frame of SISCODE, an European Union funded project focused on co-creation in policymaking that works with a transnational system of ten co-creation laboratories (SISCODE, 2017, p. 5), which helped to validate the research assumption from the perspective of co-creation laboratories in the European Union.

The research was developed in the context of an internship as service designer with SISCODE and the design department of the Politecnico di Milano, leader of the project. For this reason, the research was carried out while the project was being developed and faced the crisis of Covid-19 in 2020, which implied additional uncertainty and difficulties for each laboratory's process.

2.2. Assumption and Research Questions:

Prototyping brings uncertainty into design for policy because of its open nature. This uncertainty might be perceived as negative within the policymaking context, generating fear of failure and hindering engagement of policymakers in the process.

Research questions:

- How do policymakers interact with the uncertainty of prototyping in co-creation processes?
- Is the uncertainty of prototyping a barrier for policymakers' engagement during co-creation processes?

2.3. The Study Methodology

Table 3 The design of the Research

Phase	Steps		Output
Phase 1: Literature Review	**Literature Review 1:** Literature about the notion of Prototypes and Design Evolution	>	- Literature Appendix of prototypes' notions accross different fields - Prototyping Matrix: two dimensions to compare prototype approaches
	Literature Review 2: Literature about Prototypes in Design for policy	>	- Challenges of prototyping in design for policy
	Triangulation of information	>	- Research questions
Phase 2: Means for Verification	**Means for Verification 1:** General Analysis of the 10 SISCODE Lab prototyping approaches accordign to the prototyping matrix Focus Group with SISCODE Labs to verify analyisis	>	- Comparative Analysis of the 10 SISCODE Labs - Selection of 3 cases to deepen
	Means for Verification 2: Deepen analysis of 3 SISCODE Labs Interviews with Lab members to deepen analysis	>	- Qualitative Case Studies of 3 SISCODE Labs
Phase 3: Discussion	**Triangulation of information** Answer to research questions	>	- Types of uncertainty - Policymakers' interaction and role with prototypes' uncertainties - Future development

Phase 1: Literature Review

Literature Review 1: Literature about the notions of prototypes and design evolution

Before arriving to the assumption of the research, a literature review was carried out to understand the notion of prototypes ; first from a historical perspective, then through an analytical perspective regarding their role and changes in design discipline and finally, from an evolutionary perspective, where the emerging roles of prototypes were established according to a literature analysis, which is part of the first two chapters of this thesis. Notions of prototyping are related to design evolution itself, therefore, a literature review about design evolution and new scopes was carried out to better understand prototypes emerging roles.

39 papers and articles from different disciplines published between 1948 and 2019 were analyzed. First a general overview of all existing documents in academic data bases was conducted, then all documents with the word *prototype or prototyping* in the title or abstract were selected and registered in the following appendix format:

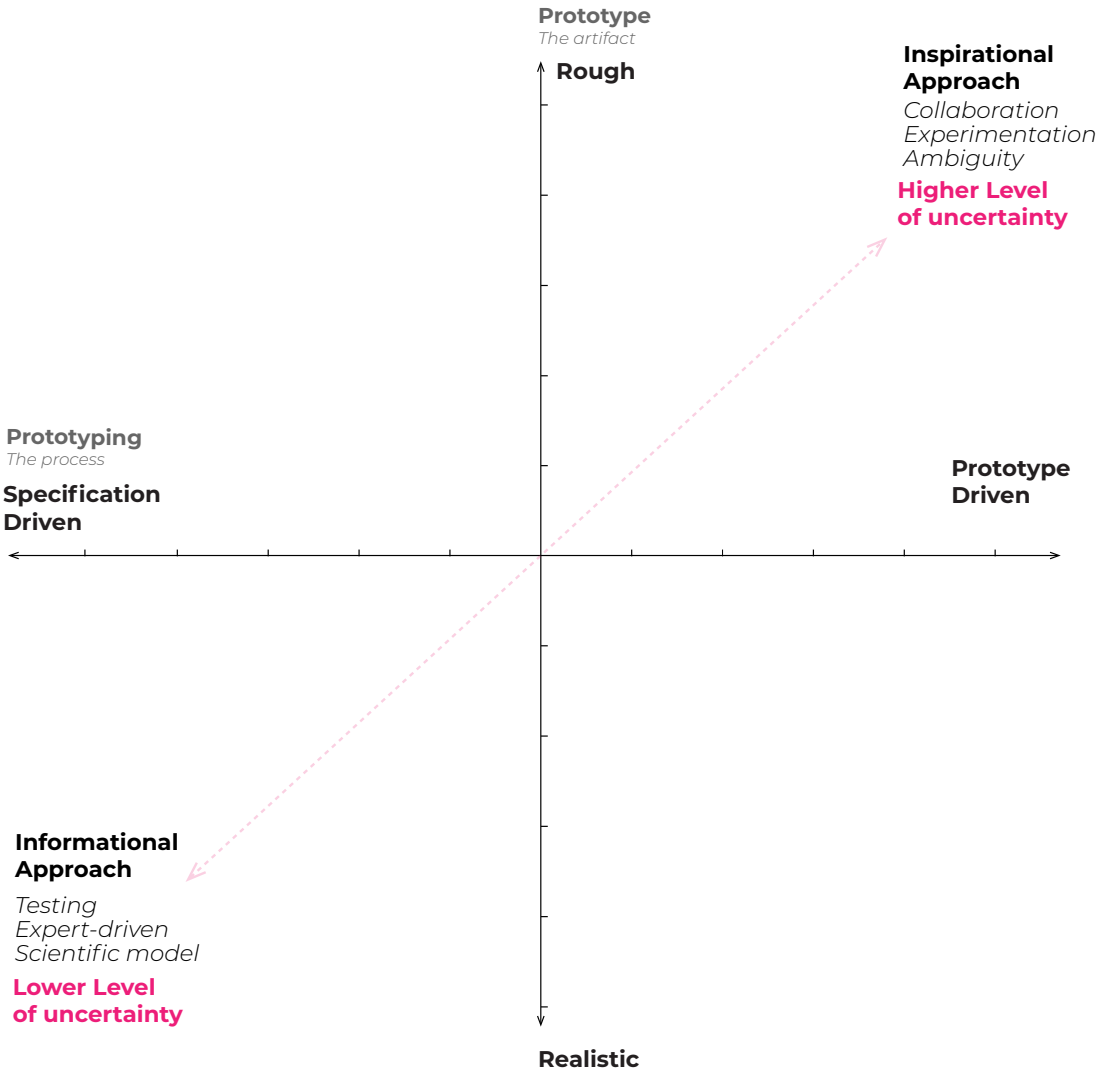
Table 4 Template Literature Appendix Format

No.	Name	Abstract	Key Words	Author	Year	Pages	Macrofield	Field	Prototyping Notion

As result from the selection process, the articles were clustered in 4 macro fields: design, engineering, science and social sciences. As some papers and articles might be overlapping between disciplines, the categorization was based on the background of the authors and institutions that published each document. In the case of engineering and design, the most relevant and quoted documents were selected for the analysis (To see the full appendix see Annex 1).

From the literature review, a Prototyping Matrix with two dimensions to compare prototype's notions was identified: the first dimension is related to the process of prototyping and the second one is related to the prototype itself. Additionally, two approaches of design research, determined by Sanders (2005), were put as vectors of prototypes approaches. These two approaches of design research are extrapolated with prototyping, as the latter can be considered also as a mean for knowledge creation. The Prototyping Matrix is the following:

Figure 3 Prototyping Matrix: two dimensions to compare prototype's notions



Two main outputs of this phase guided the following steps of the research: in the first place, the Literature Appendix enabled the understanding of notions of prototypes across different disciplines, in the second place the Prototyping Matrix allowed the comparison of this notions of prototyping and will be the tool to compare the SISCODE cases in the following phases of the thesis.

Literature Review 2: Literature about prototypes in design for policy

This literature review was carried out to understand contemporary changes in policymaking and the role of design for policy as a developing discipline where prototyping's emerging roles might have a key role.

The main output of this phase is a list of challenges of prototyping in design for policy. The list of challenges was later compared to the challenges covered by the SISCODE project. Most of the challenges were already being address by SISCODE's research, hence, this thesis focused in those challenges that were not being completely covered by SISCODE, in order to contribute and go in deep in areas where there is a lack of information or literature.

Triangulation of information

After the two literature reviews, the information gathered from both reviews was triangulated to narrow the purpose of the thesis and establish the assumption and research questions. For this dissertation, a set of ten labs included in the SISCODE project, an EU funded project aiming at stimulating co-creation in policy-design were selected. These ten cases have been selected because they represent a unique sample of co-creation labs currently engaged in applying co-design as a methodology to operationalize the engagement of policy-makers in the development of prototypes as new solutions to local challenges across Europe.

First, the list of challenges was clustered according to the emerging design approaches identified in the first literature review (in which prototypes have specific roles). Then, each challenge was contrasted with the objective of the SISCODE project to identify which of them were being already covered by the project and which of them were not completely covered.

Table 5 Challenges of Prototyping in Design for Policy

Approach	Challenge	Covered by SISCODE
Design as Exploration	a) Make prototyping last in time as an iterative process	Yes
	b) Learn from prototyping and transfer knowledge created	Yes
	c) Deal with uncertainty and failure in the local context	No
	d) Measure outcomes and outputs of prototyping	Yes
	e) Development and dissemination of design capabilities	Yes
Design as Co-creation	f) Align prototyping outputs with the policy making context	Yes
	g) Align stakeholder's expectations	Yes
	h) Versatility of roles and power distribution	No
	i) Representation of target citizens	No
	j) Engage Stakeholders	Yes

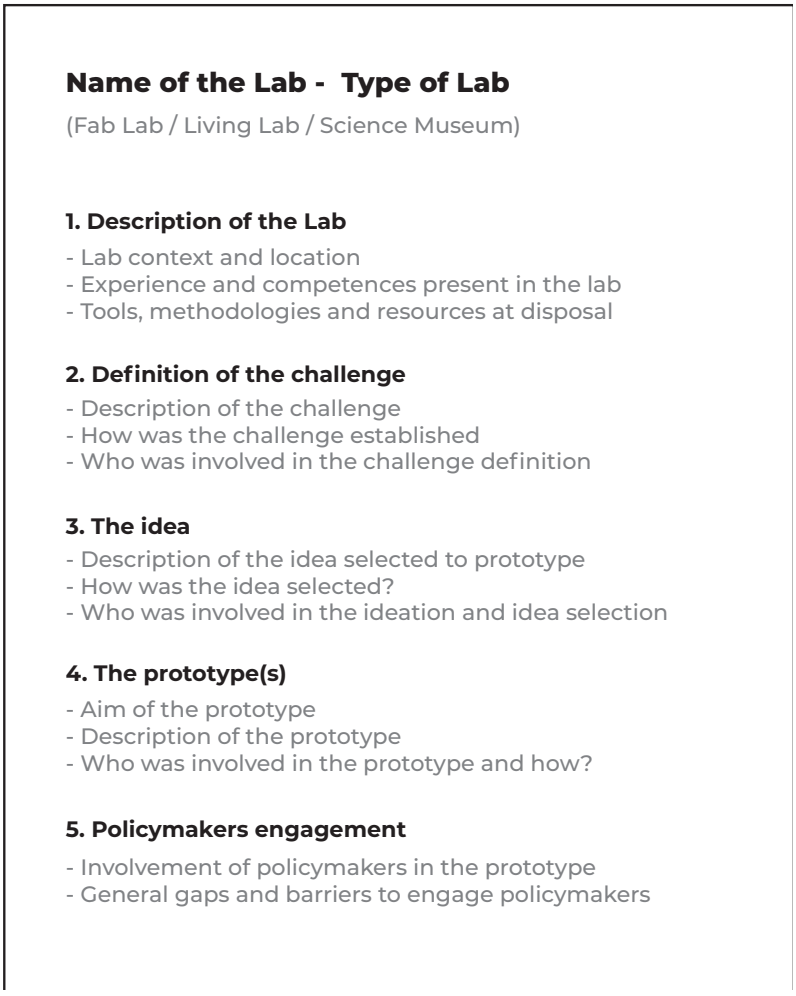
The challenges that are not being covered by the SISCODE project in *Design as Co-creation,* are related to political issues (*h) Versatility of roles and power distribution* and *i) Representation of target citizens* and although these challenges are important, they go beyond the limits of this design thesis scope. Therefore, this research focused on the challenge related to the *Design as Exploration* approach*, c) Deal with uncertainty and failure in the local context*.

Phase 2: Means for verification

Means for verification 1: General analysis of the 10 SISCODE Labs' prototyping approaches

A general review of the reports and presentations of the 10 SISCODE co-creation labs (which is the 100% of the labs working with the project, 100% of the sample) was carried out. Each co-creation journey of the lab was documented in the following template:

Figure 4 SISCODE Labs Case Study Template



After the documentation of each lab, they were analyzed through the two dimensions from the Prototype Matrix developed in the first literature review, to understand their prototyping approaches and level of uncertainty.

Focus Group: Dialogue among researchers and practitioners

To validate the general analysis, an online focus group was carried out to share with the labs part of the first literature review and contrast the general analysis of their prototyping approaches with their own perception according to the two dimensions that emerged from the literature review in the first phase. Seven of the ten labs were present in the focus group, which was at the same

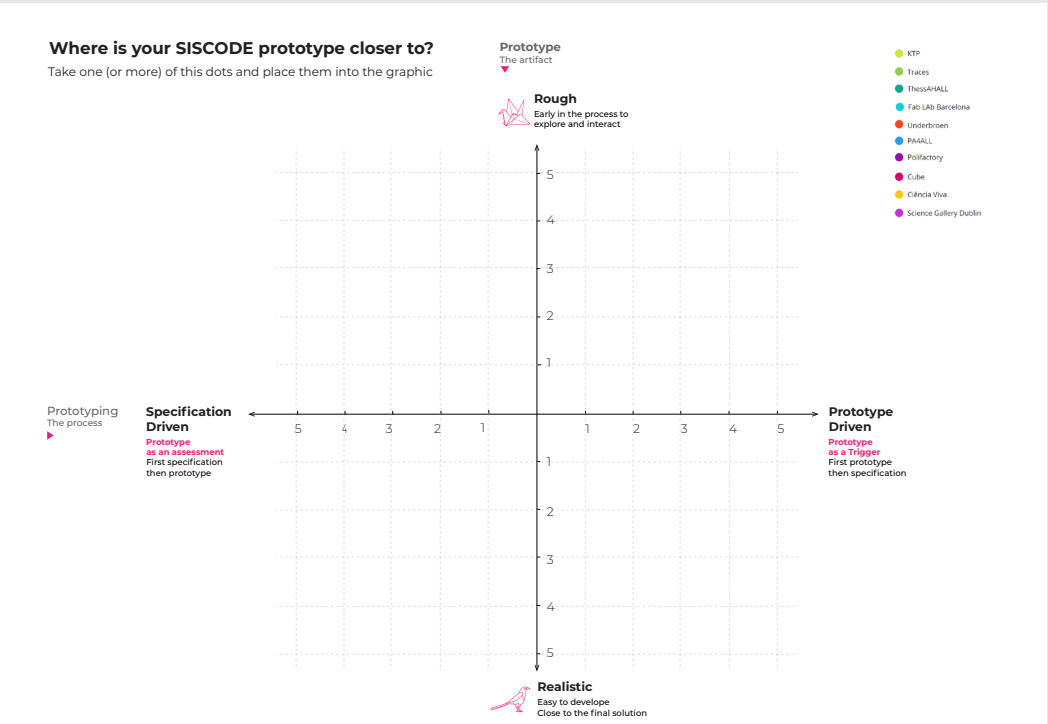
time the first session of an initiative from SISCODE called “Dialogue between practitioners and researchers”, that seeks to bring closer researchers with practitioners of the co-creation labs.

The focus group started with a brief presentation of the literature review about prototypes including what uncertainty in prototyping means, in order to set the context of the research. Then the labs were given the task to place their SISCODE prototypes into the Prototyping Matrix. Later, each lab explained the reasons why they considered that their prototypes were situated in the proposed location. Finally, two questions related to the assumption of this thesis were made to initiate a dialogue between the participants.

Table 6 Design of Focus Group: SISCODE Dialogue among researchers and practitioners

Time (Min)	Activity	Aim	Tool
15	Brief Presentation of Literature Review 1: about Prototypes' Notions	Set the context of the research	Power Point Presentation + Microsoft Teams
3	Presentation of the Prototyping Matrix: two dimensions to compare and analyse prototyping approaches	Explain two dimensions of analysis	Power Point Presentation + Microsoft Teams
5	Self-Assessment: placement of each Labs' prototyping approach in the Matrix	Gather and compare their perspective about their prototypinig approaches	Prototyping Matrix: two dimensions of prototyping approaches + Miro
40	Presentation of each Lab's prototyping approach	Understand why they perceived their prototype in the wat they did	Prototyping Matrix: two dimensions of prototyping approaches + Micrcosoft Teams
30	Comparison of the analysis before and their self-assessment	Contrast previous analysis with the Labs' perspective	Prototyping Matrix + Micrcosoft Teams
20	Dialogue about the assumption and research questions	Explore the interaction between their prototupe approaches and policymakers involvement	Power Point Presentation + Microsoft Teams

Figure 5 Focus Group Template: Prototyping Matrix with two dimensions to analyze



The results from the first general analysis and the focus group were the inputs to do the comparative analysis of the ten SISCODE labs. This comparative analysis was made based on the two dimensions of prototyping approaches, its level of uncertainty and its interaction with policymakers' involvement.

Based on the level of uncertainty, three labs were selected to verify if this aspect is affecting and how is it related to policymakers' engagement in the co-creation process. The cases were selected as follows: one lab that has a high level of uncertainty, one that has a very low level of uncertainty and one with a medium level of uncertainty, based on the two dimensions of the Prototyping Matrix.

Means for verification 2: Deepen analysis of 3 SISCODE Labs

Three semi-structured interviews with one member of each lab were carried out to understand de interaction of their prototypes' uncertainty level and the policymakers engaged in the process. The interviews also seek to deepen in the information provided in the reports to have a more depth understanding of the prototyping context.

Figure 6 Interview structure and guiding questions

Interviews guiding questions

1. Introduction

Good morning/afternoon_____, thanks for agreeing to this interview.

My name is Alejandra Campo, I'm doing a master of Product, Service, System Design at the Politecnico di Milano and currently I'm developing my thesis about the role of prototypes in design for policy.

The aim of the research is to understand how does the openness and experimental nature of prototypes, and the uncertainty it implies, affects the relationship and engagement of policymakers in the process.

Through the analysis of these case studies within the SISCODE framework, I seek to understand each specific prototyping process regarding this issue.

For the purpose of the academic research I'll record this interview starting from now.

2. General Questions

- Could you tell me more about the current state of the prototype?

- How were the policymakers involved in the prototyping process? (Were they creating the prototype, testing it, or being informed about it?) Why?

- Did you find difficulties to involve policymakers into the prototyping process? Why? What did the lab do to overcome these difficulties?

- Was the engagement of policymakers in the prototyping process different from their engagement in other phases of the project? How?

- Do you think the prototyping process brought any level of uncertainty to the project? Why?

- Do you think that the level of uncertainty had negative impacts in the engagement of policymakers during prototyping? If yes, how did you overcome these negative impacts?

- Did the lab have experience prototyping with policymakers before? If yes, how was the experience?

- Is the lab planning to continue prototyping in future or other projects? Why?

3. Specific questions about each Lab's prototype

According to the information available of each lab, specific questions about the prototypes were asked.

All interviews shared eight standard questions and each lab had between two and three specific questions regarding their own prototypes and context, however, as these are guiding questions, other questions appeared along the interview according to the answers of each interviewee. The interviews were carried out virtually and had a duration between one hour and one hour and a half.

One participant observation into one of the labs prototypes was possible, in which the level of uncertainty during prototyping was experienced, as well as the involvement of policymakers involved in the activities. This helped to deepen the understanding of this lab approach to prototyping and its relationship with policymaker's engagement.

Finally, a further examination of the lab documentation was carried out to better establish the policymaking context. The three case studies were developed considering the following aspects:

Figure 7 Three Qualitative Case Studies SISCODE Template

Phase 3: Discussion and conclusions

Triangulation of the information

This chapter synthetize the findings of the ten case studies analysis, with special attention of the three cases that were selected to deepen the investigation. First, a description of three types of uncertainties identified is presented, followed by an analysis of policymakers' interaction with these uncertainties and an hypothesis of four main policymakers' roles in prototyping, which are correlated with the two dimensions of analysis of the prototyping approaches and their level of uncertainty (Prototyping Matrix).

3. Literature review 1: Prototypes and Design evolution

To understand the role and potential of prototypes in design for policy, an analysis of the prototype's history and emerging roles was done first. The following literature review is about their evolution through history and the changes of the design discipline that has driven to transformation in how prototypes are understood and employed across different fields.

3.1. Brief history of prototypes

The meaning and role of prototypes have changed along history, from early sketches and models in art, design and architecture (Küchler, 2010, p. 310), to digital simulations and participatory practices to make sense of future scenarios (Sanders, 2013, p. 1). These transformations in prototype's definitions respond to a change, not only in the disciplines where prototyping emerged, but also in the contemporary landscape of organizations that seek for flexibility, provisionality and anticipation every time with more urgency, opening new opportunities for the potentiality of prototyping (Kimbell & Bailey, 2017 , p. 216).

At the beginning, prototypes responded mainly to the need of translating thoughts into material representations: three dimensional artefacts that could be tested and then refined. In a general definition, prototypes are the first version of a product meant to be reproduced several times (Kimbell & Bailey, 2017 , p. 217) (Coughlan, Fulton, & Canales, 2007, p. 3) (Buchenau & Fulton, 2000, p. 424). From a material culture perspective, Küchler describes prototypes as a "world made to measure, a material world whose calculated nature could enable one to transcend chance" (Küchler, 2010, p. 311). According to Küchler, one of the first prototypes in history is the first computer by Jacquard Loom in 1834: "This inventor of the first mechanical loom recognized that weaving, although an intricate and delicate task, was also a highly repetitive task. He believed that the weaving of complex patterns could be automated and conceived a system that relied on stiff, pasteboard cards with various patterns of punched holes." (Küchler, 2010, p. 310) This system is by itself a translation of his thoughts into an artefact that would become later in the first computer. Prototypes started their history as a material translation of ideas, as first steps and attempts to materialization of thoughts.

Prototypes were usually made in a late stage of the product development process, when details and design ideas were already configurated and it's role was related more to communicate the design idea within work teams and, or persuade possible clients or stakeholders (Sanders, 2013, p. 4) However, their role in the design process has changed over time, by appearing earlier in the project thanks to technological advances. Schrage (1996) presents the case of Toyota as an example of change in the approach of prototyping in the automobile industry; instead of creating these elaborated clay models, they designed first with Computer-Aided-Design (CAD) tools, saving time and allowing the team to make changes easily. The physical clay models were made later as a result of the CAD prototypes iterations. Schrage refers to these approaches as cultures of prototypes; in the case of General Motors, the prototyping process was led by the specifications, it is a *specification-driven prototype* approach. On the contrary, Toyota used the prototype to create the final specifications, on what Schrage calls *prototype-driven specifications.* (Shrage, 1996, p. 4)

Technological advances have contributed to change how prototypes are conceived and used, "With modern tools for CAD, much of the design of an automobile can be completed on-line, and can be visualized through high-quality graphics" (Shrage, 1996, p.

5). Other technologies such as topography and photosculpture in the late nineteenth century made possible 3d printing, or as some refer to as rapid prototyping (Lengua, 2017, p. 7). The possibility of creating quick, accurate and detailed models with tools such as CAD or 3d printing opened the door for prototypes in other industries such as health and science. Regarding these areas, prototypes are used, again, to translate 2D data into 3D representations that allows experts to learn and take informed decisions about, for example, congenital heart diseases. (Vettukattil, Samuel, Gosnell, & Kurup, 2017, p. 9) The prototyping process begins with established specifications (2D data) and seeks to evaluate them in specific scenarios, they are *specification-driven prototypes.*

Other approach of prototyping comes from interaction design and software development, that have led to a change in the way prototypes are made and has increased its visibility as an essential practice (Corsín, 2014, p. 381). "Developers are here known for releasing beta or work-in-progress versions of their programmes, as an invitation or call for others to contribute their own developments and closures." (Corsín, 2014, p. 381) In this case, the prototype is open to other members of the organization, not for them to review it or evaluate it only, but also to be involved in the prototype development. The prototyping process is not fully led by specifications, as it happens in the cardiac disease example, instead it leaves some space for failure and exploration of possibilities, "An important feature of prototyping in this case is the incorporation of failure as a legitimate and very often empirical realization" (Corsín, 2014, p. 1)

The evolution of prototypes perspective has led to different notions of prototypes, which varies across different fields. In the following section a description of different notions of prototypes within their disciplines is presented.

3.2. Notions of Prototypes: from tangible features to intangible dimensions

"Is a brick a prototype? The answer depends on how it is used. If it is used to represent the weight and scale of some future artifact, then it certainly is; it prototypes the weight and scale of the artifact.
This example shows that prototypes are not necessarily self-explanatory. What is significant is not what media or tools were used to create them, but how they are used by a designer to explore or demonstrate some aspect of the future artifact." (Houde & Hill, 1997, p. 368)

Blomkvist & Holmlid synthesize the definition of prototypes through different disciplines as *a representation or manifestation of ideas or assumptions about the future that can be tested* (Blomkvist & Holmlid, 2011, p. 2). However, this general definition is applied differently according to the field and the prototype's purpose. As it has been mentioned above, prototypes' notion began within the industrial design and engineering discipline from a tangible perspective: physical artifacts that represent

an intangible idea, however, other disciplines such as Human Computer Interaction has challenge this notion of prototype and have entered into the field of intangibles, focusing the attention on interactions more than physical features. Below, a brief description of different notions of prototypes is presented.

Industrial design, engineering and science

In product design, engineering and science prototypes were meant to proof or validate an already specified design solution. "Therefore, prototyping in the engineering design literature is mainly regarded as an expense and an activity that takes place in the late stages of the design process to verify and validate performance and functionality of the design." (Elverum & Welo, 2016, p. 1) Nevertheless different studies about prototype's role within the practices in manufacturing companies (Elverum & Welo, 2016) (Lauff, Kotys-Schwarz, & Rentschler, 2018) have concluded that prototypes are used along the whole process of product development to; (1) *communicate* the design idea between internal and external actors involved in the design project, (2) *learn* about the design solution, from framing the problem correctly to validating performance and explore possibilities in collaboration with users, and finally to (3) *inform decision-making* regarding feasibility, desirability and viability of the product. In these fields, prototypes are understood as physical representations of a design idea.

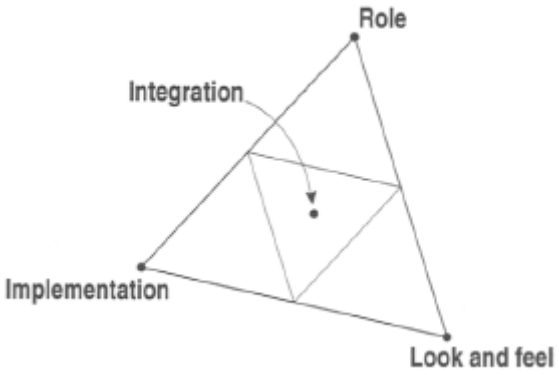
Human Computer Interaction

In Human-Computer-Interaction (HCI), prototypes play an important role in exploring designs for interactive computer artifacts, which are complex as they deal not only with a material dimension but also with an intangible structure that affects the experience of the user, "Any artifact can have a rich variety of software, auditory, visual and interactive features. Users experience the combined effect of such interrelated features; and the task of designing and prototyping—the user experience is therefore complex." (Houde & Hill, 1997, p. 367). In HCI language, artifact is understood as any interactive system being designed, regardless the mean. (Houde & Hill, 1997)

Houde & Hill (1997) established four types of prototypes within the HCI field; the firsts ones are the (1) *Role Prototypes* which aim at investigating questions about the function of the artifact and evaluate how users could interact with it. It also helps to communicate the main role of the design to other members of the team. The second type are the (2) *Look and Feel Prototypes,* to explore and demonstrate possibilities related to the experience of an artifact, it can be used to visualize how the design solutions could look and share it with other members outside the design team and users. The third type are the (3)*Implementation Prototypes* which answers technical questions about how the artifact might work, "They are used to discover methods by which adequate specifications for the final artifact can be achieved-without having to define its look and feel or the role it will play for a user." (Houde & Hill, 1997, p. 376) They help to experiment and understand the feasibility of the artifact. Finally, a fourth type combines the last three into one that represents the complete user experience of an artifact, considering the look and feel, role and implementation aspects, they are called

the (4) *Integration Prototypes* and help to discover and solve constraints overlapping between the last three dimensions.

Figure 8 Four Principal categories of prototypes on the model



(Houde & Hill, 1997, p. 367)

Lim, Stolterman and Tenenberg (2008) propose a more general categorization of prototypes, they divide them in two main groups: prototypes as filters and prototypes as manifestations of design ideas. *Prototypes as filters* could encompass the types of Houde & Hill (1997) previously described; each type would be a filter that helps designers to *generate and evaluate discovery* about the artifact and the user interaction in one of the first three dimensions, without representing the design completely, "A primary strength of a prototype is in its incompleteness. It is the incompleteness that makes it possible to examine an idea's qualities without building a copy of the final design." (Lim, Stolterman, & Tenenberg, 2008, p. 7:7) What is critical is to decide which filters will allow to examine and explore what is needed for the project.

Similar to the analysis of Küchler (2010), Lim, Stolterman and Tenenberg (2008) characterize the second group as *prototypes as manifestations*; in this group prototypes are described as a materialization of thoughts, which enables designers to create knowledge and learn from iterations, "... externalization of thought gives rise to new perceptual and cognitive operations that allow for reflection, critique, and iteration." (Lim, Stolterman, & Tenenberg, 2008, p. 7:9)

Approaches from HCI and product design have been the base to build the prototypes notions for emerging fields such as service design, organization design and design thinking, among others. "As the reach of design has moved beyond the design of products to the design of interactive systems, and even to elements of service design, many of these newer prototyping methods, such as those that involve role-playing and scene enactment, are becoming more deeply embedded in design practice" (Coughlan, Fulton, & Canales, 2007, p. 4). This changes within the design field has contributed to the transformation of prototypes' notions, hence a deeper understanding of these changes is needed to understand the foundations of prototypes' emergent roles inside and outside the design discipline.

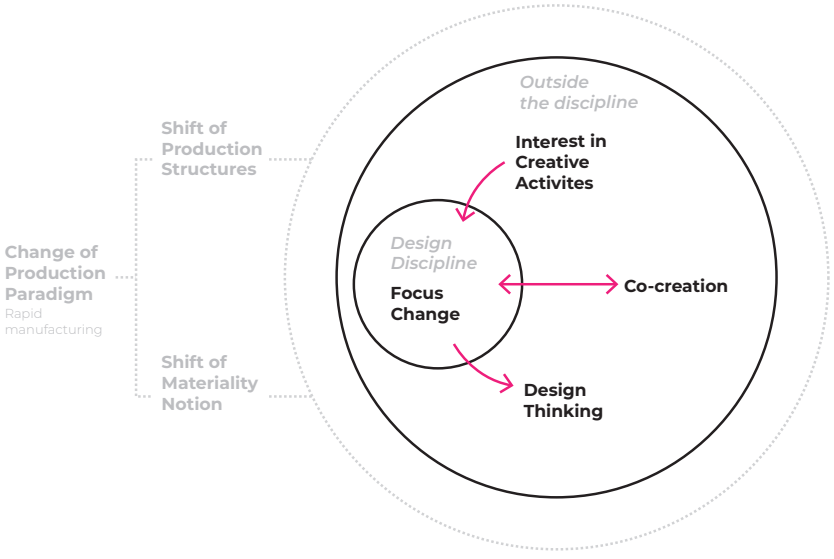
3.3. Changes in design: broader scope and new scenarios

To understand emergent roles of prototypes it is necessary to understand changes in design discipline that have opened a broader scope of intervention; expanding from the physical or built world, to an intangible scenario where new disciplines such as service, system design or social innovation become part of the design discipline. Within these emergent areas, prototypes have evolved and supported design development.

Sanders (2013) establish four manifestations of change in the design discipline. These manifestations respond to a wider transformation in contemporary production systems and organizations. On the one hand, second industrial revolution with rapid manufacturing has challenged the notion of materiality (Buchli, 2010, p. 280), which has affected design as a discipline that was born in a material culture addressed to the creation of physical artifacts. On the other hand, "Rapid manufacturing suggests that the classical social structures associated with production are further challenged: creator and producer are one" (Buchli, 2010, p. 281), this change defies also the notion of author, focusing the attention in relations and interactions, which calls for a change in how organizations must behave (Corsín, 2014, p. 382)

These drivers are manifested inside the discipline of design and from the discipline towards other fields. The first manifestation is an internal change of focus and purpose of design, extending design scope and boundaries. In the second place, there is an external change from other disciplines towards design, that is the increasingly interest from non-designers into creative activities. In the third place, there is a new branch of design discipline that spreads outside design discipline into multiple fields. Finally, in the fourth place, there is a macrotrend that affects different disciplines, including design: co-creation as a new paradigm of knowledge production. The last one also gets nourish from design discipline, which offers co-design as an approach to make co-creation possible.

Figure 9 Changes in Design Discipline



Based on theories of Sanders (2013)

Focus change

The first manifestation is the change of the focus of design; it has changed from focusing in the production of objects to focus on the purpose of the design, which is not necessarily manifested in physical artifacts.

Table 7 Old and New Design Domains

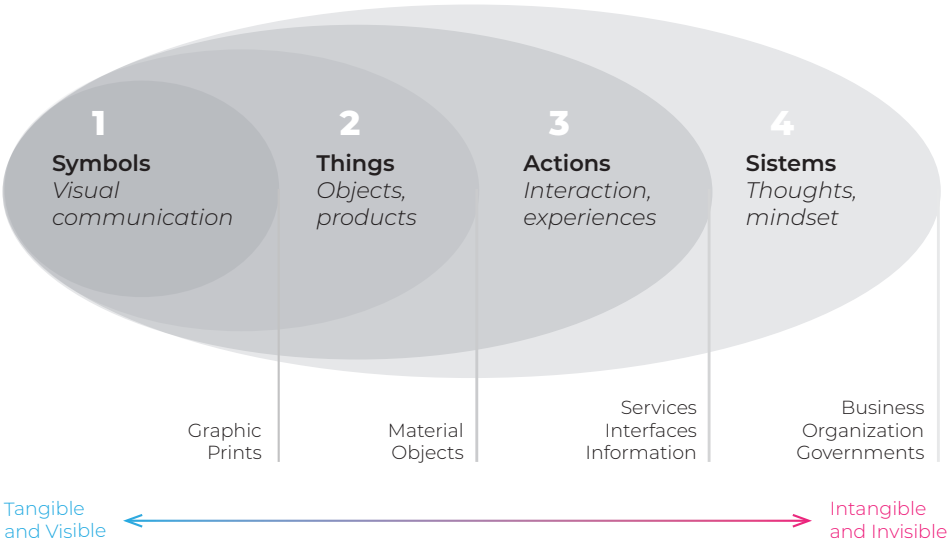
Traditional Design Disciplines	Emerging Design Disciplines				
Visual communication design	Design for Experience	Design for Service	Design for Innovation	Design for Transformation	Design for Sustainability
Industrial Design					
Interior Space Design					
Architecture					
Interaction Design					

(Sanders, 2013)

The new design domains focus on the people and the context of their lives, it goes beyond the "stuffs". This change claims for a change in how design is being performed and the tools and methodologies required, including prototyping and prototypes. "There is a need for alternative forms of conceptualization and embodiment beyond stuff." (Sanders, 2013, p. 2) When the focus of design changed, the role of prototyping also shifted.

Regarding the shift of the notion of materiality, Buchanan (2001) questions also the notion of product, and how its transformation is part of what he calls the *revolution in design,* which he explains through four orders of design in the twentieth century. From the first two orders of design, which are based on symbols and things, to the last two based on actions and experiences; "... the products are more than physical objects. They are experiences or activities or services, all of which are integrated into a new understanding of what a product is or could be." (Buchanan, 2001, p. 11) The following graphic explains the four orders of design and their relation with materiality and intangible focus:

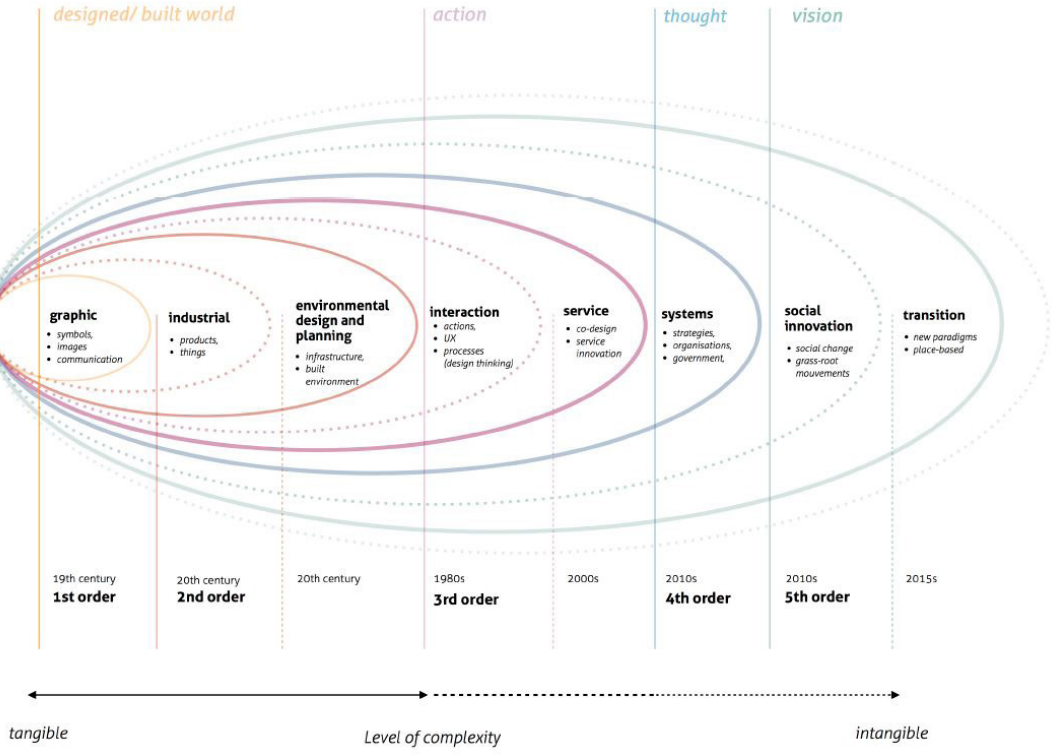
Figure 10 The four orders of design



Based on the four orders of Buchanan (2001)

Morelli (2002) talks about the necessity of a shift from production of products to the provision of systems of products and services, in what he refers to as PSS (Product Service System). The design approach can contribute to the evolution of PSS, moreover "..the involvement of designers in the development of PSS would require an extension of designers' activities to areas previously covered by different disciplinary domains." (Morelli, 2002, p. 3) Beaulé (2018) expands the four orders of Buchanan (2001) into an eight layers diagram, where it is visible how the focus of design expands into new fields, including government and grass-root movements:

Figure 10 The evolution and growing complexity within design fields



(Beaulé, 2018, p.8)

The last layer called *transition* refers to the *transition theory,* which aims at understanding the behavior of complex systems that go from equilibrium cycles to short periods of instability and chaos (Puerari, Koning, Mulder, & Loorbach, 2017, p. 203)

Creative activities for non-designers

The second manifestation is an increase of interest in creative activities for non-designers, "This can be seen in the growth of DIY (do-it-yourself) industry and the resurgence of crafting at all levels" (Sanders, 2013, p. 2). The change in production structures opens the possibilities for people from different fields to be creative and craftmanship recovers value into a landscape where experts are becoming part of a horizontal hierarchy, where "lay" people knowledge and capacities could also contribute to production and knowledge generation. "It has become increasingly evident that everyday people are no longer satisfied with simply being consumers." (Sanders, 2005, p. 6)

Design thinking

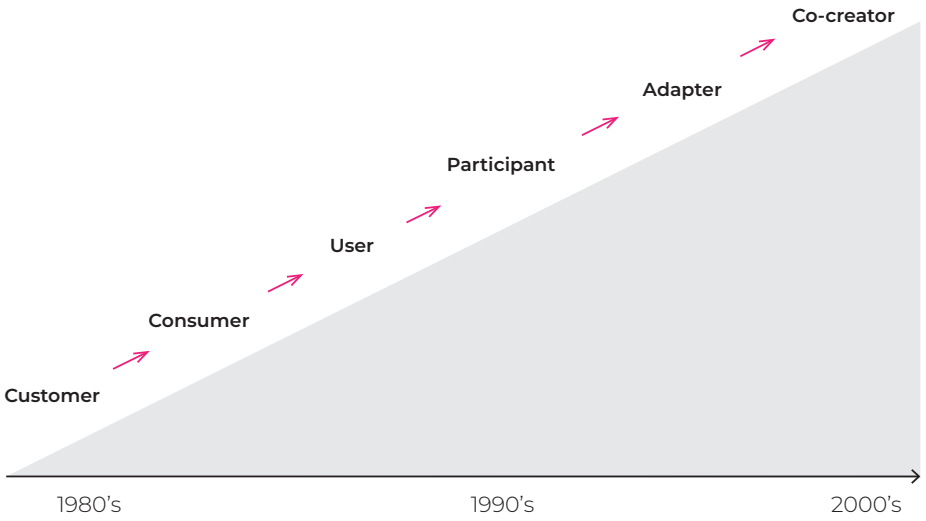
The third manifestation is the spread of "design-thinking" in the business community that has expanded also in other fields such as mathematic (Simon & Cox, 2019) or policy design (Kimbell & Bailey, 2017). "Design thinking is already of such interest that business schools within universities around the world are attempting to revamp their curricula to meet the needs of business students who do not want to play the business as usual game" (Sanders, 2013, p. 3) Connected to the latter manifestation, organization are getting interested in alternative approaches to problem solving, where classical structures of knowledge production are getting replaced by horizontal structures.

Companies like IDEO have taken this opportunity to another level, using prototypes within organizational design as boundary objects that impact companies at an organizational level "our emphasis is primarily on change in individual work behavior, organizational capability building, and cultural change as objectives and benefits of prototyping." (Coughlan, Fulton, & Canales, 2007, p. 5)

Co-creation

Finally, the fourth manifestation is the interest in co-creation in different fields, including design. “Design, and prototyping has migrated towards an increasingly collaborative practice (Sanders, Prototyping for the design spaces of the future, 2013, p. 4); The way design think and interact with people affected by the design has change from a customer perspective to a co-creator perspective.

Figure 11 Changes in the way we think about people



(Sanders, 2005, p. 5)

The value of prototyping as boundary object is a relevant asset for other disciplines looking to involve people in process that were before closed to a group of experts: “Medialabs, hacklabs, community and social art collectives, dorkbots, open collaborative websites or design thinking workshops are spaces and sites where prototyping and experimentation have taken hold as both modes of knowledge production and cultural and sociological styles of exchange and interaction.” (Corsín, 2014, p. 381)

The spread of design- thinking and DIY industry are also manifestation of a change in how organizations and disciplines aim to generate knowledge and create solutions with people. “In particular, the drive towards more participatory approaches has been extended to areas of policy making that more than others have traditionally been considered the domain of experts.” (Rizzo, et al., 2020, p. 15) The design discipline brings co-design as an alternative to operationalize co-creation, and prototypes play a key role in this process.

The transition from tangible and visible features of the prototypes to intangible dimensions gives birth to emerging roles of prototypes, not only in the design discipline, but in other areas in which prototypes were not considered before.

3.4. Emerging roles of prototypes

As design discipline has evolved, so has the concept of prototyping; from translation of thoughts towards a collective thinking and knowledge construction, prototyping is becoming a participatory activity (Sanders, Prototyping for the design spaces of the future, 2013) that has the potential to anticipate future scenarios, generate knowledge and changes within an organization.

Table 8 Changes in Design Discipline and Emerging Roles of Prototyping

Prototypes Emerging Roles ↓ / Design Changes →	Symbols *Graphic Communication*	Things *Industrial Products*	Action *Interaction Service Experience*	Thoughts *Strategy Systems Organisations*	Vision *Social Innovation New Paradigms*
	Tangible Visible				*Intangible Abstract*
First Version of *Representations*					
A result of innovation					
Manifestations *Filters of features*					
Collaborative Activity *Participation and engagement*		**Rise of creative activities for non-designers**	**Focus on purpose, beyond stuff**	"Collective thinking" or "thinging" through prototypes	**Co-Creation as a new knowledge production paradigm Co-design**
Boundary Object *Communication tool across boundaries*				**Design Thinking seeking cultural behavioral change**	
Exploratory *Anticipation of the unknown*				New experimentalism	Speculative design, Make sense of the future
A triger for innovation					

Based on theories of Buchanan (2001), Sanders (2013), Lim & Stolterman(2008), Coughlan, Fulton, & Canales (2007)

To analyze prototype's roles in different fields, a literature reviewed was carried out and two aspects were considered to map these roles: and the first one is related to the prototype itself; the second aspect is related to the process of prototyping. To analyze the literature, the previous aspects were considered and two approaches of design research, determined by Sanders (2005), were put as vectors of prototypes understanding and roles. These two approaches of design research are extrapolated with prototyping, as the latter can be considered also as a mean for knowledge creation.

The first approach is the *informational approach,* which is based on a scientific model and expert-driven process to measure performance and specifications. The second one is the *inspirational approach,* which values the perspectives of actors involved in the design and implementation process and is based on experimentation and ambiguity, drawing from the future and the unknown. (Sanders, 2005, p. 10) As ambiguity increases, the uncertainty in prototyping increases, which makes it a process fertile for exploration and experimentation. Although in the informational approach the level of uncertainty is lower, it doesn't mean that it doesn't exist; as it has been mentioned before, prototype itself relies on the unknown and the possibility of failure, which is what allows it to test possible outcomes and iterate from them.

About prototypes

- Realistic prototypes: easy to develop high fidelity prototypes
- Rough prototypes: early rough prototypes

...As design scope has gone beyond material artefacts towards interactions and relations, the role of prototypes, has also changed "Physical manifestation of product ideas are no longer adequate to visualize the emerging design spaces where facing challenges of large-scale social issues" (Sanders, 2013, p. 3). Tools such as role playing and scenarios have emerged as "intangible" solutions to these challenges, similarly, but following a different direction and objectives, technology has evolved to enable high- fidelity representations and simulations of design solutions.

Fidelity is one dimension of prototypes; "... is a measure of how authentic or realistic a prototype appears to the user when it is compared to the actual service." (Virzi, 1989, p. 224) Although sometimes is difficult to draw the line between a high-fidelity and a low- fidelity prototype, there are prototypes that aim at achieving a high level of detail of the design solution, while others seek to simulate situations and interactions regardless the detail of the prototype itself, these prototypes could be considered as rough-prototypes.

According to Sanders (2013), prototypes have evolved in 2 different approaches: (1) *easy-to-develop high-fidelity prototypes and (2) early rough prototypes*. The first one is due to technological progress that has enable an increasingly fast develop of prototypes with realistic details demanding less effort than, for example, the Toyota's CAD models in the 1980's; realistic prototypes might be centered in the tangible dimension of the prototype, meaning the details of the physical or digital artifact. The second one seeks for a different purpose; it focuses in the interactive value of prototypes rather than the look and feel dimension, which is an aspect more intangible than the later.

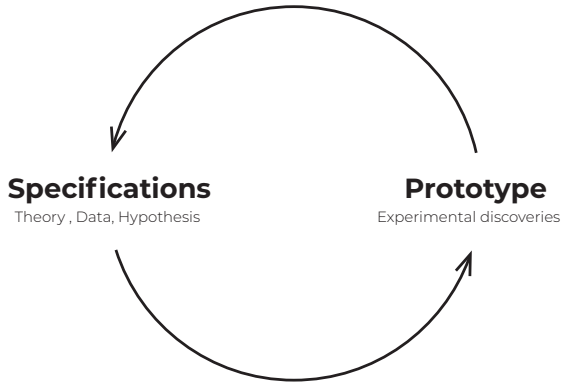
Both have advantages; the first one makes easier to sell design ideas before investing large amount of resources, as it can represent in a very realistic way the proposed solution. The second one can occur at the beginning of the design process and evolve progressively along the project enabling learning through making and leaving space for interaction and collaboration, as it was learnt from software design, "... people are more likely to respond with constructive feedback to a rough prototype of an interactive sequence than to an interactive sequence that looks final". (Sanders, Prototyping for the design spaces of the future, 2013, p. 4)

About prototyping

- Specification-driven approach: prototyping to validate specifications
- Prototype-driven approach: periodic prototyping as a trigger for innovation

To analyze prototyping as a process, two approaches were considered; on one side is the *(1) specification-driven approach*, which relays heavily on data before prototyping and prototypes seek to validate specifications already established. On the opposite side is the *(2) prototype-driven approach*, where prototyping usually appears from an early stage of the design process and contributes to experiment more than to validate. “At times, theory dictates the experimental agenda; at others, experimental discoveries drive the theoreticians” (Shrage, 1996, p. 3) Sometimes this dualism is hard to distinguish, the difference relays in what aspect leads the prototyping process; specifications or prototypes.

Figure 12 Specification-driven and Prototype-driven



Based on theories of Shrage (1998)

Prototyping is moving towards a more prototype-driven approach, nevertheless, this may vary according the culture of prototyping that an organization has, regardless the sector. According to Schrage, the role of prototyping is changing in two aspects: the innovation process and the innovation teams (Shrage, 1996, p. 9)

a) The process

On the one hand, the perception of prototypes as the result of an innovation process is shifting to a belief that periodic prototyping can drive to innovation processes. “Designers that are held to periodic prototyping schedules are likely to become more prototype-driven.” (Shrage, 1996, p. 9)

b) The teams

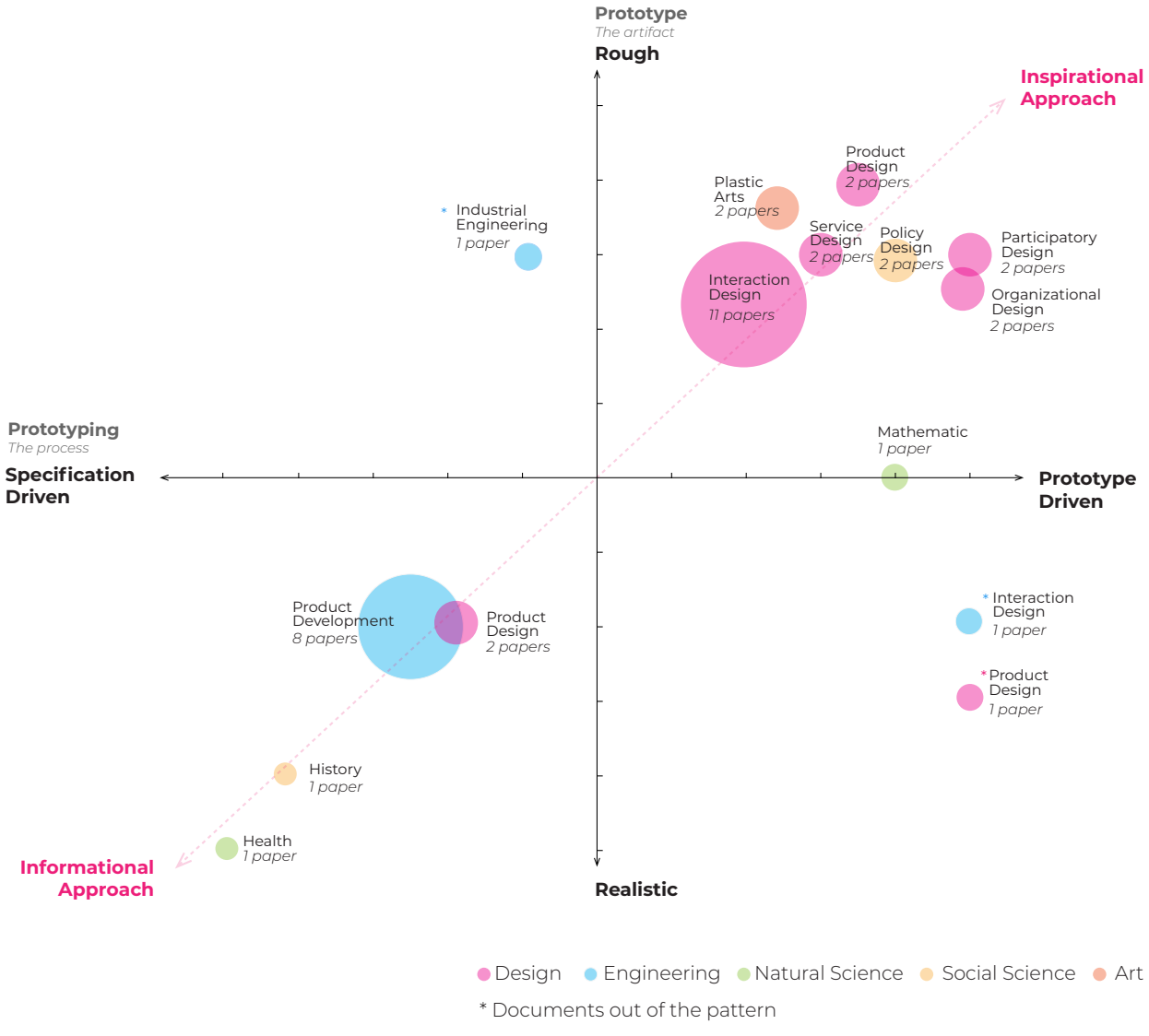
On the other hand, prototyping can also become a mean for communication between teams and stakeholders, acting as a boundary object that invites to dialogue and integration, leading to a cross-functional organization of teams. “... conceive of the process of prototyping as “thinging,” that is, not only as a thing (an object) but as a socio-material relationship in which issues can be dealt with.” (Tironi, 2018)

In this sense, prototyping is becoming a collective activity, which aims to involve stakeholders and users from the beginning of the design process into a practice that can make sense of the future, beyond testing features of a design solution. In other disciplines, such as art, science design and political organizations, prototypes have become part of an emerging culture based on participation, experimentation and innovation. “The experimental and open-ended qualities of prototyping have become a surrogate for new cultural experiences and processes of democratization” (Corsín, 2014, p. 382)

Literature analysis

A literature review was carried out to understand the role of prototypes in different disciplines, and how prototyping as a process and prototypes as artifacts are used. 39 documents from design, engineering, science and social sciences between 1984 and 2019 were analyzed, to see the list of documents go to the Annex in Page 135. In the following graphic, the position of

Figure 13 Analysis of Prototypes Literature Review between 1984 and 2019



Most literature about prototyping belongs to engineering (9 documents) and design (22 documents) fields. Although there are more documents in the literature than the ones reviewed for this study, the most relevant and quoted were selected for the analysis. Regarding other fields, documents in which the word *prototype* or *prototyping* appeared in the title or abstract were considered for the study.

All documents from engineering are in the bottom-left quadrant, with specification-driven and realistic prototypes. In engineering field, prototypes are regarded from a specification-driven approach and the literature gives importance to the technological advances to make high fidelity prototypes possible, such as rapid prototyping. Nevertheless, as it is shown in the graphic, this tendency is getting close to the center and the approaches may vary depending on the specific sector. Prototypes are present during the whole process of design and its role varies according to the stage in which is used.

Most documents coming from the design field are placed on the opposite quadrant of the matrix, expect some documents coming from product design field. In the case of design literature, a differentiation between the micro fields and its prototyping approaches was necessary; organizational and participatory design tend to be closer to the prototype-driven approach, closer to the exploration through the prototype. In the case of service and product design prototypes tend to be rougher but slightly less prototype-driven than the organizational and participatory design authors. As it has been mentioned before, interaction design started the shift in prototyping approaches, focusing more in a prototype-driven approach and establishing methodologies for rough prototypes such as *paper-prototyping* and collaborative activities, this can be seen in the larger number of literature talking about this approaches.

In science most prototypes literature is related to the engineering approach, valuing rapid prototyping as an accurate methodology to test specifications and requirements. However, in the field of mathematics, a design thinking approach was found in which a prototype-driven approach was dominant, from a theoretical framework the author tries to explore possibilities through design thinking methodologies of prototyping. Only one paper coming from social science was found, in this case the prototype was created from specifications to recreate past technologies, *Prototyping the past* by Jentrey, S. (2015) address prototyping from an interesting point of view; instead of prototyping to anticipate to possible futures, the document tries to recreate the past, trying to prototype lost technologies to validate some historical hypothesis of previous times, using 3D models that aim at being as realistic as possible.

Most literature remained in two quadrants of the Prototyping Matrix, they were either specification-driven and realisitc prototypes or prototype-driven and rough prototypes. However, as Sanders (2013) suggest, there are technological advances and changes of mindset that allows different configurations of prototyping approaches. Documents with the * mark are examples of alterantive prototyping approaches, as they are specification-driven and rough or prototype-driven and realisitc. Proto-

type-driven approacges take advantage of technology to easily develope realistic prototypes while exploration parts of the process. To see what documents are located in these quadrants, please refer to the Annex in Page 135.

In terms of policy design, Kimbell and Bailey (2017) present examples of prototyping in governments, such as Dubai and the London studio, highlighting specially the impact prototyping has at organizational levels:

> *"Whereas policy teams can commission 'user' research about citizens and stakeholders and get help in organizing Co-Design workshops, the exploration of policy options through prototyping touches more directly on organizational capabilities in government, democratic commitments and political agendas." (Kimbell & Bailey, 2017 , p. 215)*

Although only two documents containing the words *prototype* or *prototyping* in the policy design field were found and included in the appendix, many documents considering the value of design in policy making were found and considered for the second literature review of this thesis. Kimbell and Bailey (2017) presents the first directions in which prototypes can contribute to policy design and how organizations in public administration are seeking for prototypes that "mediates existing knowledge and anticipates possible futures" (Kimbell & Bailey, 2017 , p. 217) In the following literature review, a deeper understanding on the relations between prototypes and design approaches in design for policy is presented.

4. Literature Review 2 : Prototypes and Design Approaches in Design for Policy

"In an age of audit justifications, social impact and public and ethical accountabilities, the seductiveness of the prototype is hard not to miss. Here is an epistemic culture built on collaboration, provisionality, recycling, experimentation and creativity, which seems as much oriented to the production of technological artefacts as it is to the social engineering of hope." (Corsín, 2014, p. 382)

As it has been mentioned before, changes in design discipline are closely related to prototype's evolution and has opened the scope of both to new fields of interventions, such as policy design: "The technological promises of the prototype seem to have instated a new illusion of democracy: it has brought the worlds of objects, engineering, design, cultural practice and politics together in some new fertile assemblages." (Corsín, 2014, p. 383) The policymaking landscape has also change, and bottom-up approaches have open space for new directions of policy design, such as *design for policy,* with a collaborative and explorative attitude, inborn attributes from design thinking.

According to van Buuren, Lewis, Peters, & Voorberg (2020) there are three design approaches in public administration. The first one is called (1) *Design as Optimization,* which aims at simplifying or solving complex problems form a rational design perspective, usign formal and systematic design methodologies to achieve it. The second one is (2) *Design as exploration,* that is more related with experimentation and learning by doing, it has a creative approach and most of the Living Labs and Innovation units in governments seek to follow this approach. Finally, the third one is called (3) *Design as co-creation,* where the main focus is co-design as a process that involves citizens, private and public institutions and organizations. Although every approach has an specific focus, the three of them share a design approach and can be related to one another. The following table from van Buuren, Lewis, Peters, & Voorberg (2020) summerize the three aproaches:

Table 9 Three design approaches in public administration

	Design as (bounded) optimisation	***Design as exploration***	***Design as co-creation***
Logic	Design as translating knowledge into the best possible solution	Design as a creative art: finding novel solutions to problems	Design as a participatory endeavour: all affected actors engage in defining problems and solutions
Methods used	Tools to translate formal knowledge into artefacts	Tools that foster out-of-the-box thinking and innovation	Tools for dialogue and interaction
Motive	Putting the best available knowledge into solutions helps practice to solve its problems	Design thinking can enlarge the solution space, foster creativity and enhance imaginative power	Design processes can bring actors together, foster learning and build consensus
Related concepts	Evidence-based design, scientific design, knowledge-based design, design as problem-solving	Design-thinking, open innovation, design as imagination	Co-design, collaborative design, participatory design

(van Buuren, Lewis, Peters, & Voorberg, 2020, p. 11)

Returning to the previous table of *Changes in Design Discipline and Emerging Roles of Prototyping,* there is a clear connection between the changes in design, the emerging roles of prototyping and the approaches of design in public administration:

Table 10 Changes in Design Discipline and Emerging Roles of Prototyping: Approaches in Design for Policy

Prototypes Emerging Roles	Design Changes: Symbols *Graphic Communication*	Things *Industrial Products*	Action *Interaction Service Experience*	Thoughts *Strategy Systems Organisations*	Vision *Social Innovation New Paradigms*
Tangible Visible					
First Version of *Representations*					
A result of innovation					
Manifestations *Filters of features*					
Collaborative Activity *Participation and engagement*		**Rise of creative activities for non-designers**	**Focus on purpose, beyond stuff**	"Collective thinking" or "thinging" through prototypes	**Co-Creation as a new knowledge production paradigm Co-design**
Boundary Object *Communication tool across boundaries*				**Design Thinking seeking cultural behavioral change**	
Exploratory *Anticipation of the unknown*				New experimentalism	Speculative design, Make sense of the future
A triger for innovation					

(3) Design as Co-creation

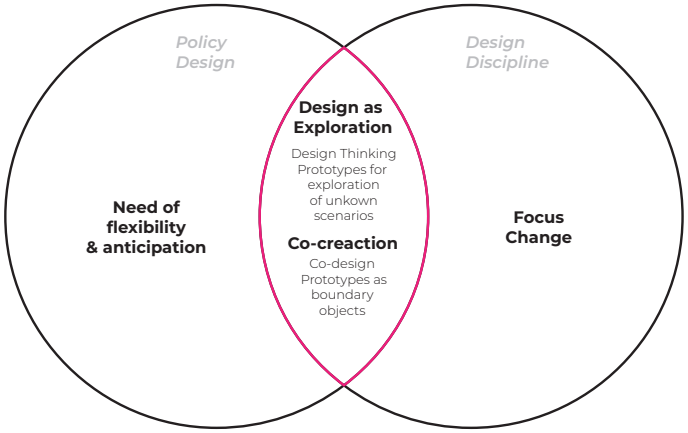
(2) Design as Exploration

Intangible Abstract

Based on theories of Buchanan (2001), Sanders (2013), Lim & Stolterman(2008), Coughlan, Fulton, & Canales (2007)

From the 4 manifestations of changes in design explained by Sanders (2013), two of them are key in the intersection of design and policy making; the first one is an increasingly interest in design thinking within policy design, the second one is co-creation as an growing practice, where co-design leads as a materialization of this model. According to the 3 approaches of design in public administration explained in chapter 2.2., these manifestations belong to the (2) *Design as exploration* and (3) *Design as co-creation* approaches.

Figure 14 Changes in Design Discipline and Design approaches in Policy Design



The focus change in design discipline towards purposes and interactions answers to a need of flexibility and capacity of anticipation in public organization that have encounter in design thinking and co-creation an alternative to face wicked problems in a changing environment where different stakeholders are involved.

4.1. Design as exploration: design thinking and organizational changes

There is a growing appearance of innovation units inside governments departments that base their methodology in this approach. Countries such as Denmark, with the first innovation lab, MindLab, Canada with different innovation and design labs or Australia with the Australian Public Service Innovation Action plan (2011) which led to the opening of several innovation units are proof of this phenomenon ;"Design thinking should matter to governments because many gaps exist between the services governments deliver and what citizens want." (Mintrom & Luetjens, 2016, p. 391)

Design thinking moves the implementation phase of policy design to early stages (Clarke & Craft, 2018, p. 12), involving stakeholders from the beginning and opening the space for experimentation of new policy options and services. This main changes regarding traditional policy making seeks to raise success chances by prototyping solutions and engaging actors involved before investing large amounts of resources, which in this case, sometimes are public.

Nevertheless, the potential of design thinking in policymaking is ambitious and although it could bring many benefits it also represents risks and challenges to achieve what Corsín (2014) calls *anticipation spaces* in the public sector.

> *"...in addition to supporting policy officials in the use of design methods in a service mode, design expertise shapes the emergence of new hybrid policy making practices, and at times problematizes the nature of policy making itself" (Kimbell, 2016, p. 2)*

Within this work frame, prototypes have two important roles: on the one hand, their exploratory attributes allow innovation units in governments to create *anticipation spaces* and experiment possible scenarios, " the benefit of design lies predominantly in broadening the scope of solutions that are taken into account and the room for experimentation" (van Buuren, Lewis, Peters, & Voorberg, 2020, p. 13) Leading to innovation in public sector which can help address wicked problems.

On the other hand, prototypes can act as boundary objects that enable communication and interaction across organizations and between stakeholders, seeking for a structural shift in organizations towards flexible entities capable of experimenting and managing uncertainty and ambiguity. This role of prototypes in design thinking is also related to the Design *as co-creation* approach; "design thinking adopts a systems-based approach and emphasizes the benefits of co-creation that considers the views and resources of a broad range of players within government" (Clarke & Craft, 2018, p. 13) This appeals for an institutional communication beyond silos and expert-driven approaches, which drives us to the following approach.

4.2. Design as a path for co-creation: co-design in policy making

Co-design and the collaborative approach of prototyping offer an alternative to make co-creation possible, engaging stakeholders and final users in the frame of an open government. "In the public sector, co-design is often invoked as a more effective, democratic, or innovative alternative to conventional approaches to community engagement, public participation, service design, and policy development." (Blomkamp, 2018)

This approach contributes to the anticipation to unknown scenarios from a *citizen -centric* approach "co-design may thus help to pre-empt future problems, especially by overcoming the common problem of policy interventions being based on flawed assumptions" (Blomkamp, 2018, p. 736). According to Sanders (2013) prototypes enable not only the anticipation and shape of the future, but the *making sense of it.* "prototypes will not just be seen as representation of future objects but as tools for collectively exploring, expressing and testing hypotheses about future ways of living." (Sanders, 2013, p. 6) Within this frame, prototyping enables a relationship of hope and trust with public institutions, "By enabling people to give life to their early and unrefined ideas using this powerful design method, we encourage them to engage others in collaboratively creating their future." (Coughlan, Fulton, & Canales, 2007, p. 11). However, this might be one of the hardest approach to achieve completely, "collaboration is often restricted to public officials and to consultation instead of co-creation" (van Buuren, Lewis, Peters, & Voorberg, 2020, p. 11) It raises questions about roles and structures as well as representation:

> *"the emphasis on prototype-(ing) not only implies a greater critical involvement of individuals, but also implies a shift from participation to appropriation, which raises ethical questions about whether those involved in the co-design process have been rightfully represented" (Binder, Brandt, Ehn, & Hasle, 2015)*

In this sense, co-design and prototyping face political questions and decisions to be made that might not be considered in design methodologies coming from the design thinking approach. The way stakeholders are identified in industrial co-design processes within the business area are different from the way that stakeholders might be defined within public issues, "As the focus of codesign research is shifting broader societal issues and public concern, the rhetoric and assumptions about stakes and stakeholders are also being challenged." (Binder, Brandt, Ehn, & Hasle, 2015, p. 161)

A literature review carried out by Hermus, Buuren & Bekkers (2020) reveals the following distribution and level of involvement of stakeholders in publications about projects with design approaches in public administration journals between 1990 and 2016, showing that civil servants are the most common stakeholders in design applications, and citizens are not so involved as experts or implementers.

Table 11 Types and level of stakeholders' involvement

	No role	Input	Design	Feedback	Test	Unclear	Total
No stakeholders specified	19	-	-	-	-	-	19
Experts	-	5	2	4	-	1	12
Civil servants (implementers)	10	22 (1*)	19 (6*)	19 (1*)	16 (1*)	1	87
Policy-makers	8	-	2 (2*)	-	-	-	10
Interest groups & private actors	-	7	5 (4*)	3	-	1	16
Citizen(s) (groups)	-	4	4 (3*)	3	1	-	12
Service users	-	4	6 (1*)	3	4	-	17
Total	37	42	38	32	21	3	173

Notes:
* = group/committee with representatives of stakeholder groups
[1] Because multiple groups of stakeholders can be involved at multiple stages in one process, this table works with absolute numbers (of instances of stakeholder involvement) rather than percentages.

(Hermus, van Buuren, & Bekkers, 2020, p. 32)

This graphic demonstrates that there are still challenges in co-creation processes and prototyping might be facing similar challenges in their process when aiming at a collaborative activity. In the following section, a description of the challenges identified through the second literature review are presented.

4.3. Challenges of prototyping in policy design

Prototyping as a collaborative activity for exploration and communication between stakeholders can defy some existing structures and relations between the actors involved. Understanding that prototyping might not be suited for all policymaking scenarios, there are key aspects to make prototyping a sustainable practice in policymaking, when needed. For this thesis, the following challenges were identified considering the literature analysis of the role of prototypes and literature review of design for policy:

Challenges in Design as Exploration

a) **Make the process of prototyping last in time as an iterative process:** As it has been analyzed in the emerging roles of prototyping regarding the process, periodic prototyping can drive to innovation processes and tends to move towards a *prototype-driven* approach. (Shrage, 1996, p. 9)However, the time and resources it requires might be a limitation in a policy-making framework (Clarke & Craft, 2018, p. 14). Making prototyping sustainable in local context means that the process won't be a one-time only event, but a systematic practice that endures through time and influence decision making and problem framing within co-creation practices.

b) **Learn from prototyping and transfer knowledge created:** one of the key aspects of experimenting and prototyping is learning and iterating from failure, otherwise the value of these practices is not sufficient; "governments experiment all the time – rolling out new policies on the populace, but without really learning if they are doing any good" (Breckon, 2015, p. 6) What might differentiate prototyping experiments is the knowledge that it generates and how this knowledge is applied to future scenarios and decisions, as well as who is getting access to the knowledge created.

c) **Deal with uncertainty and failure in the local context:** as it has been said previously, one of the key features of prototyping is the incorporation of failure and ambiguity, however, public sector and policymaking usually tries to reduce or eliminate these factors, instead of dealing with them.

d) **Measure outcomes and outputs of prototyping:** in terms of accountability, outputs and outcomes are important to measure in the public sector, as they serve as proof that the public resources have been, or could be, well invested. It is also a way to legitimate decision making and its implementation. Different authors agree that there is little evidence about the benefits that design thinking approach can bring to policy making and the possibility of scalability of this approach. (Lewis, McGann, & Blomkamp, 2020) (Clarke & Craft, 2018).

e) **Development and dissemination of design capabilities:** as it has been said before, experimenting and prototyping calls for a disposal to deal with uncertainty, which requires a cultural change and capacity building within the participants involved in the process, "The realization of this alternative approach to policymaking will depend however on how design thinking is operationalized and drawn upon in practice by governments and other key policy actors." (Lewis, McGann, & Blomkamp, 2020, p. 124) Hence, the capacities and mindset of people involved must be prepared to face this challenge. Although prototyping itself can contribute to capacity building and transformation, the learnings from this process must be disseminated and shared to create a bigger impact and improve the quality of prototyping as a process through time.

Challenges in Design as Co-creation

f) **Align prototyping outputs with policymaking context:** the outputs of participation and co-creation need to 'fit' within the machinery of policymaking: there is a need of tools and machinery to incorporate the results of co-creations and prototyping into the policymaking system (Deserti, Rizzo, & Smallman, 2020) As Clarke and Craft (2018) enunciate, one weak point of design thinking in design for policy is to ignore the political context that permeates decision making. As it has been said before, there is a need to meet *top-down* and *bottom-up* perspectives in a middle point that allows grass roots innovation to scale and policies to be aligned with citizens needs and governments constrains and agendas.

g) **Align stakeholders' expectations:** a collaborative process means dealing with the expectations of all the participants, one challenge of policymaking is that it entails several stakeholders from private and public sector with different motivations and needs that build the expectations towards a prototyping process. Prototypes as boundary objects might enable a collaborative channel of communication and negotiation, nevertheless, different (even opposite) expectations of the actors involved could hinder the process.

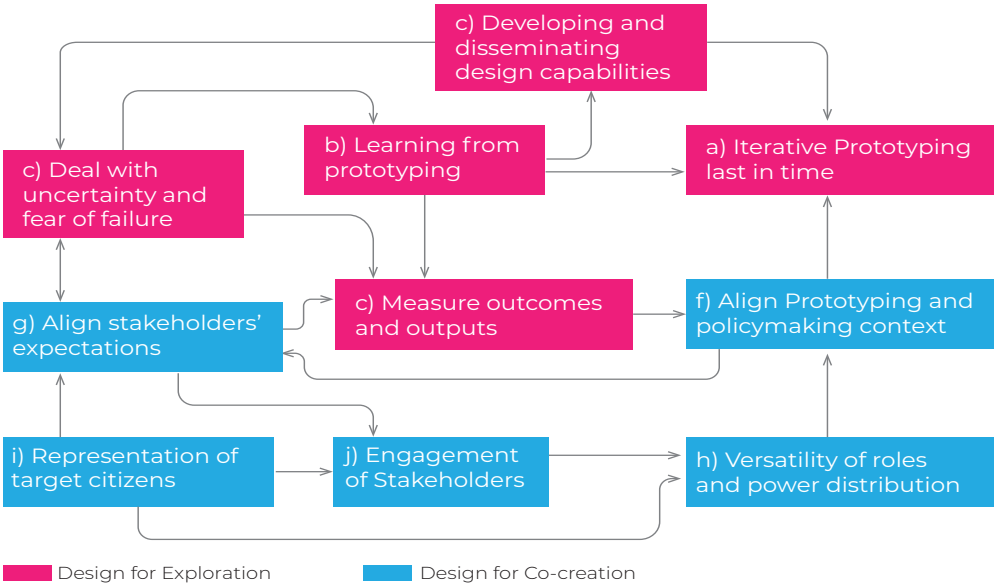
h) **Versatility of roles and power distribution:** co-design and in general *bottom-up* approaches defy hierarchal structures and traditional roles (the expert- the *lay people,* the citizen as a customer – citizen as a co-producer) which might me hard to change within public institutions. Clarke and Craft (2018) talk about the complexity of different public entities and policies implied in one issue, and the impact of *policy mixes* during the policy design process. These factors might affect the potential of the output and in consequence, the outcome of prototypes.

i) **Representation of target citizens:** the participation of people in the prototyping process within a design for policy framework, raises questions about democratic processes and representation of affected communities, **"**The transition from prototype (-ing) to implementation is the assurance that an outcome is reached and that a sort of decision has been made, but it is also a transition from participation to appropriation that may well raise questions as to whether those affected have been rightfully represented." (Binder, Brandt, Ehn, & Hasle, 2015, p. 156) Regarding this aspect, the question would be how is design thinking and its methodologies different from other participatory initiatives from government? "design thinking suffers from the same limitations of other policymaking approaches by protecting the powerful." (Lewis, McGann, & Blomkamp, 2020, p. 112)

j) **Engage stakeholders:** prototyping requires time and energy to interact with others involved in the process, for actors to invest time and resources in this process, it's necessary to engage them to achieve quality contributions and higher participation.

However, it is important to clarify that the challenges are not elements independent from each other, rather are part of a system and some aspects are strongly interconnected. Moreover, the fact that the challenges are being categorize according to the two approaches of design in public administration doesn't mean that they are exclusively from one approach, as has been mention before, both approaches are complementary, however, some challenges are core from specific approaches.

Figure 15 Systemic view of challenges of prototyping in design for policy

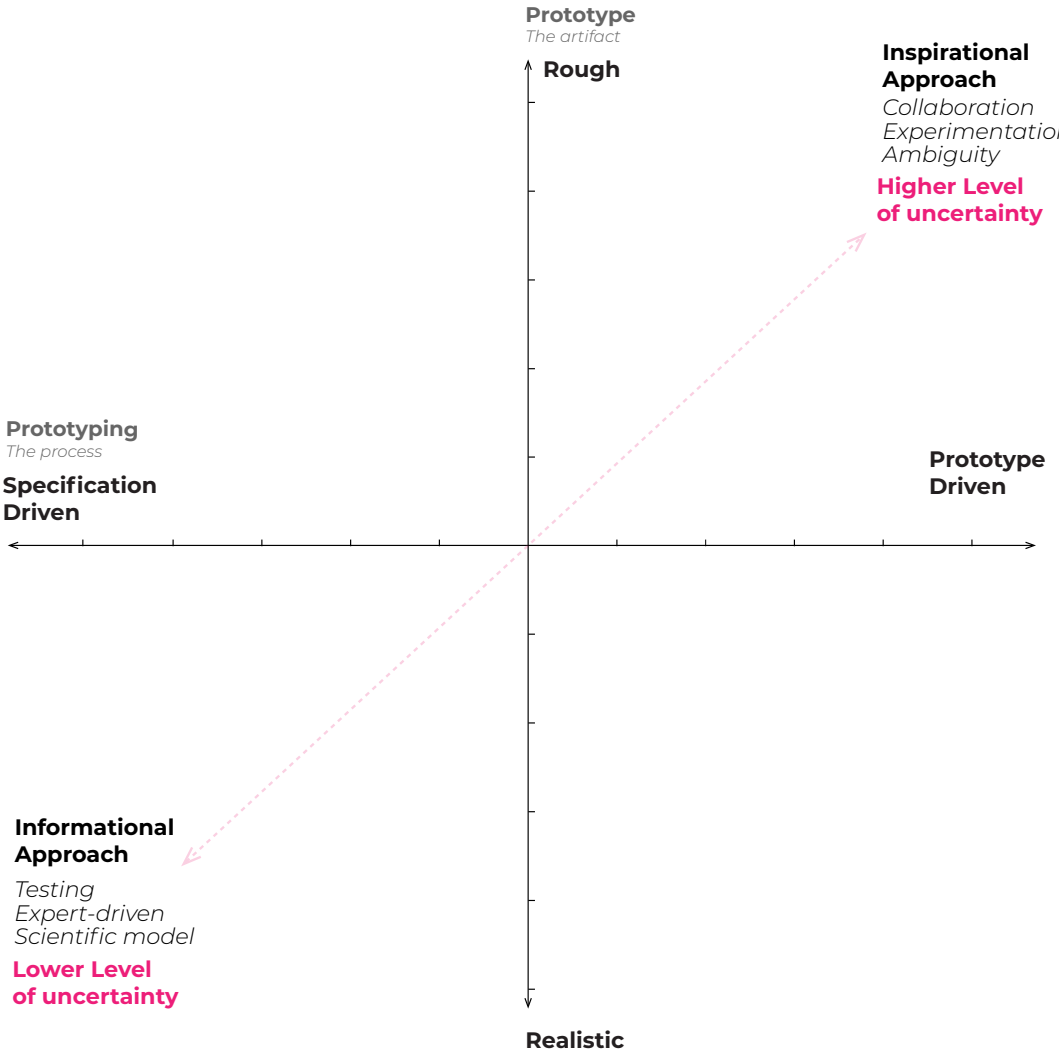


The identification of these challenges helped to address this thesis research, together with the triangulation of the information of the previous literature review, the research questions were established as is explained in the following chapter.

5. Triangulation of information

From the two previous literature reviews, two main outputs contributed to the development of the research questions and following analysis of the ten SISCODE co-creation labs: The Prototyping Matrix and the list of challenges of prototyping in design for policy.

From the first literature review about notions of prototypes and design evolution, a Prototyping Matrix with two dimensions to analyze prototyping approaches and its level of uncertainty was developed. This Matrix was applied to the literature review and was used to analyze the SISCODE co-creation prototypes.



From the second literature review about prototypes in design for policy a list of challenges of prototyping in design for policy were identified. First, the list of challenges was clustered according to the emerging design approaches in policy design: design as exploration and design as co-creation. For this dissertation, a set of ten labs included in the SISCODE project, an EU funded project aiming at stimulating co-creation in policy-design were selected. These ten cases have been selected because they represent a unique sample of co-creation labs currently engaged in applying co-design as a methodology to operationalize the engagement of policymakers in the development of prototypes as new solutions to local challenges across Europe. Each challenge was contrasted with the objectives of the SISCODE project to identify which of them were

being already covered by the project and which of them were not completely covered. Below, the table of challenges, its category and state according to the SISCODE project is presented:

Approach	Challenge	Covered by SISCODE
Design as Exploration	a) Make prototyping last in time as an iterative process	Yes
	b) Learn from prototyping and transfer knowledge created	Yes
	c) Deal with uncertainty and failure in the local context	No
	d) Measure outcomes and outputs of prototyping	Yes
	e) Development and dissemination of design capabilities	Yes
Design as Co-creation	f) Align prototyping outputs with the policy making context	Yes
	g) Align stakeholder's expectations	Yes
	h) Versatility of roles and power distribution	No
	i) Representation of target citizens	No
	j) Engage Stakeholders	Yes

The challenges that are not being covered by the SISCODE project in *Design as Co-creation,* are related to political issues: (*h) Versatility of roles and power distribution* and *i) Representation of target citizens* and although these challenges are important, they go beyond the limits of this design thesis scope. Therefore, this research focused on the challenge related to the *Design as Exploration* approach*: c) Deal with uncertainty and failure in the local context*. In the following section, a brief explanation of what uncertainty means and how is it related with prototypes notions is presented.

5.1. Dealing with uncertainty and fear of failure

"Ignorance and uncertainty about environmental problems are not overcome by recourse to participatory methodologies alone. Rather creative dialectics between science and art, science and politics, experts and lay people, reductionism and holism, local perspectives and global perspectives need to be actively constructed" (Woodhill, 2010, p. 66).

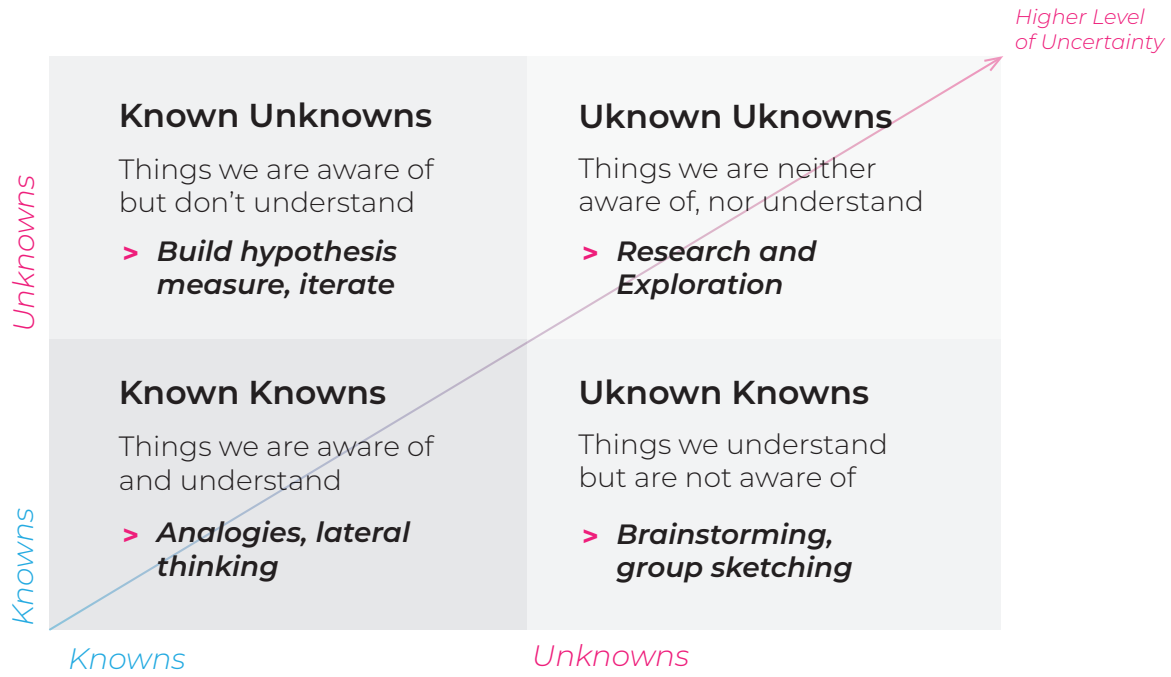
In the case of prototypes, the issue with uncertainty is not about how to reduce it, but how to embrace it and learn from early failures. In *Design for Exploration*, experiments and innovation projects start with an objective and a goal, nevertheless the exact steps and effects of the decisions to be made cannot be anticipated if the intention is to explore, rather to validate initial assumptions. In a *specification-driven* prototyping processes the possible outputs can be foreseen, however, in *a prototype-driven approach*, uncertainty is one of the key features and this means facing the possibility to

fail, or to obtain unexpected outputs. Prototypes are “deliberately fabricated to ‘hang’ in a regime of uncertainty: it is a temporal construction that tolerates uncertainty as a reasonable and feasible outcome.” (Corsín, 2014, p. 391)

Uncertainty is defined as a situation or something that “is not known or certain” (Cambridge Dictionary, 2020) . Corsín (2014) talks about prototypes experiments as traps for unknowns, following the metaphor of Rheinberger (1997); prototypes are meant to be like a spider’s web, they must predict what the spider is unable to foresee and be able to catch these *unknowns*. “The trap works therefore to ‘artefactualise’ the illusions of self-movement: it opens up a space and time where the mechanics of regularity and predictability and the eventfulness of the unknown are folded and kept in mutual suspension.” (Corsín, 2014, p. 390).

The concept of *unknown unkowns* comes from the Johari Window, a model designed to understand interpersonal relationships created by the psychologists Joseph Luft and Harringtong Ingham in 1955. Later,Donald Rumsfeld, United States Secretary of Defense used this concept to answer questions about the lack of evidence of Iraq’s government weapon distribution to terrorists groups. (Justo, 2019).According to the complexity of a context, the *unknown unknowns* emerge, and the approach to address them varies according to the scenario.

Table 12 The Johari Window and design techniques to surface type of knowledge



Based on Joseph Luft and Harrington Ingham (1955) and (Justo, 2019)

In the public sector, a relation of trust between citizens and public institutions is important, and so it is the need to respond to complex contexts and wicked problems. “Certainty is the foundation of trust; you need to create certainty for other people. Uncertainty is the foundation of growth; you need to embrace uncertainty for yourself.” (Yang, 2018) Manage the equilibrium between certainties that generates trust with people and exploring through uncertainty is a challenge, especially in policymaking where, traditionally, the uncertainty and ambiguity are meant to be reduced as much as possible. “Government tends to bury failure or to learn from it only in the sense of veering away from it.” (Schön D. , 1973)

.Bringing uncertainty from the design discipline, where this concept usually is equal to opportunity, to policymaking context, where it is associated with risks and failure, might prevent stakeholders to engage with the process. The required skills to navigate through uncertainty are trained within the design discipline, however the implications and this capacity change in the design for policy. This thesis aims at understanding this phenomenon.

5.2. Research questions

Prototyping brings uncertainty into design for policy because of its open nature, this uncertainty might be perceived as negative within the policymaking context, generating fear of failure and hindering engagement of policymakers in the process. This thesis aims to investigate the interaction between the process of prototyping and the engagement of policy makers in co-creation through the following research questions.

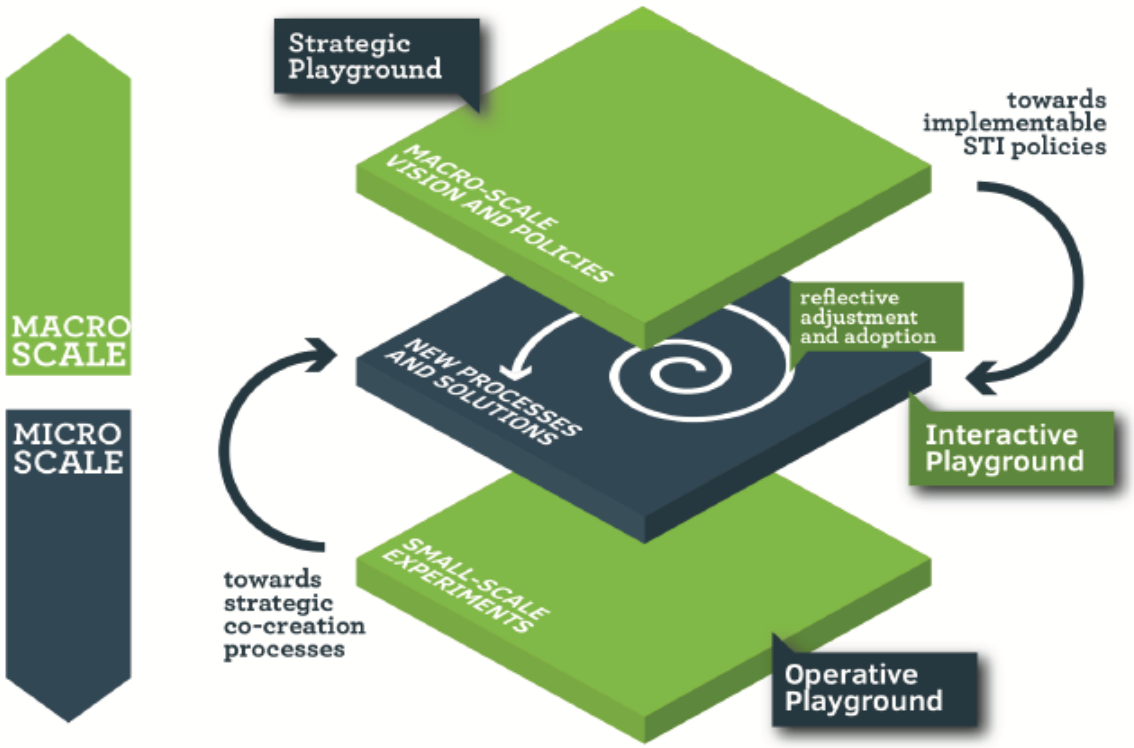
- How do policymakers interact with the uncertainty of prototyping in co-creation processes?
- Is the uncertainty of prototyping a barrier for policymakers’ engagement during co-creation processes?

6. Comparative analysis of SISCODE case studies

In the following chapter the description of the SISCODE project and its ten co-creation labs is presented, followed by a comparative analysis that aims at addressing the research questions previously mentioned.

SISCODE is an EU funded project that aims at “understanding co-creation as a bottom-up and design-driven phenomenon” (SISCODE, 2017, p. 4) to do so, the project has three main objectives; the first one is to study the existing co-creation ecosystems in Europe and identify effective practices and outcomes of involving people in collaborative processes within science and innovation, the second objective is to “ experiment with design as a new system of competences on which to build capacity for implementable co-creation in Responsible Research Innovation (RRI) and Science Technology and Innovation (STI) policy making.” (SISCODE, 2017, p. 5), the third and final objective is to understand the transformations needed to embed co-creation in RRI processes and STI policymaking, having into account the cultural, organisational and procedural factors (SISCODE, 2017, p. 5) SISCODE aims at closing the gap between policy design and its implementation through an “intermediate playground” that connects the two levels: decision makers at high levels and communities and stakeholders at a micro-scale.

Figure 16 Interaction between policymaking and implementation



(SISCODE, 2017)

In order to achieve these objectives, the project built a *transnational system of 10 co-creation laboratories* from existing co-creation networks, such as the European Network of Living Labs (ENoLL), the international network of Fab Labs and the European Network of Science Centres and Museums (Ecsite). The system of 10 co-creation labs selected is composed by: three Fab Labs, three Living Labs and four Science Museums distributed as follows:

Fab Labs

Fab Labs are community-based labs that aim at "democratizing access to the tools for technical invention" (Real, et al., Co-creation Journeys, 2019-1, p. 33) They act as a manufacturing network that also disseminates technical education and acts as a research laboratory. The Fab Lab Network, composed by fabricators, artists, scientists, engineers, students and professionals is composed by approximately 1.000 Fab Labs (Real, et al., Co-creation Journeys, 2019-1, p. 33). From the group of Fab Labs, SISCODE is working with *IAAC.Fab Lab* Barcelona, from Spain, *Polifactory* of the Politecnico di Milano, Italy, and *Underbroen* in Copenhagen, Denmark.

Living Labs

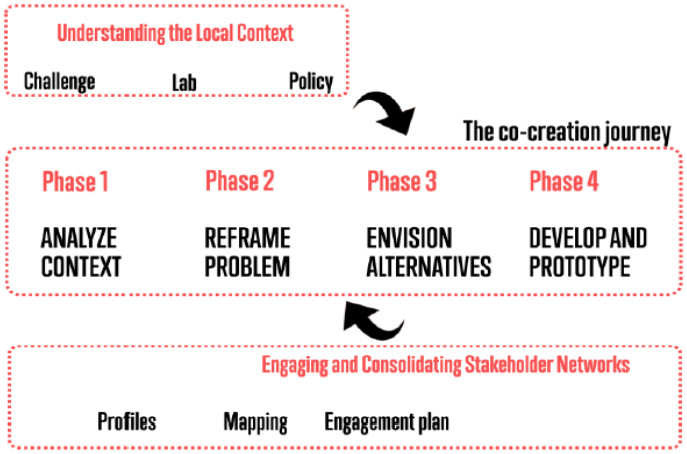
Living Labs are characterized by its "systemic co-creation, multi-stakeholder participation and active user involvement in real-life settings through multimethod approaches." (Real, et al., Co-creation Journeys, 2019-1, p. 36). The ENoLL has more than 400 Living Labs (Real, et al., Co-creation Journeys, 2019-1, p. 36). SISCODE is working with *PA4ALL* in Serbia, *Krakow Technology Park (KTP)* in Poland and *Thess-AHALL*, in Thessaloniki, Greece.

Science Museums

Finally, the Ecsite, with more than 400 organizations belonging to the network, seeks to involve people with science through accessible, interactive exhibits and programs by fostering creativity and critical thinking (Real, et al., Co-creation Journeys, 2019-1, p. 39). SISCODE is working with *Cube Design Museum*, in Kerkrade, Netherlands, *TRACES* in Paris, France, *Ciência Viva*, in Portugal and the *Science Gallery Dublin*, Ireland.

SISCODE accompany and support the 10 labs in their real-life experimentation with design methodologies aiming at reducing the gap between policy design and its implementation. The process of the Labs is divided in 4 phases as it is described in the following graphic:

Figure 17 SISCODE co-creation phases



(Real, et al., 2019-2)

For the purpose of this thesis, the documentation from *Phase 1, 2* and *3* has been analyzed to understand and have general understanding of the co-creation journey of the ten labs. The following sections describe their journey focusing on their prototyping approaches and relation with policymakers and other stakeholders.

6.1. IAAC Fab Lab Barcelona – Fab Lab

"The main values behind the co-creation approaches of the lab relies with digital empowerment, social integration, information access, knowledge sharing, open source philosophy, peer2peer production and learning by doing." (Real, et al., Co-creation Journeys, 2019-1, p. 50)

The Fab Lab Barcelona is part of the *Institute for Advanced Architecture of Catalonia,* supporting educational and research programs related with human habitat (Fab Lab Barcelona , 2020). Their main interest is related to environmental and social issues, which combined with their technological capacity allows them to participate in several project.

One of their main strengths is their capacity to digitally fabricate products, connected devices, platforms and visualization tools. Their main lab is in Poblenou, where the lab has spaces for wood, electronic, textile and metal transformation, as well as research and digital fabrication spaces. Their second installation is called the Valldaura Labs, in the Collserola Natural Park in Barcelona, where the self-sufficient habitat research centre Green Fab Lab was created. In the space the lab has laboratories of energy and food production.

The lab has experience in co-creation based on digital empowerment and knowledge sharing, where prototyping is key within their co-creation activities and is perceived as "their main strength to success in engaging with a strong diversity of stakeholders." (Real, et al., Co-creation Journeys, 2019-1, p. 50). The lab claims to make special efforts to gather insights and learning from the projects to create knowledge beyond the scope of each specific project.

Definition of the challenge

The challenge of this lab is focused on the transition towards a more circular neighborhood, specifically the neighborhood of Poblenou, specifically in terms of food distribution and transformations of local food surplus and waste. For this purpose, the mapping of current initiatives related to the challenge was required, together with the mapping of stakeholders and their relations.

In the *Phase 1. Analyzing, the context,* the lab did a research about existing policies related to food cycles at local scale, by participating in related events and carrying out 35 informal interviews with local actors. As a result, a map of the neighborhood diversity and local stakeholders was made.

Table 13 Fab Lab Barcelona Stakeholders

Main Stakeholders	Missions	Main interests in SISCODE's pilot
S1 – Local associations (Neighbourhood Associations, Taula Eixe Pere IV)	Community engagement, disseminate and discuss issues that involve the residents well-being	Community capacity building; knowledge
S2 – Restaurants 0km and cooperatives (Leka, CCP9)	Offer and distribute local and seasonal products	Co-create bio-based products to use in the spaces (packaging, plates, bowls, bioplastic) Be part of local changes Learning from/with neighbours
S3 – Urban gardens and composting initiatives (Urbonera + connect Hort)	Regenerating the city and community solidarity. Dissemination and use of composting and vermicomposting systems for individuals and community.	Support for the development of composting systems and logistics in Poblenou. Enhance the potential of urban gardens as social / open-minded communities
S4 – Maker spaces and material designers (Macus and Fab Textiles)	Spaces where people gather to make and create. The members share supplies, skills, and ideas, and often work together on projects.	Collaborative projects for material and production innovation, improvement of the local ecosystem of Poblenou; application / learning of technologies
S5 – Projects with food redistribution (Taca d'Oli)	Collection of surplus/ wasted food at local markets, meal preparation with volunteers and distribution to low-income population groups	Support with knowledge and solutions to improve logistics for food redistribution

(Real, et al., 2019, p. 19)

During the *Phase 2. Reframing the problem*, a co-creation workshop named "Synergy Soup" was carried out with the identified stakeholders to spot the synergies between them, identifying their resources and needs. During the workshop, each participant shared their projects and a vegetable to add to the soup, which they all enjoyed later. At the end of this workshop, the lab gathered more than 50 needs, 38 resources and 31 ideas of projects from the participants to address the challenge.

Table 14 Fab Lab Barcelona Challenge

What was the former challenge?	The original challenge focused on the field of urban agriculture by engaging students and local communities to contribute to the redesign of future generations of vertical farming systems within a short-loop and innovative approach.
Synthetic formulation of the reframed challenge.	Fab Lab Bcn aims at identifying and stimulating new synergies among the local community in order to co-develop educational and logistic supports for better redistributing, upcycling and composting food locally. To do so, a specific logistic for food waste collection and community engagement will be performed. Additionally, Fab Lab will provide a set of knowledge transfer sections to support the local design and production of specific tools; and finally, it will be set up a collection data system to capture the flows of material, energy and resources of the entire system.

(Real, et al.,2019, p. 19)

The idea

In the *Phase 3. Envision alternatives,* the lab carried out 5 events for ideation and sharing experiences. Which enriched the knowledge gathered from the previous phases and contribute to refine previous ideas. In the end, the lab selected one idea to develop: a symbiotic system for food surplus and bio waste valorization at a neighborhood scale, " Fab Lab Barcelona will foster the means necessary to explore the co-development of three circular community projects connected to the food value chain: food waste redistribution, bio-waste based material development, collective composting" (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 19)

As result from the previous phases, three community services related were selected: the first one is a logistic and resource service for food waste collection, the second one is a set of educational initiatives to support the production of dedicated tools, and finally, an environmental measuring set to map the material, energy and resources flows.

The prototypes

For the *Phase 4. Develop and Prototype,* the lab built personas, stakeholder's journey, stakeholders' map, a business model canvas and a service blueprint of the ideas to plan the prototyping sessions, in which the main stakeholders involved were local restaurants, stores and schools, makers/designers, residents, students and members of urban gardens and cooperatives. At the beginning of this phase the lab recognized the level of uncertainties related to the engagement of the stakeholders involved that could affect their plans:

> *"For now, many uncertainties are still present, and the pilot has to consider the different timelines of people engaged and the global financial difficulties of the entities. As it relies mostly on the free participation of many participants, the success will depend on how far the model and proposed activities will be perceived of interests for ongoing project development as for building feasible and viable scenario." (Real, et al., 2019-2, p. 23)*

The lab planned two loops of prototyping: the first one was a Biomaterial Workshop co-organized with the City Council, where the participants had the chance to (1) explore with bio-waste to create new materials, (2) co-design a circular *cargo bike* and (3) propose collective actions for the European Week of Waste Reduction (EWWR).

The second prototyping loop was the *Remix el Circular Barrio – El Barrio Circular #Poblenou*, an event that aimed at creating a set of prototypes focusing on a type of local resource to explore opportunities along with community actors. The event started with an open call for projects responding to the challenge, from where the lab selected and diffused those that were considered more promising. After the selection, the lab carried out a series of workshops to experiment with the materials, develop recipes, design product and analyze biodegradability and environmental impacts of the prototypes.

Policymakers engagement

The lab has had meetings and attended to events with different organizations of the City Council of Barcelona in charge of ongoing projects and regulations related to the challenge. However, the lab faced difficulties involving them in the co-creation process, some policymakers prefer to wait for results before getting involved in the project "even the policymakers that were not actively participating on previous activities, they open possibilities to contact and ask for collaboration once the project starts having results." (Real, et al., 2019-2, p. 25).

6.2. Polifactory – Fab Lab

Polifactory is an interdepartmental research laboratory focused on the relationship between design and new digital manufacturing processes (Politecnico di Milano, 2020). It is part of the design department together with the department of mechanics and the department of electronics, information and bioengineering of the Politecnico di Milano, in Italy. It is dedicated to experimental training, research and advanced manufactory of product-services. Polifactory is open to teachers, researchers and students of the Politecnico di Milano and other organizations.

Definition of the challenge

The challenge is framed within the health and wealth ecosystem, in which Polifactory decided to investigate the physical-motor needs of children diagnosed with cerebral palsy. This condition is the most common physical disability in childhood (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 30) and it affects the movement of the child at different levels.

For the challenge, the lab decided to focus in the translation of movement into sound stimulus, based on the principles of *proprioception* which is a "set of functions which control the position and movement of the body, based on information collected by peripheral receptors called proprioceptors." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 30) To do so, the lab decided to work with the FightTheStroke (FTS) association, with whom the lab established and reframed the challenge.

In *Phase 1. Analyzing the context*, the lab identified the main stakeholders and carried out a literature review about co-design in health care and case studies within this framework; although the lab identified several cases of co-creation labs working on healthcare issues, most of them were not related with policymaking processes. Polifactory also consulted design, engineering and business experts in the area that could continue in later phases of the co-creation journey:

Table 15 Polifactory Stakeholders

Main Stakeholders	Missions	Main interests in SISCODE's pilot
Patients association (FightTheStroke)	Support; Innovate; Share; Provide knowledge; Disseminate	Test a new "solution"; involve their associates; be in an international network
Caregivers and patients	Support; Feel good, safe, and comfortable; Improve; Have fun	Co-create a solution to improve their children movements and social life; Share their experience
Industry and innovation community	Experiment; Prototype; Earn	Support; Experiment
Scientific and research community (IoT Lab, DEIB)	Experiment; Innovate; Disseminate	Support; Experiment; Innovate
Policy makers	Support; Manage; Facilitate	Do not know yet

(Real, et al., 2019-2)

In *Phase 2. Reframing the problem,* the lab carried out a research about existing technological and medical solutions in the field of the challenge, consulting experts and patients' associations. Polifactory contacted caregivers (parents of children) through a survey to understand better their main issues, needs and impairments regarding cerebral palsy, and policymakers to understand their level of knowledge about co-design and the existing policies related to the challenge. As result from this phase, the lab mapped four main technological and musical tools to test with children during a co-design session (Kinect technology, the Theremin, the Makey Makey, and SoundMoovz bracelets). And based on the answers from the survey sent to the caregivers, the lab reframed the challenge as follows:

Table 16 Polifactory Challenge

What was the former challenge?	The former challenge was focus on "Health & Wealth of young stroke survivors". After several moment of discussion with both the president of the association and parents of children, who are members of the association, we understood that stoke is only one of the causes of cerebral palsy; therefore, we widened our focus including all children diagnosed with cerebral palsy. In addition to that, we also decide to address our attention more on wealth than on health because of bureaucratic constraints and on the Fs "fitness" and "fun" in connection with "function" (proposed by The International Classification of Functioning, Disability and Health from WHO).
Synthetic formulation of the reframed challenge.	According to what previously said, we named our challenge "BODYSOUND. Co-create innovative solutions to improve the movement of children with cerebral palsy". We specifically focus on music and movement (dance) in order to explore the physical perceptions of music.

(Real, et al.,2019-2)

Regarding policymakers' information, "Some policy makers declared their interest, but they are still on process of answering our online form." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 32)

The idea

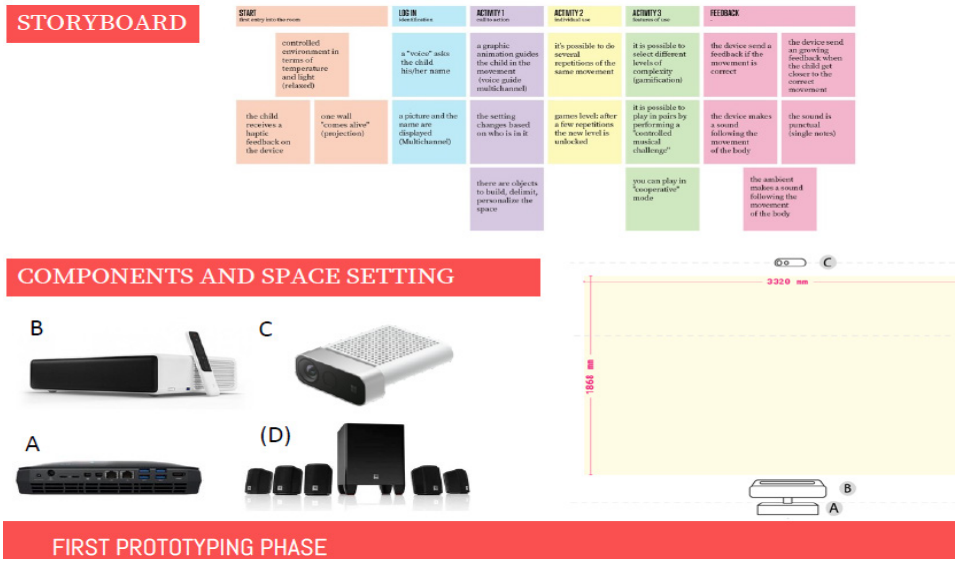
During *Phase 3. Envision alternatives,* two co-design sessions with the parents of children (caregivers across Italy), two experimentation labs with the children (patients) was carried out. In the end of this phase, the lab chose one idea called *BODYSOUND,* a solution that seeks to enable a space for activities that are not directly connected to rehabilitation and therapy, rather to playfulness through movement:

> *"is a system of motor stimulation of the limbs based on the transformation of movement into sound. Within a sensorized room, children can move (either following instructions or freestyle) and transform their movement into sounds (or melodies). The room is able to detect the child's movement and to send, through a wearable device, a haptic feedback to guide him/her in the right execution of the movement." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 37)*

The prototypes

The prototype seeks to "relate the different elements of the system (environmental detection, haptic device feedback, movement guide and generated sound). In parallel we will try to test it to co-develop the children's user experience and validate the effectiveness of the chosen technology." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 37) To achieve this, a product-service prototype was develop for the first phase of the prototype; the activities of each step of the prototype were planed and the space was equipped with existing technology devices as it can be seen in the following image:

Figure 18 Polifactory's Prototype space equipment

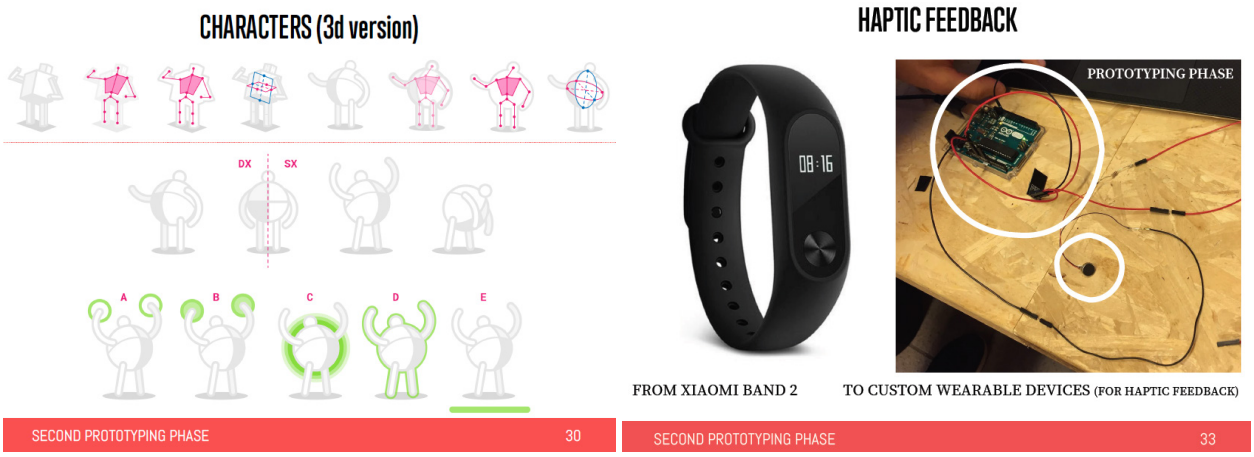


(Sedini & Cipriani, 2020)

A first version of the software was developed for the prototype and it was tested internally, then with kids and therapists:

(Sedini & Cipriani, 2020)

Based on the results and feedbacks form the first phase of the prototype, for the second phase the software became more realistic and some adjustments for the haptic feedback were made, as it is shown in the following images:



(Sedini & Cipriani, 2020)

Policymakers engagement

The lab has carried out meetings with policymakers to understand their level of knowledge of co-design practices and to understand the current situation regarding the challenge in the policymaking context. Along the co-creation journey, the lab has established contact with the Municipality of Milan through different entities such as the commission for Social Policies, Health Services and Volunteering, as well as the Council for Participation, among others. Polifactory has sent presentation of the pilots and a report about the results obtained by the co-creation workshops and experimentation labs.

6.3. Underbroen – Fab Lab

"Underbroen is a creative platform where the creation of prototypes, products and innovation processes become the focal point for dialogue and development of solutions for local and urban production." (Real, et al., Co-creation Journeys, 2019-1, p. 36)

Underbroen is a "prototype and pre-fabrication facility where traditional craftsmanship is combined with modern digital fabrication technologies" (Real, et al., Co-creation Journeys, 2019-1, p. 35) and it is co-founded by the private company BetaLab and the non-profit association Maker, which seeks to "promote and support maker communities and fab lab activities, methodologies and tools to the broader public and sectors. (Real, et al., Co-creation Journeys, 2019-1, p. 35), this non-profit association works as a network of co-creation and collaboration across different sectors and stakeholders within Denmark and Northern countries. The *Makers-Community* counts with 70 members from industrial design, architecture and entrepreneurship backgrounds and is one of the strength points of Underbroen.

The lab has a 300 m2 space equipped with laser cutters, 3D printers, wood, metal and electronic workshops and open innovation materials and tools for ideation and rapid prototyping. Maker has a rich knowledge of materials, design and production processes.

Their approach to co-creation if through hands-on activities, "where tools such as hackathons, prototyping and prototyping is part of the initial phases, and is often used as a tool as part of the ideation phase (and ongoing), to complement traditional brainstorming and post-it exercises." (Real, et al., Co-creation Journeys, 2019-1, p. 69). Underbroen divide co-creation process in two levels: the first level is when it happens spontaneous (informal) and the second level is when the co-creation is facilitated or mediated between the *maker community* and other stakeholders.

Definition of the challenge

The challenge is about the local recycling of plastic waste in Copenhagen, aiming at a "circular systemic innovation and holistic production models for recycling plastics that take the whole model chain - from local generators of waste plastic to end-buyers of locally produced goods - into consideration in a way that is economically viable and scalable." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 43), focusing on micro entrepreneurs and small-scale manufacturers and local generators of plastic waste.

For the *Phase 1. Analyzing the context,* Underbroen did two types of desk research: the first one about circular economy solutions (technologies, best practices and system models of recycling), and the second one about policy and policymaking, mapping stakeholders at a local, national and European level. Thanks to this research, the lab identified the challenges for developing a small-scale prototype of plastic recycling

system, which helped them to understand the complexity of the field and lead them to decide to frame their prototype into one fraction of the whole system first, focusing only on plastic waste generated from local SMEs and manufacturers.

Table 17 Underbroen Stakeholders

BetaLab / BetaFactory	Run makerspaces in Copenhagen, help makers scale their projects and business, design and product development, local and digital production.	To be part of design prototyping and model prototyping. To be part of the future scaled model.
Von Plast	Educate citizens, micro entrepreneurs and SMEs on plastic recycling. Act as a processor in the local system.	To be part of finding solutions for a circular system model for recycled plastic and to develop their business model in order to scale.
ChipChop, SILK Design Studio, Nils-Ole Zip (microentrepreneurs)	Produce locally sourced, sustainable products and goods. Develop their business and production to local sourcing of materials and extended producer responsibility commitments.	Development of product prototypes for assessment of quality. Access to the recycled building materials at a competitive price with the potential of quoting/ordering specific products.
AAU	Improve circular design models and processes using their knowledge and expertise on production systems and environmental impact, etc.	To work with a real-life case in Life Cycle Analysis, stakeholder mapping and circular business models.
Techn. and Environmental Dep. (City of Copenhagen)	Gain insights on how to support and establish innovative circular economy solutions.	To gain access to our results for possible upscaling and policy making.

(Real, et al., 2019-2)

In the following phase, *Reframing the problem,* Underbroen carried out field visits, workshops, meetings and interviews with stakeholders and the Maker Community to reframe the challenge. Along the process, the lab decided that training in circular economy practices is key to develop any solution to the challenge.

Table 18Underbroen Challenge

What was the former challenge?	How can the City of Copenhagen become more circular regarding material flows and utilization, local design and production, and do it in a collaborative way that empowers both makers, designers, companies and municipal initiatives in creating ecosystems and supply chains for recycling materials such as plastic, wood and textile?
Synthetic formulation of the reframed challenge.	How can local micro entrepreneurs, SMEs, commercial resellers and citizens collaborate in a circular system plastic recycling production model in Copenhagen? What facilities, systems and workflows are needed for the recirculation of local materials? How to scale and ensure high quality and steady material supply of recycled building materials and goods, and promote a transition towards more sustainable production and consumption in Copenhagen from a bottom-up perspective?

(Real, et al., 2019-2)

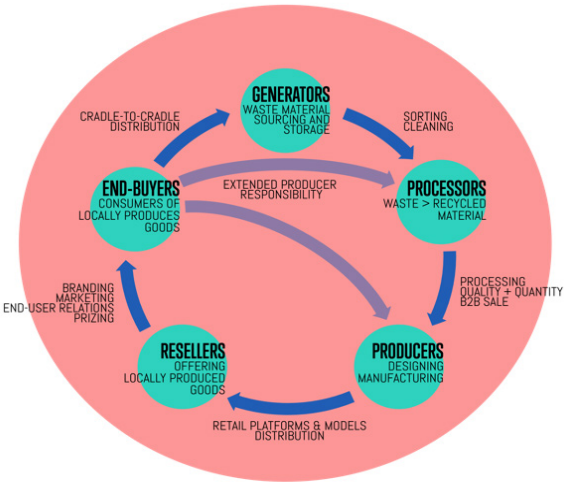
The idea

During the previous phases, several solutions were discussed along the process of co-creation, in *Phase 3. Envision alternatives,* Underbroen decided to prototype at small scale the Processor function. After analyzing the list of ideas that emerged from the previous phases, the lab decided to develop a " Circular system for local sourcing, recycling and production of sustainable plastic building materials and products." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 50) named "PIPO- Plastic In, Plastic Out". This system aims to be self-sustainable and built with local resources promoting responsible practices. The lab team decided to include training and promotion of best practices in their solution, as it is key to involve stakeholders and aim for a long-term change within the system.

The prototypes

The lab decided to divide the prototyping process in two phases: in the first phase, the lab will implement a small-scale plastic processing and recycling facility in Underbroen, offering training in plastic management to stakeholders. In the second phase, the lab aims to scale up the capacity of the previous system and complete it with the resellers and end-buyers' microprocessors.

Figure 19 Underbroen Prototype Blueprint



(Cristensen, 2020)

Underbroen's prototypes could be divided in three types of prototypes: the first one is about the producer chain of the system, where business model workshops were carried out with generators, processors and producers to assess the products and services and evaluate the prizing. The second prototype is about the engagement of the resellers and end-users' stakeholders; as it has been mentioned before, the actors within the system are key factors for the system itself to work, therefore the communication and engagement between them is critical. This second prototype was focused on branding, and new market platforms. Finally, the third prototype is about dissemination and spreading of PIPO resources; meaning online data, documentation, best

practices and technologies, among others, to be adopted into the local stakeholders' ecosystem. (Cristensen, 2020)

Policymakers engagement

The lab has faced difficulties to engage decision makers and high-level policymakers due to schedules, for this reason, the lab has decided to notify them about activities with enough time in advance to assure they can schedule the activity in their agendas. Underbroen recognizes a high interest from government to boost initiatives aiming to strength the circular economy in Copenhagen, as it is already part of their agenda and priorities. However, the City of Copenhagen usually develop their initiatives with a closed number of stakeholders, making it difficult for new members to join initiatives, as it is the case of Underbroen, making it difficult to engage policymakers in the challenge and during prototyping.

> *"This could lead to the conclusion that co-creation projects like our, initiated without the initial active engagement of policy and decision makers in Copenhagen, will have difficulties i.e. being adopted and supported at policy level, if they don't have a political mandate from the beginning." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 53)*

The relation with policymakers has been mostly though emails and meetings informing and inviting them to participate in workshops and activities of the lab.

6.4. PA4ALL – Living Lab

PA4ALL the living lab establish by *BioSense,* the Research and Development Institute for Information Technologies in Biosystems, which aims at fertilizing two important sectors in Serbia: ICT and agriculture (BioSense, 202). PA4ALL is an open and multi-stakeholder innovation ecosystem focused on user-driven precision agriculture. Situated in Vojvodina, an important agricultural sector, the lab aims to apply a collaboration and co-creation approach within stakeholders of the agricultural scene of Serbia through a speed dating methodology. PA4ALL brings together actors from different fields, such as researchers, public institutions, technology experts and end users. Digital Farm is one of their successful projects, in which an open-air showroom allowed farmers to see, test and assess innovative AgTech solutions.

Definition of the challenge

The lab seeks to bring long term benefits to agriculture by introducing precision agriculture tools in high schools (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 69), which will shape a new generation of professionals. In the *Phase1.Analysing the context,* the lab carried out a desk research about gaps in ICT and agriculture in the current educational system of Serbia and interviews with teachers and students to understand their needs, as well as with policymakers, farmers, startups and SMEs

working in agriculture. From this first phase, he lab concluded that " there was a significant mismatch between the demand for ICT skills in agriculture and the education students in high schools specialized for agriculture receive." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 70)

In the *Phase 2. Reframing the problem,* the lab consulted students, farmers, SMEs and start-ups from the BioSense network, which help them to understand what was needed and desired from future professionals in agriculture. The meeting with schools was possible through the Science Festival at the University of Novi Sad, in which students had the chance to propose different ideas regarding agriculture issues. Farmers participated at an Annual ANTARES Workshop in which PA4ALL could gather insights about what was needed from future professionals.

Table 19 PA4ALL Stakeholders

Main Stakeholders	Main interests in SISCODE's pilot
Students and Teachers from high schools specialized in agriculture	Providing their opinions on the major deficiencies of the educational system at the moment, providing new ideas on ICT in agriculture, improving the infrastructure of schools, etc.
Policy Makers	Improving the policies, laws and regulations connected to the educational sector, how curriculums could be enriched, new equipment acquired for the needs of better education in Serbia
Farmers	Information on the market and which kind of problems do professionals encounter on the market and how can it be improved
The scientific community(Researchers from BioSense)	Ideas on the most important aspects in the field which should be presented in schools, Knowledge transfer to teachers, students
The Innovative Community (SMEs and AgTech start-ups)	Providing ideas from an ICT perspective, new market trends, what kind of professionals lack on the labour market, etc.

(Real, et al., 2019-2)

The use and understanding of new technologies and data analysis were considered important skills for young students, which is align to what the government seeks to achieve from agriculture education: "individual consultations with a representative of Digital Serbia Initiative pointed us in the direction of capitalizing on the ongoing national efforts of bringing ICT education to schools." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 74) To do so, schools must provide the necessary equipment and teachers must be trained in this area. The identification if this gaps in the challenge, allowed them to re-frame it and become more specific about the desired result.

Table 20 PA4ALL Challenge

What was the former challenge?	Identifying aspects that are lacking in high schools specialized in agriculture that would enable students to innovate and develop new solutions for future agriculture, become more competitive in the market and secure employment.
Synthetic formulation of the reframed challenge.	Identifying ways of introducing ICT in high schools specialized in agriculture in way that fosters the development of specific skills, greater connection to market needs and relevance for agriculture of the future?

(Real, et al., 2019-2)

The idea

In the *Phase3.Envision alternatives,* PA4ALL organized a workshop with students to discuss about the importance of data to understand yields, meteorological and weather conditions. (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 75) Having into account previous ideas suggested by students in the Phase 2., the lab selected one idea: an *ICT based education high schools specialized in agriculture,* which would provide a meteostation together with required equipment and training, taking advantage of the land available in most agricultural specialized schools.

> *"The meteostations will provide information such as soil humidity, air temperature, precipitation amounts, air humidity, wind direction, etc. At the moment, the curriculum in high schools specialized in agriculture does not support these kinds of activities and therefore, students lack the crucial knowledge to implement ICT." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 76)*

This idea was selected from the ones proposed by the workshop carried out with students, the school with the winning idea was selected also to develop the first prototype of the idea.

The prototypes

The prototype consisted in equipping the selected high school with meteostations, computer, printers, solar energy panel, among other required tools (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 76). At the same time, PA4ALL provided training in how to use the equipment and analyze the data that would emerge from the meteostation. The prototype aims to be a close-to-real pilot in one of the schools and the performance of the meteostation will be monitored and assessed to evaluate its success.

However, due to the Covid-19 crisis, high schools had to close during the first semester of 2020, making it difficult to prototype as planned. Most of the activities programmed for the prototyping with students and teachers were postpone until the end of summer 2020.

Policymakers engagement

"Traditionally, the lack of democratic institutions has led to a lack of bottom-up initiatives and little understanding for the co-creation process when talking about new initiatives and changes in the system." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 78)

The challenge combines two backgrounds; on the one hand is the agriculture sector, and on the other hand is the ICT. ICT is a growing sector in Serbia, which has enable the creation of clusters among companies and institutions around these issues, however, in the agriculture sector, there is still a lack of development regarding collaborative approaches related to policymaking, "In this field, compared to ICT, serious co-creation and bottom-up policy initiatives have not yet happened." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 78) For this reason, PA4ALL decided to focus more on the ICT sector and the Digital Serbia Initiative agenda, considering the opportunities that this community and framework offers.

However, the lab sensed a lack of trust in public institutions from part of students and teachers, who didn't believe in the possibility of scaling up the prototype towards an structural change in the educational system (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 78) The approach to engage policymakers into a long-term change is to demonstrate successful results with the prototype first.

6.5. Krakow Technology Park (KTP) – Living Lab

"Apart from inspiring new innovative technological enterprises and facilitating technology transfer, KTP's strategic goals also include commercialising scientific research results from local universities, colleges and research institutions, and initialising co-operation between industry and the academic community" (KPMG, Invest in Poland , 2009, p. 30)

Krakow Technology Park (KTP) is a public based business innovation centre that works as an incubator and accelerator of entrepreneurs and Small and Medium Enterprises (SMEs), aiming at the grow of Malopolska economy through communication, technology and e-driven solutions. The park has a valuable network of experts, government departments and community leaders and has already experience in co-creation processes and participatory activities.

The Lab offers SMEs infrastructure, state-of-the-art labs, spaces for work, training and information that can contribute to their development and grow. It also supports local and regional authorities in public challenges involving citizens and local communities. Some of their main fields of expertise are IT/ICT, engineering, industry 4.0, IoT, gaming and multimedia sector.

KTP has experience leading workshops, hackathons, seminars and design thinking sessions with large groups of people. Furthermore, it has experience in applying these methodologies with public institutions, as is the case of the SMART KOM strategy project, which was developed with the Malopolska Voivodeship, and the Municipality of Krakow.

Krakow Living Lab offers a space to prototype products and services with final users. Its approach to co-creation comes from the business field (Real, et al., Co-creation Journeys, 2019-1, p. 81) and their methodology adapts to the context of each project and its scope. One of the most important strengths of KTP is their network of stakeholders that allows them to involve experts, customers, suppliers, citizens and academics in co-creation processes.

Definition of the challenge

Pollution and air quality is a problem in Krakow, which has rated as one of the most polluted cities in the world according to a World Health Organization study (Real, et al., Co-creation Journeys, 2019-1, p. 83) This situation affects the health of citizens who are suffering from chronic respiratory diseases. Although there have been several initiatives from the government to improve air quality, none of them seem to engage citizens enough to change behaviours that could lead to relevant changes in the air conditions.

In the *Phase 1. Analyzing the context,* an analysis of documentation related to the challenge emerged from the SMART KOM strategy was carried out (national and regional reports, legal acts, etc.), followed by meetings with public stakeholders such as Marshal office of the Malopolska Region, Department of Environment; City of Kraków and Plenipotentiary for Air Quality Management, among others. (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 59) and an opening event was carried out with 220 experts in air pollution. In the end of the first phase, the initial challenge was defined.

In the *Phase 2. Reframing the problem,* the challenge was reformulated after a series of workshops conducted with stakeholders and open to inhabitants of the region. The workshops were based on a design thinking methodology and aimed at diagnosis the problem and the generation of possible solutions. Tools such as empathy maps and personas were used to identify the needs and difficulties related to the challenge. The outputs of these workshops lead to the re-definition of the challenge:

Table 21 KTP Challenges

What was the former challenge?	To improve the quality of life by integrating and promoting activities aimed at improving the health and physical condition of the Krakow population mainly focused on air pollution and mobility.
Synthetic formulation of the reframed challenge.	The KPT's challenge is to improve the quality of the air in Krakow by motivating citizens to change their ecological attitudes, transportation and heating habits and to support decision makers with relevant tools and instruments for the co-creation of local new policies applying a user centered approach.

(Real, et al., 2019-2, p. 62)

Although these workshops were open to the public, the attendance of citizens wasn't as representative as expected, which led to the organization of two additional meetings designed for inhabitants of the region, which meant two key adjustments to guarantee participation: different locations (in regional communes) and different schedules (outside working hours). During these meetings was possible to gather expectations and needs of citizens regarding the quality of air.

Table 22 KTP Stakeholders

Main Stakeholders	Missions	Main interests in SISCODE's pilot
S1 Marshal office of the Malopolska	Author and manager of Air Protection Program for Malopolska Region	As the manager of preparation of the APP they are directly involved in the process and are interested in the results of co-creation process
S2 Inhabitants of the region	Final users of the air	As the final users it is crucial to include their needs and expectations in the process
S3 Local authorities	Developers of the APP	As the implementing bodies they need to understand the process and be a part of creation of the regulations
S4 Regional academic and scientific centres; public institutions	Providers of the knowledge and expertise	Ensure that APP programme is based on current updated air protection guidelines and regulations
S5 Business	Providers of possible products and solutions	To understand the expectations and support local authorities by concrete products and solutions

(Real, et al., 2019-2, p. 62)

To address this challenge the network of Eco-advisers in Malopolska municipalities was created to support the implementation of the program, acquire funds, engage citizens in the participation of the co-creation journey and give technical advises to support the solutions.

The idea

The solution envisioned by KTP is the Preparation of the new Air Protection Programme (APP) for Malopolska. In the *Phase 2. Reframing the problem,* KTP gathered preliminary ideas about how to solve the challenge, together with the insights, empathy maps and the personas, these inputs formed the basis of another set of workshops carried out in the *Phase 3. Envision alternatives.* These workshops aimed at generating solutions for the re-framed challenge and were also open for the public. The ideas from the previous phase were clustered in 3 categories: (1) Transport and mobility, (2) Effective information and consultation and (3) Monitoring and controlling system, which were the categories for the *Phase 3* workshops ideation activity.

From thess workshops, 8 ideas were selected to be developed in what would be the new Air Protection Programme (APP) with the help of experts in the subject. However, the ideas are meant to be part of the APP, while the APP itself is the solution KTP is proposing for this challenge. The APP includes the description of short- and long-term remedial actions, including among others the introduction of air pollution levels alarms and introduction of control tools and instruments making efficient implementation of the programme feasible. For this reason, the prototype is not about one of the selected ideas, rather it is about the Programme as a whole.

The prototypes

The prototype aimed at test "the main assumptions of the APP among regional decision makers in the following cities: Tarnów, Nowy Sacz, Chrzanów, Nowy Targ, Kraków." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 65) The prototype would help the lab to understand the feasibility of the APP in local contexts from the decision makers' perspective and to define the terms of references to define an entity to lead the Programme if approved. To do so, KTP planned to develop two prototypes: (1) The Air Protection Programme prototype and (2) the Smogathon Special Price.

A) **Air Protection Programme (APP)**

The APP prototype's first iteration was developed through 6 consultation meetings with a total of 250 participants that contributed with suggestions and recommendations. One of the big learnings of these meetings was de difficulty to align stakeholder's' expectations, that are sometimes opposite, like the case of big companies' interests vs. local agriculturists.

After the first version, the Lab plans to run a second prototype followed by official legislative consultations and a final authorization of the APP.

The consultation regarding the APP were held in two rounds; in the first one, KTP had the role of facilitator by supporting the methodology of participation of stakeholders and the workshops carried out with them. After the first consultation and the Smogathon Special Prize (second prototype), the APP was reformulated and a second round of open consultation was carried out, in which KTP had the role of observer, taking notes and comparing them with the insights gathered from the first round of consultation. In both cases the Marshall Office of the Malopolska Region is the owner of the APP.

b) **Smogathon Special Prize**

On the other hand, is the Smogathon Special Prize, which prototypes specific solutions that would be part of the implementation of the APP. KTP decided to do a Smogathon (hackathon on air pollution topics) to prototype these ideas and select one project to be implemented. The event reunited 170 people and 30 prototypes were developed within five categories: (1) Pollution Monitoring & Forecasting, (2) Health Effects of Air Pollution, (3) Transportation Emissions Management, (4) Identification of Pollution Sources and (5) Industrial Pollution Control. The selected idea was a monitoring system for industrial pollution, constituted by 3 elements: a web platform, a mobile app and a monitoring system.

According to the KTP team, the ideas were basic and need to be adjusted to local

contexts, for this reason a team of experts, companies and policymakers contributed to their further development. KTP maintains weekly calls with the winning teams to discuss about the ideas' details and every two weeks the lab has calls with policymakers to check the advances. The further development of the platforms would be made with Qubit team, followed by the cooperation with relevant institutions and a final assessment of a high-fidelity prototype with final users.

Policymakers engagement

The KTP challenge is framed within the policies of the region and the public institutions are directly involved and committed to the co-creation process, "The Department of Environment of the Marshal's Office of the Małopolska Region played a key role here. It decided to fully open the consultation process by inviting the residents to the discussion." (Real, et al., Co-creation Labs: solutions and policies , 2019, p. 67) The fact that the challenge emerged from a government strategy (SMART KOM) has shown a deeper commitment of policy makers. " Their final opinion is very positive and they are very satisfied with the recommendations which were delivered after 3rd phase of the journey." (Real, et al., Co-creation Labs: solutions and policies , 2019, p. 68) However, the level of engagement seems to low down in the co-production phases. KTP highlights the collaboration of the Marshall office during the Smogathon.

The involvement of citizenship seems to be more difficult than the engagement of policymakers, which has led them to adjust their strategies and invest effort in communication and integration of inhabitants of the region.

6.6. ThessAHALL – Living Lab

The Thessaloniki Active and Healthy Ageing Living Lab (Thess-AHALL) is part of the Laboratory of Medical Physics of the Medical School of the Aristotle University of Thessaloniki, Greece. The lab collaborates with the Active and Healthy Ageing (AHA) network in Greece and the Balkan region working as a hub for user-driven research and innovation. It is also part of the Greek Inter-Municipal Network of Healthy Cities.

Thess-AHALL has experience in co-creation projects and collecting data directly form the community settings. Usually co-creation activities involve different stakeholders such as experts, healthcare service providers, caregivers, researchers, day care centres and final users such as older adults, chronic patients and patients' associations, which interact during every stage of the project (design- prototyping, iterations and implementation). They have 8 years of experience in user-driven innovation and evidence-based research within the AHA domain, using methodologies from the design thinking through workshops, focus groups, meet-ups and personal interviews with stakeholders.

It is equipped with technology devices for cognitive and physical training, two technology show case rooms called e-homes with the devices mentioned before, and a Care Health System that works as a cognitive and physical training service. One of their most valuable resource is a large volume of data collected from several pilots, the data includes behavioural recordings of movements, activity levels, emotions, physiological signals and neuropsychological recordings.

Definition of the challenge

Elderly people (over 60 years old) and chronic patients (people with Down Syndrome/ Autism, mobility problems, cancer, heart disease patients, etc.) usually spend most of their time isolated or with other people sharing their conditions, feeling secluded from society. There is a lack of awareness about this situation from the public and policymakers, which makes the segregation stronger.

The challenge chosen by ThessAHALL seeks to decrease the risk of "loneliness and social isolation in the ageing population and chronic patients, using open science and social research as its means" (Real, et al., Co-creation Journeys, 2019-1, p. 97) For this purpose, the "Participate 4"learning programme have been selected to involve the target population in the research process, aiming to eliminate the frontier between scientists and people through a series of co-creation activities where they can express their needs and participate actively from the research as partners. They would co-design the possible solutions, place research questions and co-ordinate the co-creation sessions with the guidance and support of ThessAHALL.

As it has been mentioned before, ThessAHALL has a large volume of data, from which the challenge has emerged. Moreover, in the *Phase 1. Analyzing the context,* an in-depth research was carried out to set the basis of the research hypothesis by collecting quantitative and qualitative data about ageism, social exclusion and the cultural stigma, among other related topics. Field visits, surveys and interest group discussions were also carried out, together with interviews with the elderly and chronic patients.

As a result, a more detailed context was established and valuable insights about participants' views and propositions were gathered. Thanks to these activities, the lab confirmed that involving elderly and chronic patients into the process makes them feel already active, useful and socially included. It was also a chance to bring them together with the academia, in some cases, for the first time.

For the *Phase 2. Reframing the problem,* ThessAHALL carried out a series of focus groups with experts from the health care sector (Psychologists, doctors, physiotherapists and nurses) as well as in person discussions with other organizations and private entities from which they received positive feedback and support to carry one the co-creation process.

Table 23 ThessAHALL Stakeholders

Main Stakeholders	Missions	Main interests in SISCODE's pilot
Citizens (older adults/ chronic patients)	They are the primary stakeholders of the challenge, the main beneficiaries. Active involvement in every stage of the challenge, engagement of other people, to spread the message of co-creation, to share their knowledge and experience, assessment of their participation in research and if it helped them to feel socially included and active citizens.	To tackle the social exclusion and loneliness through their active involvement of every stage of the challenge, co-designing, implementing and disseminating participatory research, based on their needs and views.
Experts (doctors, healthcare professionals, cargivers)	Consultation and reframing of activities and the main objectives of the challenge. Their involvement and experience are crucial in order to recognize the needs and the problems of the primary stakeholders, to motivate their participation in activities valuable for them and to map the social exclusion and the cultural stigma over specific sensitive populations.	To find new approaches for tackling social exclusion and motivate older adults and patients to be engaged in social activities, enhancing competencies and their self-confidence.
Civil Society (patient associations, day care centre organizations)	Their experience is significant to map the social isolation and the cultural stigma phenomena, experienced by chronic patients, as well as the kind of inclusive activities they would possibly like to participate.	Patient associations could have the interest of participating in co-creation and being integral part of the challenge, increasing their self-confidence and feel active again. Organizations and NGOs could possibly find new ways of engaging their beneficiaries in participatory, social activities, also taking the advantage of collaborating with researchers.
Policymakers	Active participation of the local authorities in joint co-creation activities and support of the democratized research for the benefit of the society and its citizens. The Academia to recognize and adopt the value of participatory research for the society and to open its doors to the citizens, as partners and not as subjects.	Both the political authorities and the Academia could be benefited by a "win-win" collaboration of citizens and researchers, in order to make value for the society and to increase the impact of research for the commonweal.
Scientific & Research Community	The closest collaborators of the primary stakeholders, supporters and motivators in every step of the co-creation activities. Also, the "voice" of the University to promote its accessibility and to motivate the adoption of user-centred and co-creation methodologies.	The scientific community will not be considered as a "close" entity anymore and researchers will take the advantage of their collaboration with end-users, citizens themselves.

(Real, et al., 2019-2, p. 62)

However, from the expert's point of view, social exclusion is a broader and complex issue that exceeds the scope of the "Participate " programme, as these kind of initiatives usually have short duration and impact, they instead suggested to shift the focus of the challenge to " the co-creation activities in which older adults and chronic patients participate in the Lab, and also to find "what is in it for them" as members of *the Collaboration and Research Community for the Independent Living* of the Lab, and not how they could help other potential beneficiaries." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 86)

Table 24 ThessAHALL Challenge

What was the former challenge?	THESS-AHALL's big challenge is to break the social exclusion walls and welcome institutionalized and chronic disease outpatients, as well as older adults, back to the community, introducing the "Participate 4" campaigns.
Synthetic formulation of the reframed challenge.	THESS-AHALL's big challenge is to break the social exclusion walls and welcome older adults and chronic patients back to the society, introducing the "Participate 4" co-creation research and life-long learning programme.

(Real, et al., 2019-2, p. 62)

The idea

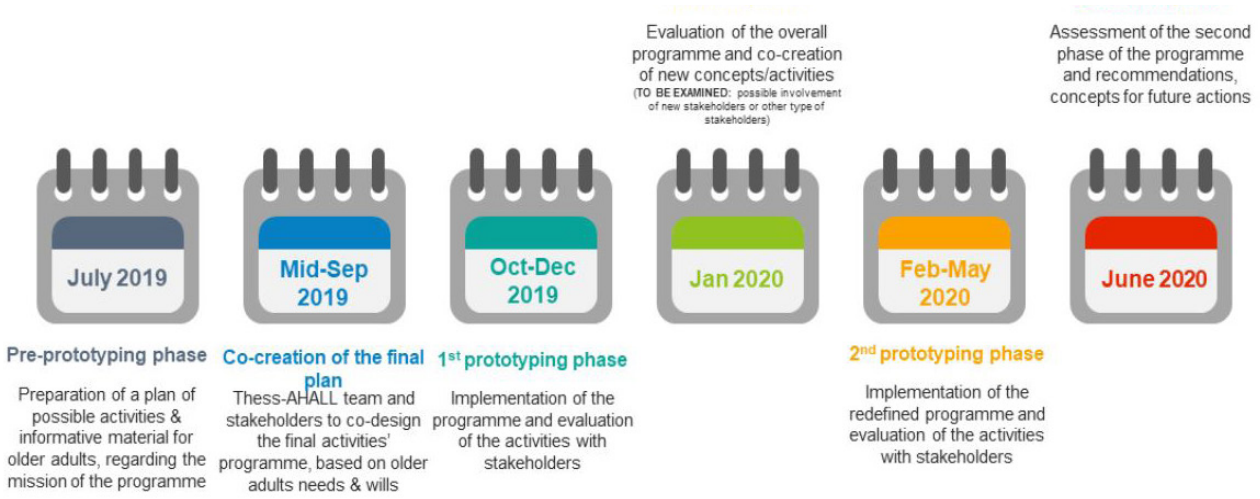
For the *Phase 3,* a database of possible co-creation activities was compiled, having into account the insights from the *Phase 1* and *Phase 2.* From the list of possible ideas, ThessAHALL chose the *Partners of Experience* idea, a participatory programme for older adults and chronic patients, in which they are researchers for a whole academic year becoming partners in real-life activities of the lab.

The programme will include design thinking sessions, lectures to medicine students from their personal experience with their disease, visits to university structures, desk research, academic events and contribution to academic research papers.

The prototype

ThessAHALL prepared a prototyping plan with the following phases, however, the Covid-19 situation has affected some deadlines of the plan.

Figure 20 ThessAHALL Prototyping Plan



(Real, et al., 2019-2)

The prototype is a learning process, it is a methodology for inclusive research and participation of older adults in activities for co-designing and co-working with researching for solutions to improve their daily live. The initial plan was to implement step by step a research methodology, ThessAHALL asked older adults to be in the "research-

ers' shoes" for a whole academic year and from the design phase until the presentation of their solutions to policymakers just as the lab would do.

The prototype started with some visits to the library of the university to do desk research, find references to validate their assumptions. Elderly people participating placed their own research questions about how to make their city healthier in three fields: environment, health and social welfare and active citizens. According to these themes, the participants divided themselves into three groups (each group with 15 adults). They worked with researchers from the lab and students from the university.

Policymakers engagement

High-level policy makers lack awareness of elderly people and chronic patients' needs, and their involvement with related policies depends on *tangible evidence* of the benefits the policies could bring them, that " usually translate the benefit into financial gain or votes, before they fund the research or support the implementation of its results in society." (Real, et al., Co-creation Journeys , 2019, p. 101) In order to get policy makers attention, it is necessary to have proofs of success through metrics, for this reason it is difficult to involve them from the beginning of the co-creation process.

Local, European and early national elections in Greece interfered with the first Phase of the co-creation process, making it difficult for them to be involved in the related activities.

6.7. Cube Design Museum – Science Museums

Cube is a design museum dedicated to the *design process,* working as a museum and as a laboratory for innovation (Cube, 2020). Experts in design thinking, design research, graphic and product design work in the lab, which has space and equipment for rapid prototyping such as 3D printers, plotter and laser cutters.

Their approach to co-creation comes from the design thinking field, from which the lab has designed a methodology composed by 4 iterative phases: ask, imagine, create and evaluate (Real, et al., Co-creation Journeys, 2019-1, p. 118) Usually a multidisciplinary team run design challenges using this methodology.

Definition of the challenge

Cube's challenge is wide; as it focuses on current and future challenges of an ageing society. In *Phase 1. Analyzing the context* a desk research was carried out, considering policy reports about ageing and loneliness and demographic statistics At the same time, Cube carried out informal workshops with citizens to "explore social challenges and needs related to ageing and possible solution ideas" (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 114) During this phase, the lab contacted policymakers

from the municipality of Voerendaal, which help them understand the policymaking context and needs. Although policymakers recognized as valuable co-creation approaches, "are cautious when it comes to responsibilities and expectations" (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 115)

Table 25 Cube Stakeholders

Main Stakeholders	Missions	Main interests in SISCODE's pilot
Municipality of Voerendaal	- a social and sustainable municipality - together with citizens, companies, associations, and villages invest in a city where it is nice to live and work, where people can count on each other, where initiative is appreciated, where healthcare and support is provided, and where criminal activities are being eliminated.	- gain insights in needs of citizens in the context of how to make the villages of Voerendaal future proof - addressing (future) societal challenges related to the 'participation society' - possibly new ways of policy making
Citizens' cooperation "Ransdaal voor elkaar"	- increase and maintain quality of life for all citizens of Ransdaal - influence policy making, in regard to their own life/ in their own neighbourhood/village	- possibility to increase support among citizens - possibility to increase knowledge about co-creation methods - possibility to increase commitment from municipality/policy makers
Neimed	Neimed is a Centre of expertise on Demographic Changes and is a joint initiative of Zuyd University of Applied Sciences, and the Open University in the Netherlands. They - collects expertise in the Netherlands and beyond with special emphasis on the City Region Parkstad Limburg. - tackle issues related to demographic change: significant population decline, ageing population, declining of the work-age population - support the quality of life of citizens and communities in shrinking areas and identify constructive scenarios derived from the mentioned demographic processes	- develop and increase knowledge base about quality of life in ageing society and new possibilities for citizen engagement and co-creation
Studio hyperspace	- studio hyperspace seeks for new ideas and practices that are in tune with the chaos and acceleration of our time, by establishing an a-disciplinary network of sociologists, designers, artists, researchers, teachers, and creatives that share the same feeling: do meaningful stuff.	- 'do meaningful stuff' - gain experience and knowledge - increase network
Studio kernland and Other designers	- designers want to 'make a difference' and are driven to use their abilities and skillsto find solutions for small and big human challenges - studio kernland is one of those designers, focusing on exhibitions design and storytelling	- 'do meaningful stuff' - gain experience and knowledge and expand portfolio

(Real, et al., 2019-2, p. 62)

In *Phase 2. Reframing the problem*, Cube worked with local policymakers (through one workshop), citizens' communities and demographic experts to reframe the challenge as follows:

Table 26 Cube Challenge

What was the former challenge?	How might we increase the quality of life of people living and growing up in an ageing society like Parkstad (South Limburg region) and more specifically fight loneliness?
Synthetic formulation of the reframed challenge.	How might we increase/ensure the quality of life of people of all ages living and growing up in the context of an ageing society, now and in the future, drawing on the self-organizing potential of the community in co-creation with policy makers, by broadening perspectives and providing an open mind to the future starting with a pilot in Voerendaal?

(Real, et al., 2019-2, p. 62)

The idea

As it has been mentioned before, the envisioning of ideas began from the first phase of the co-creation journey, therefore, in *Phase 3. Envision of alternatives,* the lab already had several ideas and solutions from past workshops and meetings with stakeholders. During this phase the lab focused on synthesizing the ideas collected to address the challenge according to the findings and proposals.

By the end of this phase, Cube decided to go further with the idea of a *Future Citizens Lab x Ransdaal,* a programme that "combines a new policy structure/system with social and educational activities and an IT-product, which aims for social innovation: bottom-up initiatives from citizens of a neighborhood or village are facilitated and supported by policy makers of their community." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 120)

The programme works as a platform to connect social innovation with decision makers and stakeholders in order to impact the policy framework. It is composed by three main parts: the first one is a workshop modality that allow citizens to propose ideas within the framework of design thinking and social innovation. The second part is an event, where the proposed ideas can be presented to local policymakers that could scale the solutions. Finally, the third part is a digital space where citizens can support and invest in other ideas.

The prototypes

The prototype aims to test the concept of citizen participation through workshops and events with citizens and policymakers. To prototype this part of the idea, Cube carried out two co-design workshops with an open question: *How can we design for citizen participation to improve the quality of Life in Ransdaal?* The workshops were addressed to citizens, aldermen, civil servants and city council members. The aim of this specific workshops was to engage stakeholders and explore shared values and goals. These workshops seem to be still exploring possible solutions together with stakeholders by prototyping and co-creating with them along the way. "We need to have an open mind in which not the initial idea is the goal but the development and realization of a program/product that brings together policy makers and citizens in

a sustainable way." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 121)

Policymakers engagement

There is still a lack of involvement of policymakers in co-creation processes; although citizen participation is increasing, it usually don't scale up in the policymaking context, "Policy makers are struggling with how to give room for bottom-up initiatives and ownership, without giving up their public responsibility, as well as with thinking beyond existing frames." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 122). Until the moment, co-creation is perceived as a one-way process in which citizens propose and policymakers decide, in a hierarchical and top-down direction.

Cube highlights the importance of finding common goals and making sure policymakers agenda are align with the project or challenge, there is also fear about changing the way things could be done, as co-creation challenges traditional organizational structures and mindset " Sometimes the policy makers want to work together but the civil servants are afraid of extra work load, skeptical about the outcome or just not convinced that co-creation is the way to go." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 124) Cube emphasize about the importance of *change management* as a skill that should be developed within the policymaking framework, as well as *expectation management*. One of the gaps identified about policymaking is to work their fear of failure (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 123) , which they think could be tackled by cooperating and learning from failure.

6.8. Traces – Science Museum

> *"Traces aims to create living lab spaces in which to reflect, experiment and innovate in the fields of science in society, science education and public communication of science." (Real, et al., 2019-1, p. 40)*

Traces is a non-profit association in Paris interested in participatory science, it oversees the Espace des Science Pierre-Gilles de Gennes (ESPGG), a culture center that can be considered as a bridge between science and people. ESPGG is part of the ESPCCI, engineering college of Paris, and the PSL Research University.

Traces has three columns of action: the first one is focused on interdisciplinary reflection on science and its social impacts, the second one is about science communication and education training addressed to scientists, students, teachers, among others. Finally, the third column is dedicated to consulting for museums, companies and public institutions. (Ecsite , 2020)

The infrastructure of Traces allows spaces for brainstorming, conferences, workshops, co-creation, 3D printing and prototyping, among different creative activities. In the

same campus there are other specialized labs that can be used by Traces if requested, those labs are run by university students. Regarding knowledge and competencies, the Lab has strong capabilities in science engagement and social inclusion methods and collaborative training in Responsible Research Innovation (RRI).

In the search to connect science and citizens, the Lab approaches co-creation in the blurred line between knowledge production and knowledge dissemination: "That is, activities that satisfy at the same time the needs of the general public and the needs of the research and innovation community" (Real, et al., Co-creation Journeys, 2019-1, p. 134) As a living lab, it involves final users in the design of solutions through exploration, experimentation and evaluation.

Definition of the challenge

In a world where algorithms are increasingly shaping the way we interact with others and take decisions, how can people be conscious about their choices and at what point do they understand the technologies that surround them and might influence their behaviour? The challenge of Traces is addressed to make Automated Decision Systems (ADS) intelligible by the public, "allowing users to understand when their data is used, and their profile calculated and what comes out of it." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 140) The privacy of data and how companies and organizations might use it for their benefit rises ethical questions " there is a real need of including discussions on the topic in contexts and situation easily accessible by general audiences, such as in educational or cultural activities." (Real, et al., Co-creation Journeys, 2019-1, p. 135) There is where Traces can play a key role as a mediator and facilitator of discussions between experts, new technologies and general audiences that are being affected by them.

In the *Phase 1. Analyzing the context,* a mapping of stakeholder's network was carried out; 5 categories of stakeholders were identified as follows: (1) policymakers, (2) researchers, (3) education, (4) citizen rights and (5) innovation sector associations. Later, some interviews were carried out according to their areas of interest and availability. Finally, 5 events were organized with the aim of enable spaces for interaction between experts in the issue and people. The events had different approaches; the first one was a World Café, the second one was a conference, followed for a moving debate, an Ill-fated tribunal and a GDPR night event.

As a result, different practices to raise awareness about decision making within the frame of the challenge were identified, "the ill-fated tribunals allowed people to go beyond their *zone of comfort* by playing with argumentations in a quite theatrical way and having fun in the process." (Real, et al., Co-creation Labs: solutions and policies, 2019-2, p. 141)

In the *Phase 2. Reframing the problem*, a deeper analysis of stakeholders was carried out identifying links between them:

Table 27 Traces Stakeholders

Main Stakeholders	Missions	Main interests in SISCODE's pilot
S1: L'arbre des connaissances	Association founded by researchers to promote dialogue between producers of science and society	*"Working together and discovering the others actors of the area that we can build something together with us but with different perspective is rewarding."*
S2 : Laboratoire de Recherche en Informatique	The research topics of the laboratory cover a broad spectrum of software-based computing and include both fundamental and applied aspects (ex: algorithms, databases, programming…)	*"We are always looking for new methodologies that allow us to better understand the questions we ask ourselves and as researcher, this kind of format allows it".*
S3 : Fondation Internet Nouvelle Generation	A reference think tank on digital transformations	Partnerships
S4 : Université PSL / DIMs Ile de France	Involved in PRAIRIE, a new center dedicated to research in AI	The PSL university can be interested in being associated with the pilot; DIMs researchers are dedicated to the subject determined by Ile de France region policy makers
S5 : Activists of Civil society / hackers = AlgoTransparency	eBastille and Algotransparency Its an NGO whose aim is to inform citizens on the impact of algorithms which biaise what information we get online. They did some experimentation during US elections in 2016 then during presidential elections in 2017.	

(Real, et al., 2019-2, p. 143)

Based on this information and the insights gathered from the several events in the *Phase 1*. The challenge was reframed:

Table 28 Traces Challenge

What was the former challenge?	How to explore the issue of ADS with different actors and build together a way to trigger awareness of this issue among the general public?
Synthetic formulation of the reframed challenge.	How to organise interactions between research, education, civic right and policy making in order to identify ways to raise awareness of algorithmic decision making within general cultural activities ?

(Real, et al., 2019-2, p. 143)

The idea

For the *Phase 3,* Traces organized an Open Lab Day with workshops addressed to experts. These workshops aimed at sharing and discussing knowledge from different fields, map approaches to promote awareness of the issues related to the ADS and propose ideas to address those approaches. To do so, the participants initiated their dialogue from real case studies of three main areas: research, education and right protection.

As a result from the Open Lab Day, 3 options of prototypes emerged: the first one is about designing an educational or cultural product *for* Artificial Intelligence (AI), the approach to AI in this idea changes, it puts AI as the target user and aims to understand and explore possible relations with this system. The second idea is to develop

art-science workshops about decision making assisted by algorithms. The third idea is to involve high-school students in the development of a scenario regarding the challenge. Finally, the idea of changing AI from a tool to a user, was the concept selected to develop the prototyping phase.

The prototypes

After the Open Lab Day, another event named TURFU was carried out. During this event a dialog among researchers and young people around AI was possible through workshops and prototyping sessions. Traces used this space to go in deep with their concept and answer some questions about this ADS. Questions like “How do the AI learn?” or “If algorithms listen to what we say, what would we want to tell them?” Finally, a library for AI was developed, including records, films, books and artworks.

The library was later the inputs for the next prototyping workshops that Traces developed to carry on with their concept for the SISCODE challenge. Also having prototyped already solutions, helped them to explore situations and nourish their prototyping ideas.

Traces aims to play with the role of the actors involved in a cultural activity; usually in a cultural activity we have the author and the person that experience the cultural activity, usually accompanied by a support device (telephone, tablet, laptop). Traces search to transform the role of the support device and place it in the center of the activity, not only as a support element, but as an autonomous subject. At the beginning we Traces tried to see how a play is addressed to AI only, but then the lab realized that it was more interesting to see a person accompanying an AI seeing a play, guiding the exploration towards the concept of co-spectatorship.

To do so, the Lab decided to prototype a cultural activity such as a theater play: a monolog of Hamlet was performed by an actor while being observed by different AI systems, which allowed Traces to gather data about what the AI saw or perceived from the monolog.

The role of those prototypes is to explore new educational approaches to create awareness about ADS, create links between stakeholders in the art field; such as artists, educators, researchers and influencers and promote empowerment in educational activities and Responsible Research Innovation (RRI).

Policymakers engagement

There are no local policies directly related to the challenge, however, the lab has had contact with the Ile de France Region vice-president of research who is aware of the challenge and is curious about the project. He was invited to assist to the Open Lab Day but cancelled in the last minute, which suggest that the project is still not a priority. There is still a gap between supporting the initiative and getting involved into the co-creation of it. The lab recognizes the necessity to engage middle-management policymakers that could be part of the prototyping process.

Important stakeholders from Theatre de la Ville have been supporting and participating in some of the activities carried out during prototyping, contributing to the recognition of the project within the theatre community. In terms of the research community, many members of important institutions are interested in the project and have participated in their activities, however their participation is as individuals, not as official members of the institutions.

6.9. Ciência Viva – Science Museum

Ciência Viva, the PortugueseNational Agency for Scientific and Technological Culture, is a non-profit association of public institutions, research laboratories and science centers, it was created to promote public awareness of science, technology and education. It was created as part of the Ministry of Science and Technology in 1996 (ERC=-Science[2], n.d.), since then the lab has been involved in different projects for science, education, RRI and open science, which include the national participatory budget for science (Real, et al., 2019-1, p. 41).

For Ciência Viva, co-creation is a “more interactive approach to science communication, to engage the public with complex issues involving science, technology and society, raising awareness of the issues at hand and of the importance of participation.” (Real, et al., 2019-1, p. 108) And it is usually translated into events and meetings such as focus groups or specific participatory activities, but not as a whole process including prototyping from a collaborative approach, as the one being developed with SISCODE.

The lab has space equipped for meetings, workshops, events and it has access to the Pavilions’ DOING augmented factory, a space for prototyping supplied with 3D printers, cutter plotters, soldering stations and Arduino, among other tools. (Real, et al., 2019-1, p. 108) Ciência Viva’s has a team for communication, design and digital fabrication, and it has developed a database and resources about ocean literacy, climate change, marine litter and other related subjects, which is part of the origin of the chal-

lenge's theme selected.

Definition of the challenge

In a country as Portugal, the sea plays an important role in the culture and citizens daily life; however, there are few marine leisure activities. (Real, et al., 2019-1, p. 109). In the case of the river Tejo, close to the location of Ciência Viva, the lack of these leisure activities prevents economic incentives to maintain the navigability of the river (Real, et al., 2019-2, p. 100).

The lab seeks to bring people closer to the sea, while promoting awareness about its value. In *Phase 1. Analyzing the context,* a desk research was carried out about recreational boating and water-based sports in Portugal. From this research, the lab identified and interviewed some stakeholders and carried out field research in the river of Lisbon, documenting with pictures, videos and field notes the activities and life around the river. Later, the information gathered was analyzed looking, patterns, trends and actors involved. As result, the lab identified two problems: the first one is about limited physical access to water, and the second one is about a resistance to water-based activities from people.

In *Phase 2. Reframing the problem,* Ciência Viva carried out a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis and a stakeholder mapping identifying each actor's needs, interests, skills, and relations between them.

Table 29 Ciência Viva Stakeholders

Main Stakeholders	Missions	Main interests in SISCODE's pilot
Representative of Association of the Parque das Nações	An advocate for leisure boating; plans and develops mobilization activities in the river; lobbies for improving access to water	Sees this as major event that can frame their plans for "political" river parades, i.e., tours as statements asking for improving access to the river, and development of the "water way"
Representatives of Resident and business association of Parque das Nações	Identify and report opportunities and issues for citizens and businesses in the neighbourhood of Parque da Nações. Help organizing activities in the neighbourhood and mobilizing individuals, families, businesses and local authorities.	Interested in popular initiatives in the neighbourhood drawing attention to local potentials and barriers
Municipality + Neighboorhood	Experts in the regulatory framing and strategic planning of activities related with our pilot; organizing activities relevant to our pilot (e.g., municipal school programme for water sports)	Fits their plans of attracting people to the river, rebranding Lisbon/neighbourhood as water friendly places; fits major incoming initiatives taking place in the city/neighbourhood, 2020-2022 (Capital of Sports; Green Capital; urban/water front regeneration for visit of the Pope/Youth Festival)
President of Marina (also researcher in leisure boating and related fields)	Planning, developing and supporting leisure activities in the river. As researcher in this field: identifying and mapping issues at stake in water leisure activities in Portugal/Lisbon	Help establishing the Marina as "manager" of water front/water activities in this part of the city; attracting more people to water sports; interesting the public in "maritime culture" in general
Maritime scouts; local school; Sea woman association	Developing, organizing and participating in recreational boating activities in the river (for young people and older women respectively); raising awareness about the environment, human and ocean health.	See the pilot as new, interesting challenge for development their activities

(Real, et al., 2019-2, p. 62)

Later, a workshop with four important stakeholders was carried out to reframe the challenge as follows:

Table 30 Ciência Viva Challenge

Table 47 Ciência Viva Challenge Synthesis

What was the former challenge?	What service, equipment or practice could help engaging the public in marine leisure activities, while promoting ocean literacy and awareness, and being accessible to a wide range of users?
Synthetic formulation of the reframed challenge.	What interesting, mobilizing, safe and accessible experiences could our co-lab create in the river in this part of the city?

(Real, et al.,2019-2, p. 62)

The idea

Ideas were collected from the beginning of the co-creation processes, from the meetings and interviews with stakeholders that manifested their ideas and possible solutions for the challenge. For *Phase 3. Envision of alternatives,* two workshops were carried out specifically to generate ideas, from which a pattern was identified: solutions that involve actual experience on the river. Other issues like accessibility to the river were considered as out of the lab´s scope, but still it was considered for the idea generation.

The idea selected is called *Build your own boat/Bring your own boat,* that consist on, what the lab calls, an "anchor activity" accompanied by complementary events. The activity is the construction of a boat through a yearlong workshop, "The workshop will have successive modules comprising different subjects: the river, boat design, floatability, boat construction, basic navigation skills, safety, etc." (Real, et al., 2019-2, p. 107). The results from the workshop will be exhibit in an event in which different activities around the river will be held. "Our approach aims at immersion and interaction with water environments, and involves a wide range of people – not just children or sports people, but also the public, researchers, makers, artists, families, businesses – creating something that explores different uses of the river." (Real, et al., 2019-2, p. 107)

The prototype

The prototype is meant to be already a mean for stakeholders to interact around the river, raising interest and awareness about its possibilities and value. For the prototype, the lab did a research about DIY boat construction and its preparation requirements, based on the research they designed a Kayak building workshop, which is meant to be followed by other prototypes and an *immersive science festival* in the river. The first prototype was at small scale, involving limited but varied number of key stakeholders.

(Praça, 2020)

The workshop Viva Kayaks! Involved students and other stakeholders that built a total of 70 kayaks together. After the activity, the lab gathered feedback from the participants to nourish the next steps of the prototyping process, which will be the Festival Viva Kayaks! Due to the Covid-19 situation, the activities programmed to carry out the festival had to be postponed until autumn 2020.

Policymakers engagement

Co-creation dynamics are not common in the Portuguese policymaking context, in which consultations with experts and limited participation of citizens are the common approaches. Thanks to the relation of Ciência Viva and network of stakeholders the first approach to the Municipality and neighborhood governments was easy; moreover, the challenge is part of the existing agendas of the local policies which increased the interest of policymakers into supporting and disseminating the project.

Nevertheless, policymakers invited to the workshop didn't assist, which seems to mean that their role is more as supporters than collaborators of the prototype, "We do feel that they will be supportive once we show them a more definite plan, with concrete initiatives." (Real, et al., 2019-2, p. 109)

6.10. Science Gallery Dublin – Science Museum

SGD is a non-profit gallery part of the Trinity College of Dublin that started in 2008 to promote "creativity and discovery where science and art collide" (Real, et al., 2019-1), through exhibitions and events that combine the knowledge of scientists, artists, designers, students and entrepreneurs. Being part of the Trinity College of Dublin has allowed them to have connection with a large network of researchers that makes this possible.

The Lab has space for group activities such as brainstorming, creative sessions and presentations and is equipped with rapid prototyping tools and materials. SGD has multidisciplinary teams that collaborate in the exhibitions and events, as well as a specialized marketing and event team that are part of the SISCODE project implementation.

Definition of the challenge

SGD challenge is about mental health and well-being management with young people in Ireland; which topic emerged and is nourished by past exhibitions of the lab. In the *Phase 1. Analyzing the context,* SGD carried out a desk research about mental health for young people in Ireland and a list of relevant stakeholders was identified.

Table 31 Science Gallery Dublin Stakeholders

Main Stakeholders	Missions	Main interests in SISCODE's pilot
S1 Young People	Navigating transitioning from adolescence to adulthood, along with all the pressures of school/university/career.	They first got involved during the educational workshop weeks and were interested in having a say on the topic.
S2 Academic Researchers	Conduct research, lecture, write publications and disseminate research.	Learning about the co-creation process.
S3 NGO Staff	Working in lots of different mental health areas such as prevention, suicide and eating disorders.	Learning about the co-creation process.
S4 College Welfare Officers	Usually post-college students who stay on for a year to take on the role, really care about the community of students and their mental health.	As they work as the welfare officers in colleges across Dublin they have a lot of insight into issues for college students (and are of student age).
S5 Clinicians	Clinician's mission is to help those with mental health problems, sometimes they can also be researchers.	Very busy, so were difficult to engage, but were all enthusiastic about making a change for young people.

(Real, et al., 2019-2)

Next, 34 meetings with the identified stakeholders (psychologists, counselling services, youth social workers, policymakers, researchers) were conducted. Moreover, a focus group with teachers and parents, a survey for young people (18-25-year-old) and three educational workshops with 60 students between 15 and 16-year-old were un-

dertaken. Based on the information gathered form these activities, SDG developed personas, mind maps and word clouds about mental health issues.

For the second phase, *Reframing the problem,* the lab carried out a workshop to generate ideas, where the results from the first phase were presented to mixed groups of stakeholders who voted for the themes they would like to explore (e.g. eating disorders, transitioning from child to adult, etc.) Each group created a conceptual map for the issue selected, which allowed them to identify more specific problems for each theme. The challenge was addressed specifically to secondary school settings, although it still aims at remaining open.

Table 32 Science Gallery Dublin Challenge

What was the former challenge?	To improve mental health and well-being management with young people
Synthetic formulation of the reframed challenge.	To improve mental health and well-being management with young people in a secondary school setting.

(Real, et al., 2019-2)

The idea

In the same event, groups working in specific themes brainstormed ideas of hobbies and technologies related to the issue, followed by a 2 minutes brainstorm of ideas for possible solutions of the challenge, which they later draw, named and finally evaluated in terms of impact and feasibility. From the ideas generated during this activity, the stakeholders selected Open Min: in-class modules with transition year students to create awareness about the importance of hobbies for mental health (Real, et al., 2019-2, p. 182) and empower them to improve their well-being through school, set up extracurricular clubs to explore their hobbies and mentor first year students in their chosen hobby. With Open Mind, students are equipped to create lunchtime clubs and connect with younger students that share the same interests.

The prototype

To prototype the idea, a pilot programme within 4-5 existing school was planned, however, due to the Covid-19 crisis, the lab had to postpone and change some of the planned activities, as these were depending on schools that due to the crisis had to close during the first semester of 2020. The prototype was adapted to remote engagement and the following steps will be carried out in September 2020.

Policymakers engagement

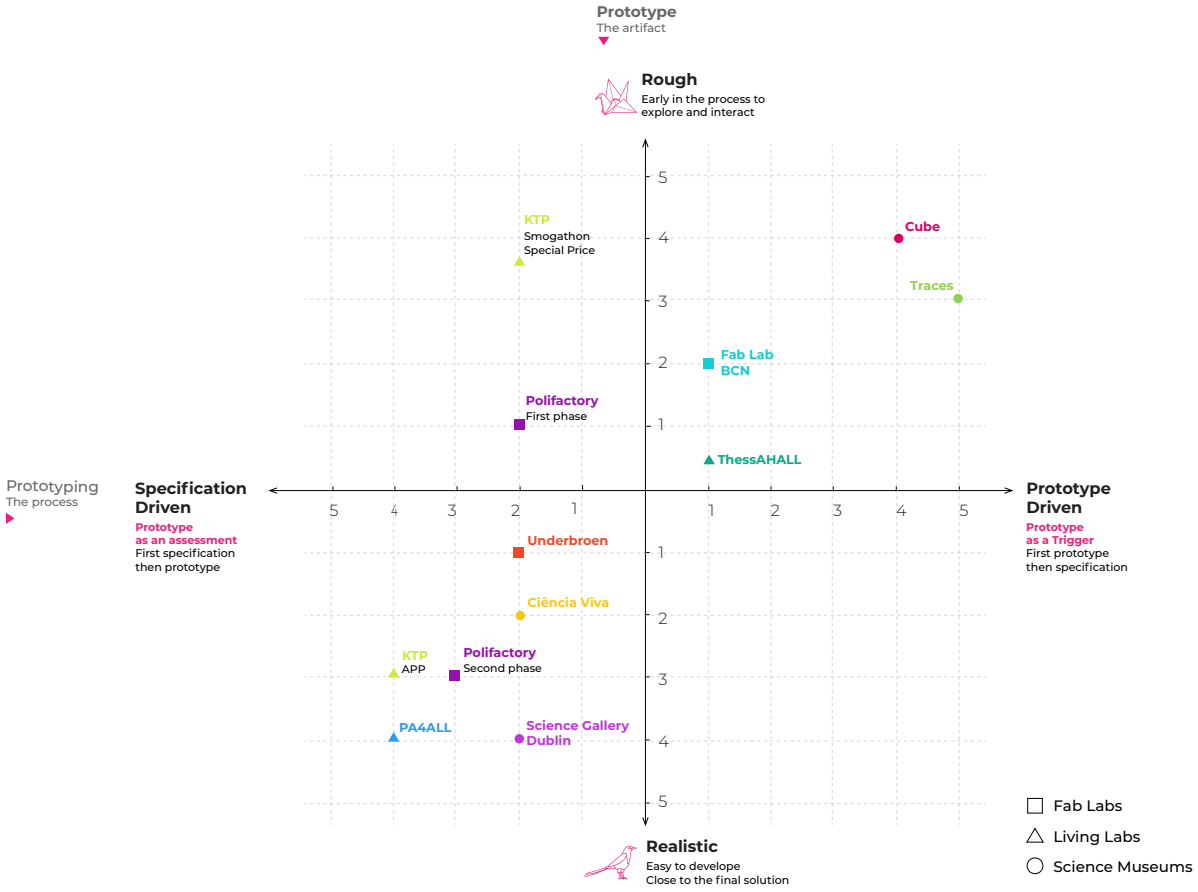
Irish government recognizes mental health as an important issue to be addressed; the Report of the Expert Group on Mental Health Policy responds to this need, however, policies still have gaps to cover all issues related to mental health related to young people and the implementation of the whole policy is still in pending.

6.11. Comparative Analysis of the 10 SISCODE cases

Labs General Analysis

After the review of each lab documentation, their prototyping approach was analyzed through the two dimensions of the Prototyping Matrix: in terms of prototyping as a process and prototypes as artifacts. The labs were placed as follows:

Figure 21 Prototyping Matrix: Labs Comparative Analysis



As it can be seen in the graphic, most of the labs are in the bottom-left quadrant, which means a validation-driven and realistic prototype. The distribution in the graphic of the Fab Labs and Living labs seems to be more validation-driven, while the roughness of the prototypes varies. In the case of the Fab Lab Polifactory, the first phase of prototyping uses a rougher prototype that becomes more realistic in the second phase. In the case of ThessAHALL and Fab Lab Barcelona, their approach is more exploration-driven, although it remains close to the center of the matrix. As an exemption, two of the four science museums are isolated in the top-right area of the matrix, both with rough prototypes and with an exploration driven approach, from the documentation review, none of the Fab Labs or Living Labs reach this level of uncertainty.

Regarding the relation between their level of uncertainty and their proximity to policymakers, we can identify that Traces and Cube, that are in the higher level of uncertainty, focus their challenges in future scenarios, which means that they are exploring into unknown unknowns more than validating known unknowns. Therefore, their approach towards policymakers tends to be more strategic than operational.

On the one hand, Cube identifies some issues regarding this aspect: "both citizens and policy makers keep thinking and acting within their current frames and have difficulties exploring new/different future possibilities" (Real, et al., Co-creation Labs: solutions and policies , 2019, p. 15). One of the recognized gaps by Cube is to "Work on their fear of failure" (Real, et al., Co-creation Labs: solutions and policies , 2019, p. 123), which is higher as uncertainty increases. On the other hand, Traces identifies itself more as an influencer of future policies around science engagement, by showing policymakers how things can be done different and tackling questions around future scenarios.

PA4ALL and KTP, together with Science Gallery Dublin are on the opposite side of the graphic. In these cases, their collaboration with policymakers is closer to the operational side, which means that policymakers are highly involved and sometimes they are co-owners of the prototypes, as it is the case of the prototype of the Air Protection Programme of KTP.

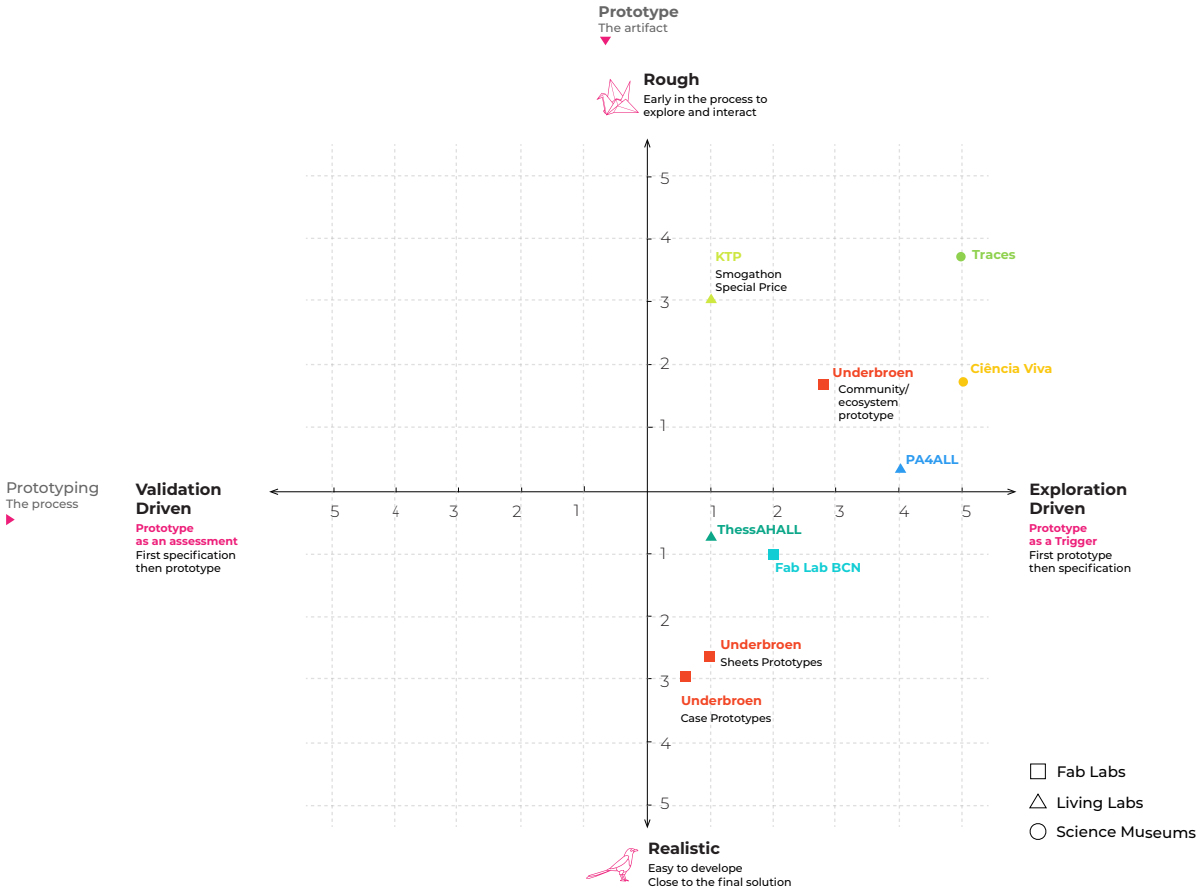
Only two prototypes are in the top-left quadrant of the graphic, and the two of them have a complementary or successive prototype; on the one hand, the first phase of Polifactory was validation-driven with a rough prototype, in the second phase it moves towards a more realistic one. On the other hand, KTP carried out the Smogathon Special Prize looking for solutions to implement the other prototype, the Air Protection Programme, which is lower, in the bottom-left quadrant.

Focus Group: Dialogue among researchers and practitioners

After the general analysis of the labs' approach to prototyping, a focus group was carried out to share with the lab members part of the research about prototypes roles and the diagnosis of their prototypes regarding the literature analysis (the matrix previously explained). Seven of the ten labs were present in the workshop which was the first session of an initiative from SISCODE called "Dialogue between practitioners and researchers", that seeks to bring closer researchers with practitioners of the co-creation labs.

Before showing the previous graphic, a blank matrix was handled, and each member of the labs had the chance to place their prototypes into the matrix. The result of their self-assessment was the following:

Figure 22 Prototyping Matrix: Focus Group Labs Auto-Assessment



Most of the labs placed themselves in the right side of the graphic and most of them consider their prototypes rough. Unlike the preliminary analysis, the bottom-left quadrant is empty, and three labs are in the bottom-right quadrant (exploration-driven and realistic prototypes), a quadrant that was empty in the preliminary analysis. However, two of those labs are close to the center, without passing from the level 1 of realistic and the level 2 of exploration driven approach.

ThessAHALL perception of their prototyping process is in the center as "It is based in some previous experience and some assumptions that we made before starting the prototype and now we want to explore, validate or not the assumptions and how we could extend this aspect and replicate them." (ThessAHALL, 2020), they identify uncertainty in terms of scaling up and scaling out their prototype.

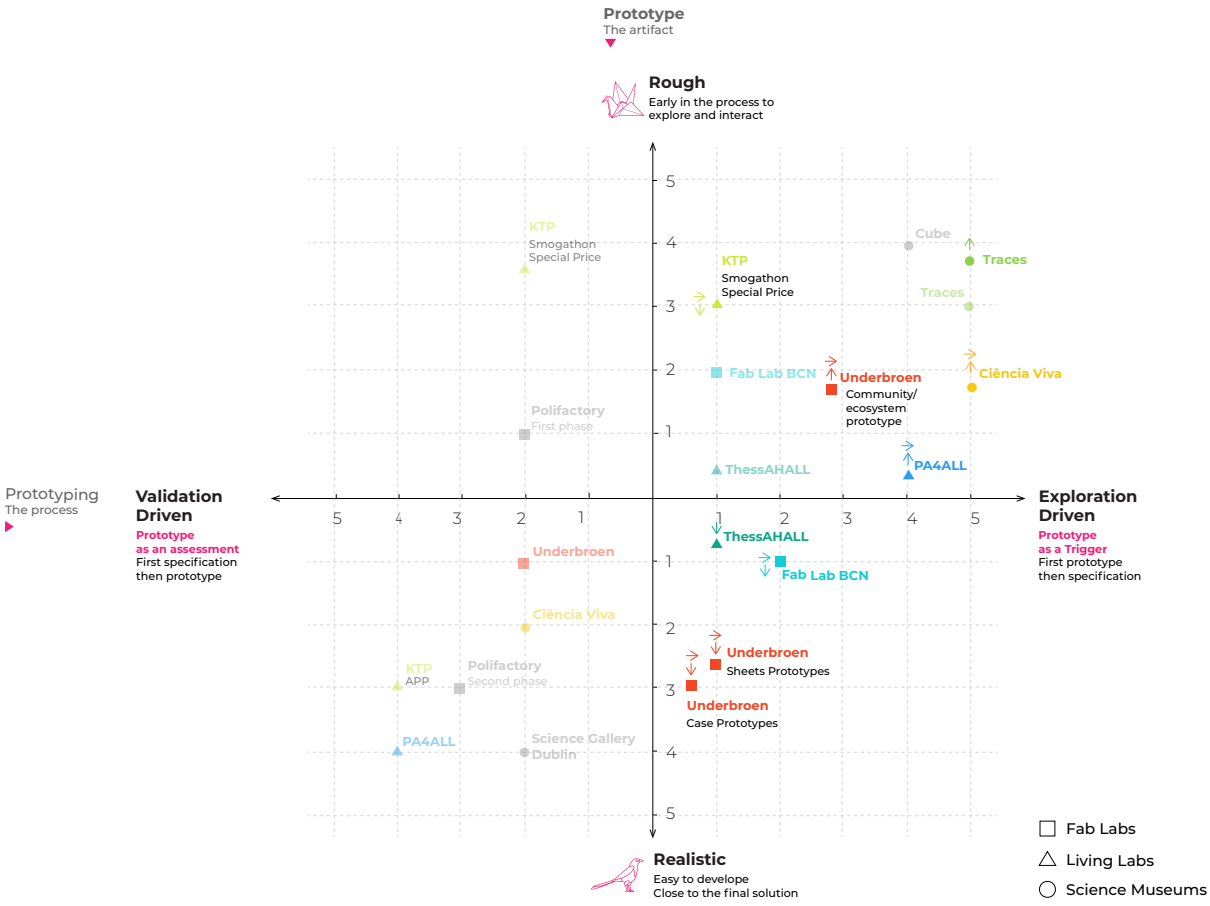
Underbroen placed three different prototypes: one regarding the creation of a community around plastic recycling in the validation-driven and rough quadrant, and two in a similar position in the exploration-driven and realistic approach: the sheets prototypes and the cases, which are tangible and closer to what could be the final product "in many ways we knew the specifications about how to realize it, but since its new techniques and production methods, still quite a lot of uncertainty." (Underbroen, 2020)

Fab Lab Barcelona placed its prototype close to the center and felt some difficulties to

differentiate between the validation driven and the exploration driven approach, “The separation between validation and exploration is very tricky, because I would say that I’m always in exploration mode, but if we are thinking on what we need now, we are finding solutions to validate our prototypes.” (FabLabBarcelona, 2020).

Besides these evident changes between the preliminary analysis and the one from the self-assessment, there are mild displacements from the other labs. In the following graphic we can see the contrast between the preliminary analysis (low opacity) and the self-assessment (high opacity):

Figure 23 Prototyping Matrix: Focus Group Labs Comparative Analysis



Traces and ThessAHALL were the only labs that remained in the same degree of exploration-driven approach, all the other labs moved in this axis towards the exploration-driven approach. The exploration was understood in terms of trying new means or ideas:

> *“It is an exploration from the beginning, from the tools of co-deign, because we are not that experienced on it, but it’s also an exploration for searching continuously for our solution and in a way is an exploration of the issues we are trying to address.” (CiênciaViva, 2020).*

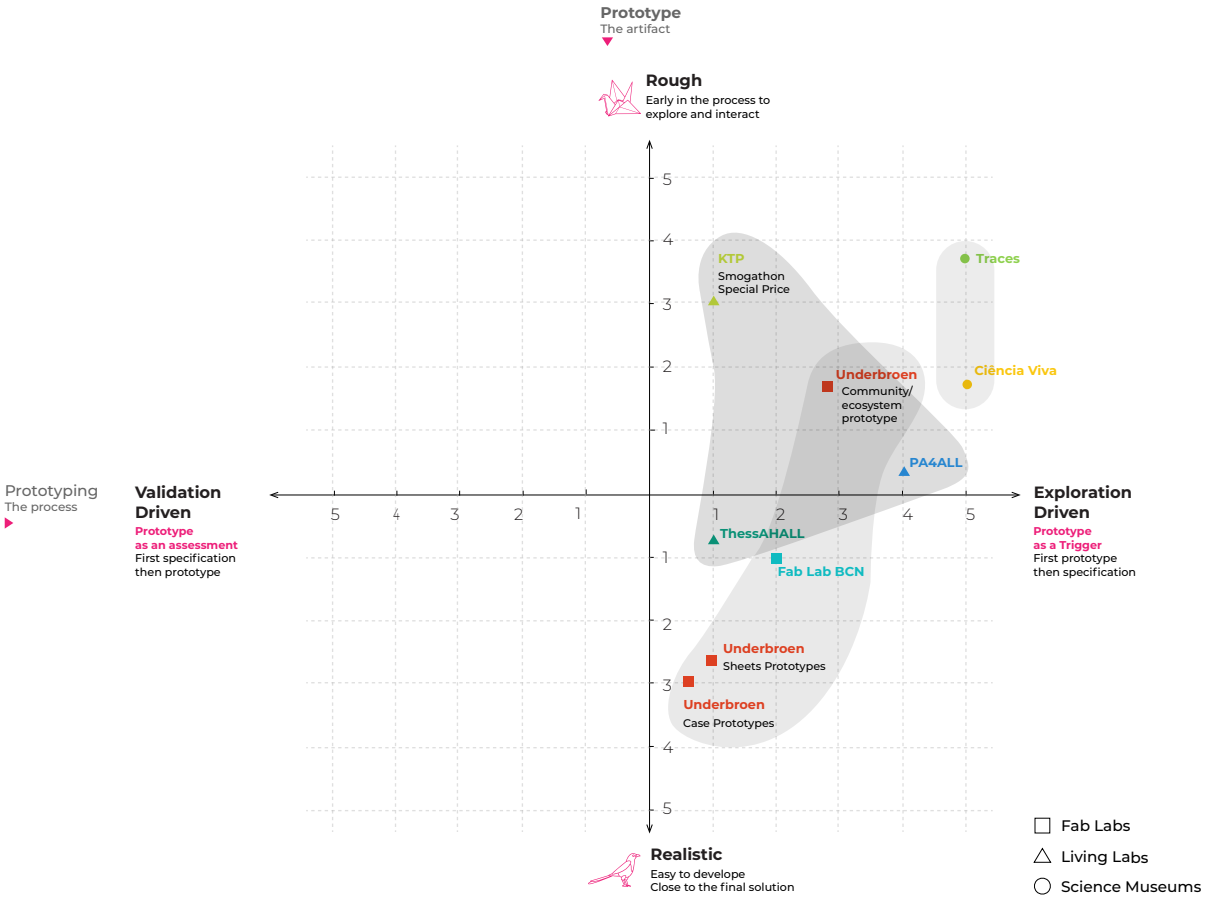
"Our prototype is connected with schools, the first thing we wanted to know is how the prototype would have to be in order to accomplish the specifications." (PA4ALL, 2020)

Four from the seven labs participating (Underbroen, ThessAHALL, Fab Lab Barcelona and KTP) moved their prototypes towards a more realistic artifact and three of them (Traces, Ciência Viva, PA4ALL and Underbroen) moved towards a rougher prototype. The term *rough* also caused some confusion, while some labs considered rough those prototypes that were not fully tested, others considered rough the ones that are not like the final solution:

"I see rough as something that can be very sophisticated and advanced but not similar in its form or use to the actual solution that could be implemented, while another person can interpret rough as something that is not fully tested. In my reading of the scale, realistic is when the prototype corresponds to the final object" (Traces, 2020)

.From the self-assessment of the labs, a pattern can be observed regarding the type of co-creation lab:

Figure 24 Prototyping Matrix: Co-creation Labs Patterns



All Fab Labs participating in the workshop perceived their prototypes in the bottom-right quadrant, (except from the one prototype of Underbroen that is in the top

right quadrant), which means that they feel that their prototyping process is exploration-driven, while using realistic prototypes. However, during the conversation they expressed their intention of "validating" known unknowns of the prototype more than exploring unknown unknowns.

In the case of the Living Labs, the three participating labs placed themselves in the top-right quadrant, although ThessAHALL and PA4ALL are in the middle between rough and realistic prototypes.

The two science museums participating in the workshop placed themselves in the more exploration-driven side of the graphic and closer to a rough prototype..

Conclusions

The two variables of the matrix are correlated, which could mean that two quadrants will be easily filled (exploration-driven/rough prototypes and validation-driven/realistic prototypes), while the other two would tend to remain empty (exploration-driven/realistic prototypes and validation-driven/rough prototypes). However, due to the technological advances to develop easily realistic prototypes, as Sanders (2013) explains, it is possible to find realistic prototypes with an exploration-driven approach. Regarding the validation workshop results, three out of seven labs identified their prototyping process in this quadrant.

Regarding the validation-driven approach with rough prototypes, although none of the labs perceived themselves in this area, two prototypes were placed in this quadrant from the preliminary analysis, based on their documentation about the prototypes. This displacement between the preliminary analysis and the validation workshop could be examined to understand the reason for the variations.

Every process of prototyping has some degree of exploration and most of the labs perceive themselves in this area even when they are looking to validate or assess their prototypes, as it can be seen in the case of ThessAHALL, they placed themselves in the exploration driven quadrant but later during the discussion expressed their interest in having validation-driven goals "We are going in the direction to validate, we want our project to find a realistic place, in the same time we are doing exploration." (ThessAHALL, Validation Workshop, 2020) Most labs perceive their prototyping approach as explorative, in the sense that they are exploring the specifications that need to be clarified.

In terms of the relation with policymakers, the bottom left quadrant of the graphic (validation-driven and realistic prototype) might be the "comfort zone" for policymakers' involvement, even if this is already out of their "traditional comfort zone". However, uncertainty can be a strength for policymakers' engagement, if the project is presented from the beginning as an exploration driven approach, highlighting its purpose. An exploration-driven approach with rough prototypes can be an advantage for the labs, as they can handle the risk of failure without policymakers assuming its cost and having the possibility to learn from the lab's experiences. In these cases, policymakers

as institutions have a more passive role in the prototyping process, as they are waiting for results more than being co-responsible of the process.

In the cases where policymakers were directly involved, such as KTP or PA4ALL, uncertainty can be managed through transparency in communication and a constant communication loop between the stakeholders. These labs still perceived themselves in an exploration driven approach and the uncertainty is felt in terms of meeting stakeholders' expectations and scaling up the solutions, passing from prototypes to implemented and scalable solutions.

The positioning of the prototypes might depend on the moment of the policy design in which it belongs; "It may be the case that certainty and uncertainty are corresponding to different phases of policy making and it could be an issue only in some phases while being an opportunity in others." (Deserti,Validation Workshop,2020) This can be seen contrasting two lab cases: on the one hand is Traces, which could be part of an early stage of policy design, influencing policymakers into new ways of understanding Artificial Intelligence, while handling a high level of uncertainty and a completely exploration-driven approach. On the other hand, KTP is part of a more mature stage of the policy design process, looking already for answers to implement the Air Protection Programme, which is currently part of the policymakers' agenda of the region.

7. Qualitative Case Studies: Krakow Technology Park, ThessAHALL and Traces

Based on the level of uncertainty, three labs were selected to verify if this aspect is affecting and how is it related to policymakers' engagement in the co-creation process. The cases were selected as follows: one lab that has a high level of uncertainty (Traces) , one that has a very low level of uncertainty (KTP) and one with a medium level of uncertainty (ThessAHALL), based on the two dimensions of analysis of the Prototyping Matrix. Below a deeper analysis of each case study is described in relation to their prototype's uncertainty and its interaction with policymakers.

Three semi-structured interviews with one member of each lab were carried out to understand de interaction of their prototypes' uncertainty level and the policymakers engaged in the process. The interviews also seek to deepen in the information provided in the reports to have a more depth understanding of the prototyping context.

7.1. Krakow Technology Park (KTP) – Living Lab

Challenge: How to improve the quality of the air in Krakow by motivating citizens to change their ecological attitudes, transportation and heating habits and to support decision makers with relevant tools and instruments for the co-creation of local new policies applying a user centered approach.

Prototypes: Air protection programme (APP) and monitoring and controlling system for industrial pollution.

Level of uncertainty: Low

Policy context of the challenge

In 1990 the *Special Economic Zone (SEZs)* were established in Krakow to attract investors to Poland. (KPMG, Invest in Poland , 2009, p. 10) A SEZ is "a separate, uninhabited part of the country's territory where business activity may be conducted under preferential conditions defined in the Act on Special Economic Zones of 20 October 1994" (Journal of Laws of 2007, no. 42, item 274, Journal of Laws of 2008, no. 118, item 746). In 1995 the first SEZ was opened in Mielec, 2 years later the Krakow SEZ, granted to KTP, was opened.

One of the benefits that the country offers to possible investors are the Technology Parks, with high-tech infrastructures and R&D support, together with tax exemptions, grants and funds (KTP manages the Polish Investment Zone, which allows them to authorize these tax exemptions).

One of the grants is related to the *Innovative Economy Operational Programme,* which is addressed to small, medium-sized and large companies with projects related with R&D centres or projects with new technological or industrial design solutions. (KPMG, Invest in Poland , 2009, p. 13)

This economic and political landscape reflects an institutional will to encourage innovation, and the emergence of Technology Parks such as KTP manifests an approach to innovation that beholds co-creation as a possibility of value creation. According to the approaches of design in design for policy, the nature of KTP and its relationship with local and regional authorities represents a *Design as co-creation* approach.

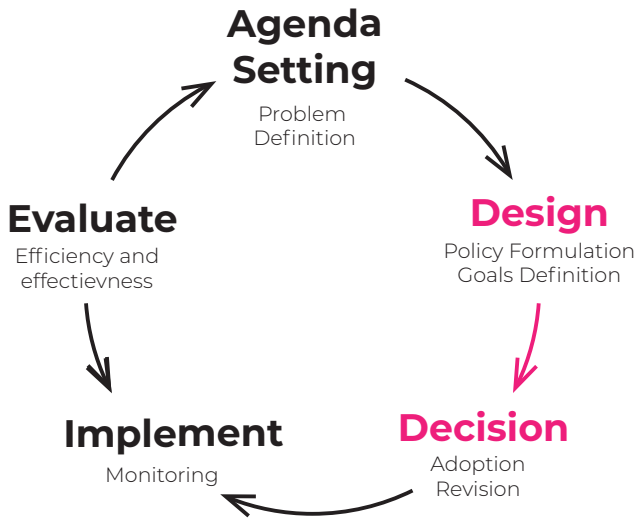
The challenge of KTP comes from the SMART KOM strategy, a previous project for Krakow Metropolitan Area developed by KTP, regional authorities and foreign partners from 2013 until 2015. One of the challenges that emerged from this strategy was "to improve quality of life by integrating and promoting activities aimed at improving the health and physical condition of the Krakow population mainly focused on air pollution and mobility." (Real, et al., Co-creation Labs: solutions and policies , 2019, p. 58) This challenge is framed in the Air Protection Program (APP) for the Malopolska Region and Integrated Quality of Air Management System in Krakow.

The environment protection is responsibility of public authorities, according to the article 74 par. 2 of the Polish Constitution (Real, et al., Co-creation Journeys , 2019, p. 84). Within this frame, air pollution is a challenge for the government, involving central and local administration levels. "Issues regarding air quality in Poland are regulated primarily by the Environmental protection law (POS) dated 27th April 2001." (Real, et al., Co-creation Journeys , 2019, p. 84) However, specific issues might be regulated by different entities of the Minister of the Environment.

The Development Strategy of the Malopolska Voivodship was adopted for the years 2011 until 2020, part of this strategy is dedicated to environment protection, " The strategy is the basic and the most important document of the voivodship self-government, defining the areas, objectives and directions of development policy interventions, conducted in the regional space" (Real, et al., Co-creation Labs: solutions and policies , 2019, p. 58)

KTP prototypes were part of an already existing local and national agenda, if we go back to the policy cycle, these prototypes are between the second and third phase, closer to the implementation.

Figure 25 KTP Prototype's Policy Cycle Phase



Based on the ROAMEF policy cycle and Grazzini (2015)

Approaches to prototyping and level of uncertainty

Both prototypes have different approaches, the Air Protection Programme is inclined to an *informational approach*, explained in Chapter 1 of this thesis, as it relies more on experts or stakeholders related to the air pollution subject, however it also has into account the needs and suggestions of inhabitants directly affected by the issue, even if they are not expert in the matter. However, the responsible of the creation and implementation of the APP is the Marshall Office of the Malopolska Region, together with the experts in air pollution.

The prototypes that emerged from the Smogathon special prize were closer to the *inspirational approach,* as they result from an explorative approach during the event. Nevertheless, the goal of the hackathon was clear: find ideas to make the APP tangible into products and services that would monitor industrial air pollution. The specifications for the ideas that would emerge were previously settled by specialists to guide the brainstorming and select the ideas.

> *"KTP worked with the Marshall Office to create together the criteria for the challenges of the Smogathon considering the APP. Specialists (relevant department employees) from Marshal office of Malopolska Region supported the Smogathon teams by delivering information and data, mentoring and answering the questions."* (Project Manager KTP, 2020)

Prototypes developed during the Smogathon were rough and quickly done by the participants of the event. After this prototyping process, KTP mentioned a need to adapt the solutions proposed in the Smogathon to local contexts. To do so, the lab has run internal tests of the internet platform to define what should be in the webpage and how it should be structured, involving colleagues from the Marshall Office of the Malopolska region. After these tests, they will incorporate the pilot into the official existing website of the Malopolska region

Policymakers role

KTP has a close relation with policymakers, which allowed them to define the challenge according to the central and local policymaking context and agenda, specifically the Air Protection Programme. KTP offers policymakers a space for exploring solutions, starting from their policy objectives and confronting them with citizens' needs and proposals.

> *"We as non-profit organization and working with the private sector, we don't have so many legal bindings as the administration has, sometimes we are more flexible, although we also follow some regulations, which allows us to look for the solutions out of the box. We try to share this with policymakers."* (Project Manager KTP, 2020)

The Marshall Office of the Malopolska Region is the owner of the Air Protection Pro-

gramme (APP), therefore their role in this prototype is the role of *owner,* which means a high involvement in all the co-creation process.

> *"KTP was supporting and facilitating the process, running the open consultation in a transparent way, inviting citizens and stakeholders to set their opinions and expectations regarding the APP"* (Project Manager KTP, 2020)

Regarding the Smogathon Special Prize event, policymakers were involved as mentors and advisor, helping to build the criteria for the challenges and assessing the ideas presented. In general, KTP didn't perceived any barriers to involve policymakers into the co-creation process, including prototyping. The type of relationship that KTP has with policymakers facilitated their involvement from the beginning and the constant meetings and consultations enabled a space for constant dialogue and agreement of each step of the process.

> *"We didn't have any special difficulties because of the long-term relation, the trust. We didn't start from the scratch. The relation with policymakers was based on day by day contact and involvement in consultations and participation in multisectoral Advisory Boards and Initiatives run by both parties. Before starting the prototyping, we did a very deep research and analysis of what is important from the policymaker's side to understand their perspective and priorities, and how much can we support them based on the role KTP plays in the region."*
>
> (Project Manager KTP, 2020)

Policymakers' interaction with prototyping's uncertainty

> *"Prototyping didn't bring uncertainty because we knew it was crucial for the Malopolska region and it has to be created and implemented in coming months, so we knew it must be delivered" (KTP, 2020)*

Although prototyping always deals with some level of uncertainty, KTP didn't perceive it, as they were constantly clarifying and controlling known unknowns through conversation with specialists. As the prototyping approach was specification-driven, the level of uncertainty was low and the way KTP manage it was through constant dialogue with experts and policymakers for which establishing a common language was important:

> *" The prototyping process itself did not bring any level of uncertainty, but definitely required wide consultation and explanation that we have a common understanding of what we are prototyping, that all aspects of the prototyped process are deeply discussed and consulted with all stakeholders involved (Air protection controlling entities as the Environmental Protection Inspector / Voivode Inspectorate of Air Protection)" (Project Manager KTP, 2020)*

KTP recognizes the relevance of being conscious about the changes that the idea

and the prototype will face, and the importance of communicating this condition to all stakeholders involved.

> *"The process of prototyping was very dynamic and we had to accept that there will be some changes during the prototyping, because the assumptions that we had at the beginning, when we went into the details, we had to modify it and discuss it with many stakeholders... Everything was to be discussed very detailed so we can be sure we were talking about the same thing, in the same way. So, when we accepted this dynamic, we had to accept the changes and modifications of the assumption. I think that is why it didn't bring so much uncertainty." (Project Manager KTP, 2020)*

Current state of the solutions

The Covid-19 situation required a change in the developing and prototyping phase of the ideas; however, it didn't represent significant delays in the timeline planned. The feedback sessions and meetings were conducted remotely and the development of prototypes of the Smogathon Special Prize continued being developed.

Due to coronavirus, the second round of consultation of the APP has been postponed. The presentation of the programme for the approval of the Regional Office of Malopolska Region is going to be by the end of September 2020.

7.2. ThessAHALL – Living Lab

Challenge: How to break the social exclusion walls and welcome older adults and chronic patients back to society?

Prototypes: "Participate 4" co-creation research and life-long learning programme

Level of uncertainty: Medium

Policy context of the challenge

Thess-AHALL is strongly connected with different actors from the health ecosystems and is member of the following international networks: the European Innovation Partnership on Active and Healthy Ageing (EIP on AHA), the International Association of Gerontology and Geriatrics (IAGG), the European Platform for Rehabilitation (EPR) and Alzheimer Europe. The Laboratory of Medical Physics is related to 9 innovation research groups.

There are several initiatives from the local government and private institutions to tackle elderly and chronic patients. Some of the initiatives include local and international policies, awareness campaigns, mentoring programmes and research regulations. (Real, et al., Co-creation Journeys , 2019, p. 100) ThessAHALL aims at changing the policymaking context for older adults and chronic patients and involve them as active actors within society, however "the local policy context has poor knowledge of co-creation and it does not promote the democratization of research and participants' involvement in it." (Real, et al., 2019-2, p. 93)

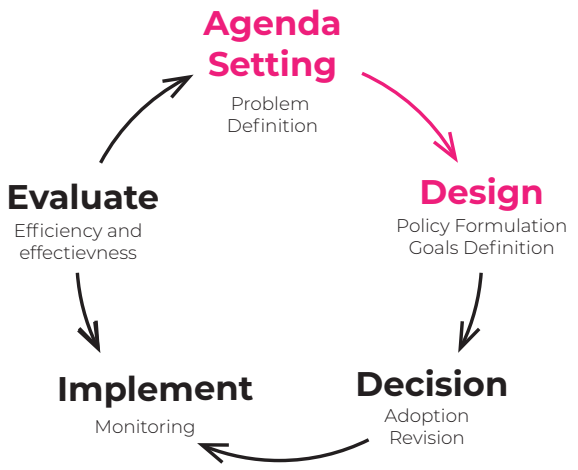
The policies vary for each target population; regarding elderly people, day care centers managed by the public-municipal administration offer sport, entertainment and educational activity programmes and benefits related to transportation and mobility. Concerning chronic patients, the policies are managed by the Greek federation of patients and the regional or national Patient's Associations, according to the conditions of the patient. There are also funds and initiatives coming from the World Health Organization and the European commission. However, "There is no central social design and the existing inclusive structures and activities are the product of short-term decisions/parameters" (Real, et al., Co-creation Labs: solutions and policies , 2019, p. 85). There are also barriers related to the bureaucracy required to communicate with

policymakers and some day care centers or hospitals, which makes it more difficult to gather evidences and information.

The initiative to create awareness about elderly people and chronic patients came from ThessAHALL, it wasn't part of government's agenda to start with, although there are already existing policies and programmes related to these issues. ThessAHALL challenge has an ambitious goal of improving conditions for elderly and chronic patients but also doing it through co-creation, which means a structural change in the policymaking context of Greece.

Therefore, the prototype is placed in early stages of the policy cycle, between the agenda setting and design phases.

Figure 26 ThessAHALL Prototype's Policy Cycle Phase



Based on the ROAMEF policy cycle and Grazzini (2015)

Approaches to prototyping and level of uncertainty

Their approach to prototyping is in the top-right quadrant, meaning they are closer to a *prototype-driven approach* and their prototype is still rough. Nevertheless, they are still close to the centre of the graphic; the goal of prototyping is clear, but they leave some space for exploration through the process.

> *"It is based in some previous experience and some assumptions that we made before starting the prototype and now we want to explore, validate or not the assumptions and how we could extend this aspect and replicate them." (ThessAHALL, 2020)*

The prototype by itself is still rough as they are simulating how the interaction between elderly, academia and researchers could be, but it is not extremely rough as:

> *"It is quite realistic to be developed because is based on previous knowledge, they can be part in a more systematic approach." (ThessAHALL, 2020)*

Policymakers role

The Region of Central Macedonia is meant to support the Living Lab by "promoting and embracing co-creation and its value for the society and the Quality of Life of specific populations, like older adults and chronic patients." (Real, et al., 2019-2, p. 93) Policymakers have been participating in events and working with elderly giving mentorship. Policymaker's role during the prototype was more as a supporter or observer, waiting for results of success to get completely involved.

> *"As Thessaloniki is a small city, it was easy to identify the key policymakers and approach them to present the project, however it is not easy to convince them to help us to scale this mission up." (Research Associate ThessAHALL, 2020)*

The lab has noticed a changed in how policymakers are perceiving the co-creation process: as they see elderly people involved in the events and activities, they have recognized the value of the project, " It is easy to show value when they can see the process with their own eyes." (Research Associate ThessAHALL, 2020)

> *"One week ago, we had a meeting with the major asking to involve them more in the process to replicate these initiatives in other parts of the city." (Research Associate ThessAHALL, 2020)*

Policymakers' interaction with prototyping's uncertainty

> *"I think that their uncertainty is that they are looking for solutions with high impacts for society. They don't want to spend so much resources or money to implement something, this is their fear." (Research Associate ThessAHALL, 2020)*

Uncertainty is perceived in terms of meeting expectations of stakeholders, for which the lab tries to manage their expectations at a medium level, being clear about the risks and implications of the project.

In terms of expectations the lab considers that policymakers don't face any uncertainty, "There is no uncertainty affecting policymakers in the process, as it has been said before, they don't have any expectations." (Research Associate ThessAHALL, 2020) As policymakers haven't been involved as co-owners or partners in the prototyping process

> *"Policymakers doesn't have great expectations; they are just happy to see older adults active. They are open to listen their needs and ideas; they are open to integrate some of their solutions, but they are a little bit distant" (Research Associate ThessAHALL, 2020)*

The "passive" role of policymakers into the prototyping process prevents them to deal with any uncertainty related to these activities, "Policymakers like the prototype be-

cause they like to see older adults involved. They don't express any comments of the process." (Research Associate ThessAHALL, 2020) the uncertainty is felt mainly by the lab and the elderly working in the project, as they don't know if the prototype will scale up in the end.

Current state of the solutions

The Covid-19 situation required a change in the way ThessAHALL was interacting with the elderly of the project, as this is a vulnerable population, meeting in person was impossible. Moreover, it is a target population that is not use to digital technologies, which made it difficult to communicate and continue working with them.

After the first loop of prototyping (explained in the previous chapter), Greece started the first lockdown because of the Covid-19. ThessAHALL decided to measure the impact so far, and then start a new round with virtual sessions via skype and viber, through group calls (E-coffees).

The groups pivoted their initial ideas for implementation for the city and they worked in similar activities at home. Each group has its own mission. The health group was about to produce an awareness campaign for older adults, now they are preparing some guidelines based on their experience with Covid-19, the main idea remains the same, but they adjusted to the emergency. The environmental group was about to codesign and renovate an abandoned park with the Municipality of Thessaloniki, to make it green again, now they are working in home gardens trying to make the city greener in another way. The third group challenge remains the same. Because of the summer period, they are moving to their summer houses and they won't participate in more calls until September 2020.

7.3. Traces – Science Museum

Challenge: How to organise interactions between research, education, civic right and policymaking in order to identify ways to raise awareness of algorithmic decision making within general cultural activities?

Prototypes: Artificial Intelligence as a co-spectator

Level of uncertainty: High

Policy context of the challenge

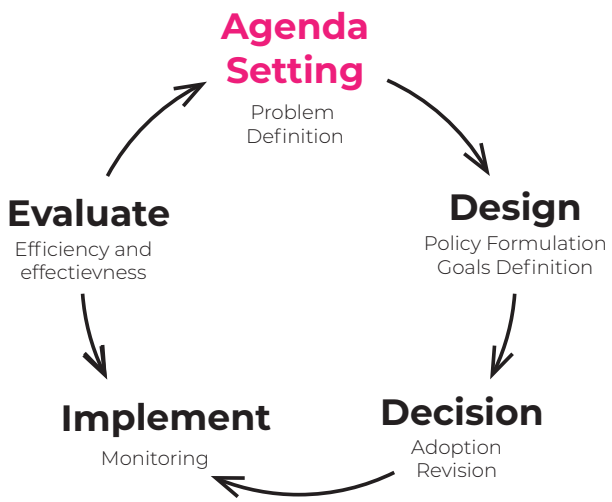
The ESPGG, the culture centre oversaw by Traces, is a leading research institution recognized in the academic and industrial sector, which places Traces in a strategic place between different stakeholders and in front of the ESPCI Paris and PSL University, actors that have been involved in past exhibitions and workshops from previous projects. The academic influences of the ecosystem of Traces seems more relevant and continuous than the relations established with the political context.

As the issue of the challenge has a global and quickly changing nature, there are no policies identified in the local context (Real, et al., Co-creation Journeys , 2019, p. 136). The aim of this challenge is to inform policymakers about the public visions regarding data privacy and algorithmic decision making. Unlike the KTP case, this challenge is not framed within an existing policy or public programme, it has a more bottom-up approach.

However, there are some regulations already addressing issues related with the challenge at a continental level. The European General Data Protection Regulation (GDPR) establishes the rules for the “protection of natural persons with regard to the processing of personal data and on the free movement of such data” (Official Journal of the European Union , 2016, p. 1). In France, the Commision Nationale de l’Informatique et des Libertés (CNIL) is responsible to protect citizens rights regarding data privacy by informing them about those rights and oversee the correct implementation of the EU GDPR law.

Traces' challenge is placed on a future scenario, where there are still no clear policies or programmes to tackle most of the issues related to algorithmic decision making, this is a field of unknowns unknows. Therefore, it is not part of the current policymakers' agenda, it is placed in the pre-phases and first phase of what could be a traditional policy cycle:

Figure 27 Traces Prototype's Policy Cycle Phase



Based on the ROAMEF policy cycle and Grazzini (2015)

Approaches to prototyping and level of uncertainty

In this case, the prototypes are a solution by themselves, they are not only a mean to explore ideas; they raise awareness through their process and engage people while doing it. These prototypes are adopting an *inspirational approach,* where uncertainty is high and is being used as fuel for co-creation. Their roughness linked with these technologies (AI, YOLO) allows them to explore different situations easily and iterate.

> *"... we really don't know the results. For me it's very interesting but it's very risky, half of the things we wanted to do didn't work, we take the risk of that, I was a bit disappointed because some of the things didn't work but you have to accept that if you want to explore." (Director Traces ESPCI Paris, 2020)*

> *"Our prototype is definitely inspiration driven; the prototype is the tool to identify the right questions to ask. So, it is not a product or s solution, it is an instrument that allows us to ask meaningful questions that we suspect might be hidden when we deal with our relationship with AI. So, through the prototype we are able to uncover hidden questions, not clarified angles and for us this is the role of prototypes, it allows us to look at things differently This is the reason why people participating is interested." (Traces, 2020)*

Each event and workshop allowed participants to develop several prototypes which made possible for the lab to iterate the idea since the beginning of the challenge. This is evident in the number of iterations carried out.

Policymakers role

Policymakers role during this prototype have been as observers that can be influenced and eventually support the outcomes of the prototype

The director of Traces explains the role of policymakers as *let goers,* which means passive agents that let other unities, such as living labs or science museums like Traces, experiment and explore, without being directly involved or being accountable of the exploration.

> *"Within our policymakers we found "let-goers", the ones that just let it flow because they recognize that diversity is important and then wait to see if something more solid will emerge and then they can start to act as promoters." (Director Traces ESPCI Paris, 2020)*

> *"Head of institutions are a stakeholder that is just there to let things happen, they allow things to happen, that's the best way to involve them in the process." (Director Traces ESPCI Paris, 2020)*

Île de France Region could be considered as a *let goer* and it has also been influenced by Traces prototype. From the beginning of the co-creation journey they have been informed and invited to the workshops and activities, after assisting to the theatre play, they got interested in the potential of the subject and carried out conferences with researchers about it and decided to fund part of future activities of Traces.

> *"... they (Île de France Region) have decided to do some things more experimental like this kind of activities, so for us this is a very nice success story in terms of policymakers, because we not only influenced them but we were also able to be funded." (Director Traces ESPCI Paris, 2020)*

There are other policymakers related to the research community that have been playing a more passive role into the prototyping, as they don't recognize co-creation as part of the research activity:

> *" We had meetings with a big consortium of research labs, we presented them the project, they were very interested and basically what they told us is "when the prototype is ready, then we come in" they didn't want to work together in open phases" (Director Traces ESPCI Paris, 2020)*

> *"The fact that other experts, artists or mediators enters not as outreach actors but as productive actors for the traditional academy is something completely new. They don't rely in people that are not experts and*

that are not within the same government system in which they operate." (Director Traces ESPCI Paris, 2020)

Policymakers' interaction with prototyping's uncertainty

Traces sees uncertainty as an advantage regarding their interaction with policymakers, as they can offer a save space to explore, where policymakers can get advantage of the good results without being accountable for their failures.

"In our experience, what they found interesting in our proposition is exactly the fact of placing it on the top-right angle (exploration driven and rough prototypes), so we made it very clear from the beginning that we were not there to propose something they were already funding but to look with a different angle and promoting new calls for proposals for science engagement." (Traces, 2020)

The aim of Traces prototypes is also to change the way policymakers see things, demonstrating them different angles of tacking one issue.

"by acting on that field, I don't think there is risk of failure, on the contrary, the possibility of failure is your strength. Policymakers are not accountable for any failure that you'll have cause it's not their project, it's just an experimentation so they will not suffer if we fail, it's not their policy that failed, it's just a project." (Director Traces ESPCI Paris, 2020)

This way Traces absorbs the uncertainty preventing policymakers to deal with it but showing them its value and importance into the field of experimentation and innovation. One example is the relation with the head of the unit of Science Society of Île de France Region, who has participated in the last prototypes:

" I think she understood now the challenge, she is a curious person she wants to have experimental activities in her programme and thanks to SISCODE she adopted us as the experimental ones, the one that challenge the way things are now." (Director Traces ESPCI Paris, 2020)

"Institutions are slow and it's better to make mistakes before getting institutionalized, cause if you make mistakes coming from a head of a unity, then the head of a unity is in danger." (Director Traces ESPCI Paris, 2020)

Regarding the research community as key stakeholders and policymakers, Traces has noticed a difference between researchers and organizations' approach to the prototypes, as the latter doesn't seem to recognize the value of prototyping with people as a research process and its uncertainty prevents them to understand its value, as it is difficult to know for sure what is going to be the outcome.

"The Research Community never experienced the format of doing

workshops of prototyping to see what happens, the way we framed the problem; we are working on the unknown aspect, so they don't recognize the subject in which we are working, they don't recognize us in their usual practice, which means that, while approving, they are not fully understanding." (Director Traces ESPCI Paris, 2020)

On the contrary, some researchers have expressed their interest in the process and have participated actively in the workshops and activities for personal purposes.

"I think we are too experimental to break through at an institutional level, one of their researchers is very engaged, he came to 4 of the events, and he is the head of a research unit of AI, he is interested in co-design but it stays at an individual level." (Director Traces ESPCI Paris, 2020)

"We had some quite well-known researchers in AI which participated in workshops but for their own research interest, but as institutions (of the Research Community) we found it difficult, because the shift from institutions and popularization activities to co-creation activities is too much." (Director Traces ESPCI Paris, 2020)

In this aspect, the challenge is not only uncertainty, but also legitimacy of co-creation processes involving lay-people and experts that are not part of the science community.

Current state of the solution

Depending on last workshops results, Traces will decide if it is necessary to carry out more prototypes; in November, two events will be lunched: one with final users will and another with high school students.

7.4. Observations

The three cases are placed in slightly different moments of the polycycle, specially Traces, which has the higher level of uncertainty, is closer to the agenda setting or pre-agenda setting phase. A relation between the phase of the policy cycle and the level of uncertainty of the prototypes could be possible, as well as the type if interaction that policymakers have with the prototype.

8. Discussion and conclusions

This chapter synthetize the findings of the ten case studies analysis, with special attention of the three cases that were selected to deepen the investigation. First, a description of three types of uncertainties identified is presented, followed by an analysis of policymakers' interaction with these uncertainties and an hypothesis of four main policymakers' roles in prototyping, which are correlated with the two dimensions of analysis of the prototyping approaches and their level of uncertainty (Prototyping Matrix).

8.1. Prototypes' uncertainty

The understanding of what uncertainty is varies; according to the analysis of the ten co-creation labs, uncertainty was related to three main aspects: the first one is related to the co-creation approach of design, the second one with the exploration approach and the third one is related to scaling-up solutions.

Co-creation uncertainty

Some labs perceived uncertainty in relation to the actors involved in the co-creation process, the more actors involved, the more uncertainty about the conditions in which the prototype was going to be developed, as it depends on the engagement and decisions to be taken with participants. This can be seen in the following quote of FabLab Barcelona about their process:

> *"For now, many uncertainties are still present, and the pilot has to consider the different timelines of people engaged and the global financial difficulties of the entities. As it relies mostly on the free participation of many participants, the success will depend on how far the model and proposed activities will be perceived of interests for ongoing project development " (Real, et al., 2019-2, p. 23)*

Another aspect related to the co-creation uncertainty is related to the expectations each actor has regarding the prototype; not knowing what is going to be the result is difficult and it is even more when there are different expectations about the final output.

> *"The only uncertainty is not to meet the expectations of stakeholders; we try to keep expectations to a medium level. Many times, we design good solutions, but the implementations are not to us, it depends on other actors to be implemented." (Research Associate ThessAHALL, 2020)*

> *"Uncertainty was felt in both sides, from KTP and from the Marshall Office of Malopolska Region. It is why is important to be transparent, we were neutral and opened the stage for everyone to present their perspective." (KTP, 2020)*

Laboratories experimenting this kind of uncertainty such as ThessAHALL and KTP, dealt with it by having constant communication with stakeholders, seeking to cultivate a relationship of trust. In the case of ThessAHALL, being transparent with the stakeholders helped them to level the expectations from the beginning and to establish a common understanding of the possible outputs of the prototype. In the case of KTP, setting a common language and verifying constantly the terms and objectives with policymakers along the process contributed to have a fluent dialogue. KTP had a strong relationship with policymakers before the co-creation journey started, and these was the basis to establish communication and guarantee a high involvement of policymakers,

this is a relation built through time and experience working together.

Exploration uncertainty

The exploration uncertainty is related to the prototype itself, with the possible outputs and not-knowing how is the process going to evolve. Most co-creation labs tried to decrease this type of uncertainty as much as possible by consulting specialists and building specifications before prototyping.

> *"Policymakers with good knowledge of local circumstances were really supporting in spotting the uncertainties to be addressed, bringing ideas down to earth." (CiênciaViva, 2020)*

> *"Our prototype is connected with schools, the first thing we wanted to know is how the prototype would have to be in order to accomplish the specifications." (PA4ALL, 2020)*

Although most of the labs identified themselves in the prototype-driven approach, which is mainly exploratory, they also recognize that their prototype's primary goal was to validate already developed solutions.

> *"We are going in the direction to validate, we want our project to find a realistic place, in the same time we are doing exploration." (FabLabBarcelona, 2020)*

Fewer labs, like Traces, faced this uncertainty different; they embraced it as an advantage and instead of trying to reduce it they used it to explore future scenarios from which there are still no answers, their prototype wasn't to validate solutions, rather to discover possible outputs.

Scaling-up uncertainty

The third uncertainty perceived by the labs was related to the possibility to scale the prototypes, labs expressing this concern about the scalability of the solutions were those with a slightly prototype-driven approach with realistic prototypes; these prototypes that are in the bottom-right quadrant of the Prototyping Matrix might be feeling higher levels of uncertainty related to the next steps of the ideas.

> *"Many times, we design good solutions, but the implementation is not on us, it depends on other actors to be implemented." (Research Associate ThessAHALL, 2020)*

> *"Prototyping has mostly been straightforward but scaling up a lot of uncertainty has been encountered both by the lab and the policy makers, more confident with small scales." (Underbroen, 2020)*

According to the comparative analysis of the ten co-creation labs, most of them acknowledge the uncertainty related to co-creation, which is handled through continu-

ous communication and construction of relationships of trust. In the case of exploration uncertainty most labs tried to reduce it at levels that some of the lab's members expressed not perceiving any uncertainty at all, which demonstrate that the specification-driven approach is predominant. The case of Traces was selected to deepen in what seems to be the lab with a more prototype-driven approach; this labs stands in the top-right quadrant of the Prototyping Matrix and has addressed uncertainty from a different perspective, as it has been explained before. Finally, the scaling-up uncertainty was expressed by the labs that were not in the two extremes of the Prototyping Matrix, those closer to the center of the matrix expressed this kind of uncertainty. These three types of uncertainties arise from different interactions of policymakers with prototypes; below, a description of these interactions is explained.

8.2. Policymakers' interaction and roles with prototypes' uncertainty

From the comparative analysis of the ten co-creation labs, two aspects are relevant to understand the interaction between policymakers and prototype's uncertainty; the first aspect is the stage of the policy cycle in which the prototype is taking place: is it happening in early stages of the policy cycle? Is it meant to implement solutions of already existing agendas? the second aspect is related to the origin of the challenge from which the co-creation journey started: is the challenge a top-down request? Or a bottom-up initiative from the labs or communities? According to these two aspects policymakers have a certain role in the co-creation process and during prototyping, this role interacts differently (or have no interaction) with the three types of uncertainties described above. Next, a description of the two aspects that determine policymakers' role is developed.

Stage of the policy cycle

The stage of the policy cycle in which the prototype is part of seems to be important to understand the involvement of policymakers in the process. This aspect emerged from the focus group dialogue with the co-creation labs and it was analyzed in the three case studies selected after. An apparent relation between the policy cycle stage and the role of policymakers was visible. On the one hand Traces, which had the highest level of uncertainty of all labs, was in an early (even previous stage) of the policy cycle, in this case policymakers were mainly waiting for results of the co-creation process, and although they were present in some prototypes their role was of participants. In this case Traces aims at influencing policymakers by showing them different ways of tackling the issue related with the challenge and presenting questions to be considered for future agendas or policies.

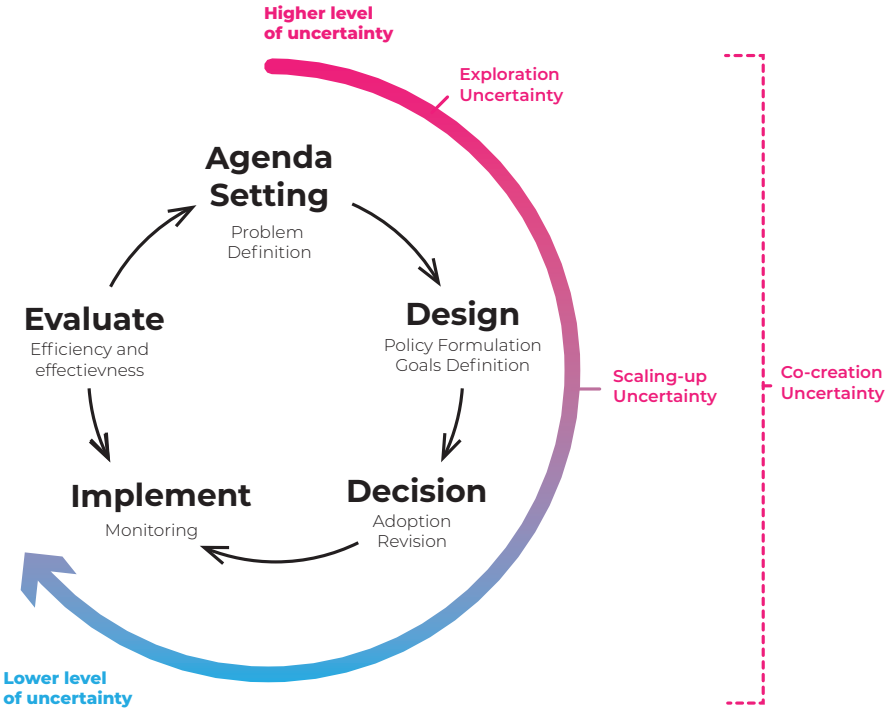
On the other hand, KTP was already in an advance stage of the policy cycle, approaching to the implementation stage. In this case the exploration and the

scaling-up uncertainty was reduce at the minimum and the policymakers acted as co-creators and co-owner of the prototype. In this scenario the uncertainty was perceived as a disadvantage and hence, something that had to be minimize.

> *"Prototyping didn't bring uncertainty because we knew it was crucial for the Malopolska region and it has to be, created and implemented in coming months, so we knew it must be delivered" (KTP, 2020)*

In the middle of both extremes, ThessAHALL perceived higher uncertainty related to the co-creation and scalability aspect, while the exploration uncertainty was also diminished before prototyping, "The initial idea changed before the prototyping, during the prototyping it has only been adjusted." (Research Associate ThessAHALL, 2020) The analysis of these three cases might contribute to the understanding of the relation between prototypes' uncertainty and the stage of the policy cycle in which they are being developed. In the following graphic a synthesis of the level and type of uncertainty in relation with the policy cycle is proposed.

Figure 28 Uncertainty and the Policy Cycle



Based on the ROAMEF policy cycle and Grazzini (2015)

As Clarke and Craft (2018) mentioned, it seems that design approaches recognized by policymakers are still "relegated to the activities intended to implement or deliver on policy objectives, such as program and service delivery" (Clarke & Craft, 2018), when the agenda of the policy cycle is already settled; in the meantime, labs that aim at working on early stages of the policy cycle,

where uncertainty is higher, tend to work independently from policymakers, who don't take part actively of the co-creation process until seeing results.

Origin of the challenge

The second aspect that influence the role of policymakers in prototyping is the origin of the challenge of the co-creation journey. The analysis of the ten labs suggest that there is a difference between the challenges originally came from government request, as is the case of KTP with the Air Protection Programme, and the challenges that started from an initiative of the co-creation labs, such as is the case of Traces and ThessAHALL. In the first case, policymakers were highly involved, the prototype happened in a later stage of the policy cycle and uncertainty was meant to be reduced. In the second case, policymakers remained skeptical and got involved gradually in the process as they saw positive results; in this scenario there was more place for uncertainty and policymakers acted as participants of the prototype more than co-creators, it was harder to involve them when the challenge was selected by the labs and they had to demonstrate results in order to convince policymakers to take active part of the process.

> *"At the beginning it was hard to convince them to be involved with the project but with time they have had the chance to recognize the value and now they are willing to take part of more events and activities." (Research Associate ThessAHALL, 2020)*

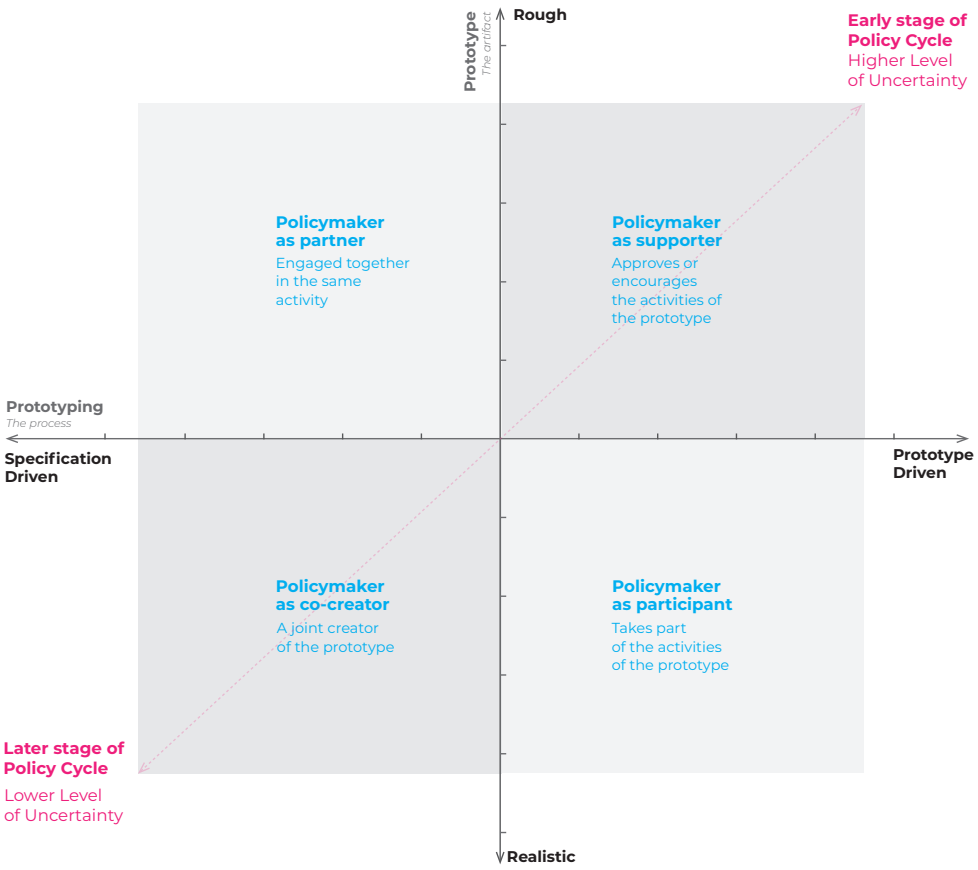
In the case of ThessAHALL, policymakers started to believe in the co-creation process as they saw elderly people participating and they have been joining to the prototype as the certainty of the solution increases. In the case of Traces, some policymakers expressed their support but didn't acknowledged the value of the co-creation process:

> *"Another key policymaker was Town of Paris with whom we have a lot of other projects, they are supporting but no more than that, the person we invited from the Town, she was informed, she expressed interest, but she never came." (Director Traces ESPCI Paris, 2020)*

Other policymakers have attended to the prototypes as participants and Traces have received fundings from Île-de-France, however most policymakers have remained passive in the prototyping process, more as spectators or participants.

Both aspects are co-related; based on the analysis of the three cases, the challenge that came from policymakers' request belonged to a later stage of the policy cycle, where there was an agenda settled. The other two cases started their challenge from their own aeras of expertise and the alignment with policymakers' agenda came later, from a bottom-up direction. The following categorization of policymakers' roles in prototyping is a hypothesis based on the analysis of the 10 co-creation labs, especially in the three cases selected to deepen the investigation.

Figure 29 Prototypes' uncertainty and policymakers' role



Policymakers as partners

This role is related to the top-left quadrant of the Prototyping Matrix (specification-driven, rough prototypes); only two prototypes were placed in this quadrant and both cases belonged to first versions of prototypes which second versions became more realistic, changing to the quadrant below (specification-driven, realistic prototype). This role is similar to the Co-creator role, the difference is that in these prototypes the co-creation labs have a higher responsibility in the prototype, however policymakers interact as partners, which means they are highly involved in the activities and are engaged with the outputs of the prototype. The Smogathon Special Price prototype of KTP belongs to this quadrant; in which KTP was the organizer of the prototype while policymakers contributed to the definition of the challenges, mentored the participant and selected the winners. After the event policymakers were also following the development of the ideas that are being produced together with the winners of the Smogathon, experts and policymakers thanks to KTP facilitation.

In this role policymakers contributed to reduce scalability and exploration uncertainty by guiding the specification of the prototype (the event), while KTP contributed to diminish the co-creation uncertainty being a connector and

translator between the participants of the event, experts and policymakers. In summary, the uncertainty was meant to be minimize as much as possible although the event gave a controlled environment to experiment possible solutions.

Policymakers as co-creators

As it has been mentioned above, this role is similar to the role of participant; however, co-creators are joint creators and share equal or comparable responsibilities in the prototype. This role corresponds to the quadrant of specification-driven, realistic prototypes, where uncertainty is low and usually the prototype has place in later stages of the policy cycle. KTP Air Protection Programme prototype belongs to this quadrant, in which policymakers were owners of the prototype and KTP facilitated the process. Policymakers are already aware of the value of the prototype and have active participation in its development; here the exploration and scalability uncertainties are very low, while co-creation uncertainty is lightly higher. Similar to what happens in the previous role, co-creation labs assume the task of leading with this uncertainty through the prototype itself. In all cases uncertainty is still meant to be reduced and the prototypes are very close to its implementation.

Policymakers as supporters

The role of supporters is placed in the bottom-right quadrant, which belongs to the prototype-driven, rough prototypes, that are explorative and have an inspirational approach. In these cases, policymakers are not as involved as the two previous roles, they might manifest their support to the co-creation process but their participation in the prototypes is low and passive. Here the uncertainty is high and usually the challenges came from the co-creation labs' initiative. Most labs placed themselves in this quadrant, however when expressing their goal with the prototypes during the focus group they manifested their intention of validating more than exploring unknown unknowns, which is closer to the left side of the matrix, in the specification-driven flank.

An example of a prototype in this quadrant is Traces' prototype, in this case Traces had different interaction with policymakers, however their role could be summarized as supporters: funding the project, helping with dissemination and sometimes participating in the prototype. Nevertheless, their involvement with the prototype is passive and they don't share any responsibility. The three types of uncertainties are high and the exploration uncertainty is seen as an advantage, as policymakers have no responsibilities in the prototype, they don't have to deal with the possibility of failure while they can benefit from the gains and findings of the exploration process, which is an advantage that co -creation labs can offer to policymakers. In this case Traces took the role of influencer of future policies, taking advantage of the uncertainty to provoke different questions about public issues and influence policymakers' perspective. The

scalability is not related to the implementation of a given solution, rather to the transformation of how policymakers address the challenge in which they are working.

Policymakers as participants

This role is in the bottom-right quadrant of the matrix, in the exploration-driven, realistic prototypes. Policymakers as participant are in between the role of supporters and co-creators, they take part more actively in the prototype than the supporters but still have less responsibility than the partners or co-creators. ThessAHALL placed its prototype in this quadrant, their relation with policymakers has evolved through the co-creation process and by the phase of prototyping they managed their relation with policymakers to connect their prototype with some decision makers, as is the case of the group working for the rehabilitation of one park of the municipality.

The two labs that placed their prototypes in this quadrant perceived the uncertainty mostly in relation to the scalability. This quadrant is between two extremes: informational and inspirational approaches. Unlike Traces, that seeks to inspire policymakers, labs in this quadrant perceive scalability in terms of implementation their solutions, however the uncertainty in this quadrant is still too high, the challenge came from the co-creation labs' initiative and the involvement of policymakers don't reach to the co-creator level, hence the scalability uncertainty is higher.

8.3. Uncertainty: a benefit or a barrier to policymakers' engagement

The analysis of the ten co-creation labs suggest that prototyping uncertainty can act both as a barrier or an advantage depending on the phase of the policy cycle in which the prototype is developed for, which influences the role that policymakers have in the co-creation process. During early stages of the policy cycle (agenda setting or policy design), exploration-driven prototypes that handle high levels of uncertainty offer a different perspective for policymakers to frame problems and identify needs and enable a space for exploration that policymakers cannot afford:

> *"There is a strong value in doing influential activities which are not directed presented as policymaking activities, but which will be influencing policymaking activities, because failure is accepted. In our case, for sure a reason of policymakers not to be involved is not because of fear of failure, they need us because we are able to fail." (Director Traces ESPCI Paris, 2020)*

In these cases, co-creation labs have the advantage of being able to explore, having an arena to play with uncertainty and use prototypes to discover possible outputs. The interaction of policymakers with this type of uncertainty is distant, they allow these

spaces to exist and support them but are not part nor co-responsible of what happens in those spaces. This type of relation must be clear for the beginning, in order to level expectations and being straightforward about the goals of the prototype and the role uncertainty plays in the process of prototyping.

> *"In our experience, what they (policymakers) found interesting in our proposition is exactly the fact of placing us on the top-right angle (prototype-driven, rough prototypes), so we made it very clear from the beginning that we were not there to propose something they were already funding but to look with a different angle and promoting new calls for proposals for science engagement" (Traces, 2020)*

On the contrary, prototypes' uncertainty could be a barrier for policymakers' engagement in late stages of the policy cycle, close to the implementation phase. Most labs working close to the implementation phases aim at reducing uncertainty and the ones with higher involvement of policymakers were those who managed to reduce these uncertainties through specification-driven approaches of prototyping. When policymakers acted as co-creators, as the KTP case, the levels of uncertainty were minimized and controlled to guarantee a desirable output. In both cases, the communication of the terms in which uncertainty is being handled is important to establish a relationship of trust with policymakers.

8.4. Conclusions

This thesis investigated a challenge for prototyping in design for policy that hasn't been deeply explored by most of the literature about prototypes and policy design: dealing with uncertainty and fear of failure. By exploring the interaction of policymakers with prototypes' uncertainty through the perspective of the co-creation labs of the SISCODE project, a deeper analysis of how this aspect influence policymakers' engagement in co-creation processes across Europe was carried out. As result, three different types of uncertainty from the labs' perspective were identified: co-creation uncertainty, exploration uncertainty and scalability uncertainty. Policymakers interact with these uncertainties differently according to the role they play in the co-creation process, which depends on the moment in which the co-creation is happening in the policy cycle and the origin from which the challenge came in the first place.

Prototypes are always handling some degree of uncertainty, however the way it is handled depends on the aim of the prototype; when prototypes aim for exploration through an inspirational approach (Sanders, 2005, p. 10) uncertainty is a benefit from which policymakers can take advantage of, however their involvement in this case tends to be passive and the understanding of how uncertainty is handled is low. From the ten co-creation labs analyzed only one addressed prototyping completely with this approach, in this case the prototype was happening in earlier stages of the policy cycle (in the agenda setting or previous to the agenda setting), uncertainty was high

and it was perceived as an advantage; while policymakers are not co-responsible of the prototype, co-creation labs can be enablers of exploration arenas to take risks that policymakers don't have to be accountable for. In this case, policymakers had a role of supporters, allowing these experimentations to happen but not being actively part of the prototype.

When prototypes aim for validation, with a specification-driven approach or informational approach (Sanders, 2005, p. 10) uncertainty is meant to be reduced, in these cases policymakers have an active role in prototyping. Most co-creation labs were close to this approach, and they were happening in later stages of the policy cycle (policy design or implementation), hence the prototypes aimed at reducing uncertainty as much as possible. In the KTP case, policymakers had a role of co-creators, which means a high involvement in the prototype. When policymakers have a co-creator role, uncertainty might be perceived as a risk or disadvantage, for which the co-creation lab tried to decrease it and control it through specifications from experts and the policymakers themselves.

Limitations of the study

This thesis was developed during the first semester of year 2020, in which the Covid-19 pandemic was a limitation, as it delayed the co-creation labs' prototyping processes, suspended events and activities that were meant to be part of the study. The crisis also affected the relation between the labs and policymakers, which had priorities related to the crisis.

Another limitation is related to the perception of uncertainty, as it analyzed prototyping uncertainty from the co-creation labs' perspective; it would be necessary to contrast this analysis directly with policymaker's perspective. Reaching them was a limitation in terms of time and geography, as they are all in different countries, moreover, the pandemic crisis suspended most of the activities involving policymakers, as it has been mentioned above.

Future development

Key questions for future discussions are related to the relation of the stages of the policy cycle and design approaches from the policymakers' point of view. According to the analysis of the ten co-creation labs, most policymakers recognize the benefits from prototyping while getting close to the implementation phase of the policy cycle, however literature review suggest that prototypes have the potential to contribute to a culture of collaboration and experimentation that can be powerful from earlier stages of the policy cycle (Corsín, 2014, p. 382) (Kimbell & Bailey, 2017, p. 216) not only in the simulation of product or services.

Anexx: Literature Appendix of Prototype's Notions accorss different fields

No.	Name	Key Words	Author	Year	Macrofield	Field	Prototyping Notion
1	A Simultaneous, Multidisciplinary Development and Design Journey – Reflections on Prototyping	simultaneous prototyping,abductive learning, probing	Achim Gersten-berg, Heikki Sjöman, Thov Reime, Pekka Abra-hamsson, and Martin Steinert	2015	Design	Interaction Design	Prototype-driven Rough
2	A Systematic Look at Prototyping	systematic, prototyping, strategy,	Chris-tiane Floyd	1984	Engineering	Interaction Design	*** Prototype-driven Realistic**
3	An Alternative Prototyping Classification	prototype classifications, prototyping practice	P. J. MAY-HEW AND P. A. DEARNLEY	1986	Design	Interaction Design	Prototype-driven Rough
4	Chapter 1 of Paper Prototyping : The Fast and Easy Way to Design and Refine User Interfaces	interface design, paper prototype	Carolyn Snyder	2003	Design	Interaction Design	Prototype-driven Rough
5	Chapter 6: Virtual Assembly Analysis enhacing rapid prototyping in collaborative product development. From: Rapid Prototyping: Theory and Practice	collaborative product development; computer-aided design; rapid prototyping; service-oriented architecture; e-tools; e-design	Kyoung-Yun Kim and Bart 0. Nnaji	2006	Engineering	Product Development	Specification-driven Realistic
6	Chapter 9: Dancing with ambiguity: Causality behavior, design thinking, and triple-loop-learning	Causality, corpus of behavior, corpus of knowledge, coordination, instrumentation, design learning, engineering design research, global collaboration, performance measurement, teamwork	Larry J. Leifer and Martin Steinert	2011	Design	Product Development	Prototype-driven Rough
7	Chapter 16 - What do Prototypes Prototype?	complexity, interactive systems, multidisciplinary teamwork,	Stephanie Houde and Charles Hill Apple Computer, Inc.	1997	Design	Interaction Design	Prototype-driven Rough
8	Collaborative Pro-totyping: Cross-Fer-tilization of Knowl-edge in Proto-type-Driven Prob-lem Solving	collaborative prototype, cross-fertilization of knowledge, prototype-driven problem solving, boundary object	Marcel Bogers and Willem Horst	2014	Design	Product Development	*** Specification-driven Rough**
9	Creating your Own Tools: Prototyping Environments for Prototype Testing	Prototyping Wayfaring Testing Experimentation	Vestad, Håvard Steinert, Martin	2019	Engineering	Industrial Engineering	Specification-driven Realistic

No.	Name	Key Words	Author	Year	Macrofield	Field	Prototyping Notion
10	Creating your Own Tools: Prototyping Environments for Prototype Testing	Prototyping Wayfaring Testing Experimentation	Vestad, Håvard Steinert, Martin	2019	Engineering	Industrial Engineering	Specification-driven Realistic
11	Cultures of Prototyping	rapid prototyping, culture of prototyping, creativity,	Michael Schrage	1996	Design	Interaction Design	Prototype-driven Rough
12	Democratic design experiments: between parliament and laboratory	participation; democracy; experiment; parliament; laboratory; thing	Thomas Bindera, Eva Brandta , Pelle Ehnb and Joachim Halsea	2015	Design	Participatory Design	Prototype-driven Rough
12	Democratic design experiments: between parliament and laboratory	participation; democracy; experiment; parliament; laboratory; thing	Thomas Bindera, Eva Brandta , Pelle Ehnb and Joachim Halsea	2015	Design	Participatory Design	Prototype-driven Rough
13	Design Prototypes as Boundary Objects in Innovation Processes	prototypes; boundary objects; Innovation process, organizational design, team management,	Holger Rhinow, Eva Köppen, and Christoph Meinel	2012	Design	Organization-al Design	Prototype-driven Rough
14	Effective prototyping for usability approaches to prototyping	prototyping techniques,usability oriented prototyping system, simulation modeling	Jack Hakim and Tom Spitzer	2000	Engineering	Software Engineering	Specification-driven Realistic
15	Empowering Users in a Task-Based Approach to Design	interactive system design, task-based design, scenario-based design, participatory design	Stephanie Wilson and Peter Johnson	1995	Design	Interaction Design	Prototype-driven Rough
16	Experience prorotyping	experience prototyping, design, methods	Marion Buchenau, Jane Fulton Suri	2000	Design	Interaction Design	Prototype-driven Rough
17	History of Rapid Prototyping. Chapter from Rapid Prototyping in Cardiac Disease	rapid prototyping	Carlos A. Gonzalez Lengua	2017	Science	Health	Specification-driven Realistic
18	How a prototype argues	digital prototype, interface design, computer prototypes	Alan Galey and Stan Ruecker	2010	Design	Interaction Design	Specification-driven Realistic
19	Leveraging prototypes to generate value in the concept-to-production process: a qualitative study of the automotive industry.	product development, product design, process, experiment	Elverum, Christer Welo, Torgeir	2016	Engineering	Automotive Industry	Specification-driven Realistic

No.	Name	Key Words	Author	Year	Macrofield	Field	Prototyping Notion
20	Methods for Prototyping Strategies in Conceptual Phases of Design: Framework and Experimental Assessment	prototype development, prototyping process, method	Camburn, Bradley Dunlap, Brock Kuhr, Rachel Viswanathan, Vimal Linsey, Julie Jensen, Dan Crawford, Richard Otto, Kevin Wood, Kristin	2013	Engineering	Product Design	Specification-driven Realistic
21	Multimodal theater: extending low fidelity paper prototyping to multimodal applications	multimodal, prototyping, low-fidelity, informal user interfaces, design methodologies, Wizard of Oz	Corey D. Chandler, Gloria Lo, Anoop K. Sinha	2002	Design	Interaction Design	Prototype-driven Rough
22	Prototype Experiments: Strategies and Trade-offs	agile development-set-based engineering-point -based engineering-prototypingexperimen-tation	Sigmund A. Tronvoll, Christer W. Elverum, Torgeir Welo	2017	Engineering	Industrial Engineering	*** Specification-driven Rough**
23	Prototype for X (PFX): A holistic frame-work for structuring prototyping methods to sup-port engineering design	prototypes design process user centered design product development	Menold, Jessica Jablokow, Kathryn Simpson, Timothy	2017	Design	Product Development	Prototype-driven Rough
24	Prototypes as (Design) Tools for Behavioral and Organizational Change	organizational change; rapid prototyping; design methods; experimentation, behavioral changes	Peter Coughlan Jane Fulton Suri Katherine Canales IDEO	2007	Design	Organization-al Design	Prototype-driven Rough
25	Prototyping and the new spirit of policy-making	policy design; prototyping; policy-making; systems design; service design	Lucy Kimbell and Jocelyn Bailey	2017	Design	Design for Policy	Prototype-driven Rough
26	Prototyping methods and constraints for small-to-medium sized enterprises in East Africa	design for development, developing countries,prototyping methods, design for manufacture engineering for global development, SMEs	Suzanne Chou, Jesse Austin-Bren-eman	2018	Design	Product Development	Specification-driven Realistic
27	Prototyping the past	jewelry media history rapid prototyping reverse engineering wearables design	Jentery Sayers	2015	Social Science	History	Specification-driven Realistic
28	Representing Future Situations of Service: Prototyping in Service Design	service design, situated cognition, prototyping, representations, surrogate	Johan Blomkvist	2014	Design	Service Design	Prototype-driven Rough
29	Rough and ready prototypes: lessons from graphic design	interface design, graphic design, coded prototypes	Yin Yin Wong	1992	Design	Interaction Design	Prototype-driven Rough

No.	Name	Key Words	Author	Year	Macrofield	Field	Prototyping Notion
30	Service Prototyping According to Service Design Practitioners	service prototyping, interviews, design practice	Johan Blomkvist, and Stefan Holmlid	2010	Design	Service Design	Prototype-driven Rough
31	Speculative prototyping, frictions and counter-participation: A civic intervention with homeless individuals	participatory designprototypes, urban design , user participation, speculative intervention	Martin Tironi	2018	Design	Participatory Design	Prototype-driven Rough
32	The prototype in 20th-century art	art ,collecting, design, prototypicality, science	Susanne Kuchler	2010	Art/Social Science	Plastic Art Anthropology	Prototype-driven Rough
33	The prototype: More than many and less than one. Journal of Cultural Economy	prototypes, experimental cultures, anthropology, traps, recursivity	Alberto Corsín Jiménez	2014	Art /Social Science	Anthropology	Prototype-driven Rough
34	The prototype: presencing the immaterial	icons, immateriality, prototypes,rapid manufacturing,technologies of presence	Victor Buchli	2010	Design	Product Development	Specification-driven Realistic
35	The role of prototypes in communication between stakeholders	case study, design practice, design management, prototypes, communication artifacts	Carlye A. Lauff, Daniel Knight, Daria Kotys-Schwartz and Mark E. Rentschler	2019	Engineering	Product Development	Specification-driven Realistic
36	The role of prototyping in mathematical design thinking	mathematical design thinking Mathematical modeling Prototyping Narrative inquiry Technology	Leah M. Simona and Dana C. Cox	2019	Science	Mathematic	Prototype-driven Rough
37	The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas	prototyping, design, design space, human-computer interaction	YOUN-KYUNG LIM and ERIK STOLTERMAN	2008	Design	Interaction Design	Prototype-driven Rough
38	What can you Learn from a Low-Fidelity Prototype?	low-fidelity prototype, interface design, testing, constrains	Robert A. Virzi	1989	Design	Interaction Design	Prototype-driven Rough
39	What is a Prototype? What are the Roles of Prototypes in Companies?	prototype roles, communication, learning, decision making, prototype definitions	Carlye A. Lauff Mem. Daria Kotys-Schwartz Mark E. Rentschler	2018	Engineering	Mechanical Engineering	Specification-driven Realistic

*** Most literature remained in two quadrants of the Prototyping Matrix: mostly were specification-driven and realisitc prototypes or prototype-driven and rough prototypes. However, as Sanders (2013) suggest, there are technological advances and changes of mindset that allows different configurations of prototyping approaches. Documents number 2, 8 and 22 are examples of alterantive approaches to prototypes, as they are specification-driven and rough or prototype-driven and realisitc.**

REFERENCES

Beaulé, C. (2018, February 22). Design as a Strategic Tool for Sustainability in Northern and Arctic Contexts, Case Study of the Arctic Design Concept in Finland. Montreal, Canada: Université de Montréal.

Binder, T., Brandt, E., Ehn, P., & Hasle, J. (2015). Democratic design experiments:Between parliament and laboratory. *CoDesign 11*, 152-165.

BioSense. (202, August 08). *BioSense*. Retrieved from About Us: https://biosens.rs/?page_id=7687&lang=en

Blomkamp, E. (2018, January 15). The Promise of Co-Design for Public Policy. *Australian Journal of Public Administration, vol. 77, no. 4*, pp. 729-743.

Blomkvist, J., & Holmlid, S. (2011). Existing Prototyping Perspectives: Considerations for Service Design. *Nordic Design Research Conference 2011*, (pp. 1-10). Helsinki.

Bolles, G. (2014, October 17). *How the Internet Evaporates the Middle: Unbundling Media.* Retrieved from Medium: https://medium.com/@gbolles/unbundling-media-6c3e79bc2d95

Breckon, J. (2015). Better Public Services through experimental government. *Alliance for Useful Evidence* , 1-41.

Bryson, J., Crosby, B., & Seo, D. (2020). Using a design approach to create collaborative governance . *Policy & Politics Vol. 48 No.1* , 167-189.

Buchanan, R. (2001). Design Research and the New Learning. *Design Issues: Volume17*, 3-23.

Buchenau, M., & Fulton, J. (2000). Experience Prototyping . 424-433.

Buchli, V. (2010). The prototype: presencing the immaterial. *Visual Communication*, 273-286.

Cambridge Dictionary. (2020, July 04). *Cambridge Dictionary*. Retrieved from https://dictionary.cambridge.org/dictionary/english/uncertainty

CiênciaViva. (2020, July 15). Focus Group SISCODE Dialogue with Researchers and Practicioners . (A. Campo, Interviewer)

Clark, A. (2001). Natural-Born Cyborgs? *Proceedings of Cognitive Technology: Instruments of Mind: 4th International Conference* (pp. 17-24). Berlin: Warwick, UK. Springer-Verlag.

Clarke, A., & Craft, J. (2018, January 23). The twin faces of public sector design. *Wiley Governance*, pp. 5-21.

Colebatch, H. (2018). The idea of policy design: Intention, process, outcome, meaning and validity. *Public Policy and Administration Vol. 33 (4)* , pp. 365-383.

Corsín, A. (2014). The prototype: more than many and less than one. *Journal of Cultural Economy*, pp. 381-398.

Coughlan, P., Fulton, J., & Canales, K. (2007, March). Prototypes as (Design) Tools for

Behavioral and Organizational Change. *The Journal of applied behavioral science*, pp. 1-13.

Cristensen, S. (2020, February 05). PIPO prototyping advancement . *Consortium Meeting*. Copengahen, Denmark : SISCODE.

Cube. (2020, August 09). *Cube Design Museum*. Retrieved from About us: https://www.cubedesignmuseum.nl/en/about-cube/over-cube-design-museum

Dang, T. A. (2019, August 03). *Known Knowns, Unknown Knowns, and Unknown Unknowns*. Retrieved from Medium: https://medium.com/datadriveninvestor/known-knowns-unknown-knowns-and-unknown-unknowns-b35013fb350d

Deserti, A., Rizzo, F., & Smallman, M. (2020, May 23). Experimenting with co-design in STI policy making. *Policy Design and Practice*, pp. 135-149.

Director Traces ESPCI Paris. (2020, June 30). Interview Traces. (A. Campo, Interviewer)

Ecsite . (2020, June 03). *Ecsite* . Retrieved from TRACES / Espace des Sciences Pierre-Gilles de Gennes: https://www.ecsite.eu/members/directory/traces-espace-des-sciences-pierre-gilles-de-gennes

Elverum, C. W., & Welo, T. (2016, February). Leveraging prototypes to generate value in the concept-to-production process: a qualitative study of the automotive industry. *International Journal of Production Research*.

ERC=Science². (n.d.). *ERC=Science²*. Retrieved from Ciência Viva - Agência Nacional para a Cultura Científica e Tecnológica: https://www.sciencesquared.eu/institutions/ciencia-viva-agencia-nacional-para-cultura-cientifica-e-tecnologica

Fab Lab Barcelona . (2020). *FAB LAB BARCELONA*. Retrieved from https://fablabbcn.org/about_us.html

FabLabBarcelona. (2020, July 15). Focus Group SISCODE Dialogue with Researchers and Practicioners . (A. Campo, Interviewer)

Fiaidhi, J., & Mohammed, S. (2018). Fab Labs: A Platform for Innovation and Extreme Automation. *IT Professional* , 83-90.

Hermus, M., van Buuren, A., & Bekkers, V. (2020). Applying design in public administration: a literature review to explore the state of the art. *Policy & Politics Vol. 48 no. 1*, 21-48.

Hill, M., & Hupe, P. (2002). Implementing public policy: governance in theory and practice . *Thousand Oaks, Calif: Sage.*

Houde, S., & Hill, C. (1997). What do Prototypes Prototype? In T. L. M. Helander, *Handbook of Human-Computer Interaction* (pp. 367-381).

Howlett, M. (2020). Challenges in applying design thinking to public policy: dealing with varieties of policy fromulation and their vicissitudes. *Policy & Politics Vol. 48 no. 1* , 49-65.

Justo, A. (2019, February 17). *The knowns and unknowns framework for design thinking*. Retrieved from Medium: https://uxdesign.cc/the-knowns-and-unknowns-framework-for-design-thinking-6537787de2c5

Kimbell, L. (2016). Design in the Time of Policy Problems. *2016 Design Research Society 50th Anniversary Conferencce*, (pp. 1-14). Brighton, UK.

Kimbell, L., & Bailey, J. (2017). Prototyping and the new spirit of policy-making. *Codesign* , 214-226.

KPMG, Invest in Poland . (2009). *A guide to special economic zones in Poland* . KPMG.

KTP. (2020, July 15). Focus Group SISCODE Dialogue with Researchers and Practicioners. (A. Campo, Interviewer)

Küchler, S. (2010). The prototype in 20th-century art. *Visual Communication*, 301-312.

Lauff, C., Kotys-Schwarz, D., & Rentschler, M. (2018, February). What is a Prototype? What are the Roles of Prototypes in Companies? *Journal of Mechanical Design*.

Lengua, C. (2017). History of Rapid Prototyping . In K. Majeed, *Rapid Prototyping in Cardiac Disease* (pp. 3-7). New York: Springer International Publishing.

Lewis, J., McGann, M., & Blomkamp, E. (2020). When design meets power: design thinking,public sector innovation and the politics of policy making . *Policy & Politics Vol. 48 no. 1*, 111-130.

Lim, Y.-K., Stolterman, E., & Tenenberg, J. (2008). The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas. *ACM Transactions on Computer-Human Interaction*, 7:1-7:27.

Martins, S., & Fenollosa, C. (2019). *T3.6: Dissemination plan within the co-creation labs ecosystems.* SISCODE .

Mintrom, M., & Luetjens, J. (2016). Design Thinking in Policymaking Process: Opportunities and Challenges . *Australian Journal of Public Administration, vol. 75 no. 3*, pp. 391-402.

Morelli, N. (2002). Designing Product/Service Systems:A Methodological Exploration. *Design Issues: Volume 18, Number 3*, 3-17.

Official Journal of the European Union . (2016). REGULATION (EU) 2016/679 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL . *Official Journal of the European Union*, 1-88.

Open Government Partnership. (2020, May 04). *Open Government Partnership*. Retrieved from https://www.opengovpartnership.org/about/

Osborne, S. (2010). The New Public Governance. *Public Management Review*, 377-386.

PA4ALL. (2020, July 15). Focus Group SISCODE Dialogue with Researchers and Practicioners . (A. Campo, Interviewer)

Politecnico di Milano. (2020). *Polifactory*. Retrieved from https://www.polifactory.polimi.it/en/about/

Praça, G. (2020). *Viva Kayaks! SISCODE Copenhagen Consortium.* Copenhagen: SISCODE.

Project Manager KTP. (2020, June 18). Interview KTP. (A. Campo, Interviewer)

Puerari, E., Koning, J., Mulder, I., & Loorbach, D. (2017). Shaping spaces of interaction for sustainability transitions. *Spaces of dialog for places of dignity* , (pp. 202-208).

Real, M., Mantziari, D., Maločić, M., Stojacic, I., Praça, G., Bertrand, G., . . . Sedini, C. (2019). *Co-creation Labs: solutions and policies* . SISCODE.

Real, M., Mantziari, D., Maločić, M., Stojacic, I., Praça, G., Bertrand, G., . . . Sedini, C. (2019-2). *Co-creation Labs: solutions and policies.* SISCODE.

Real, M., Petsni, D., Ajdukovic, A., Prada, P., Bertrand, G., Köppchen, A., . . . Bianchini, M. (2019). *Co-creation Journeys* . SISCODE.

Real, M., Petsni, D., Ajdukovic, A., Prada, P., Bertrand, G., Köppchen, A., . . . Bianchini, M. (2019-1). *Co-creation Journeys.* SISCODE.

Research Associate ThessAHALL, A. (2020, June 22). Interview ThessAHALL. (A. Campo, Interviewer)

Rizzo, F., Deserti, A., Crabu, S. S., Hjort, J., Hansen, S., & Menichinelli, M. (2020). Co-creation in RRI Practices and STI Policies. *SISCODE Co-design for society in innovation and science*.

Sanders, E. (2005). Information, Inspiration and Co-creation. *6th International Conference of the European Academy of Design*, (pp. 1-15). Bremen.

Sanders, E. (2013). Prototyping for the design spaces of the future. In L. Valentine, *Prototype Design and Craft in the 21st Century.*

Sangiorgi, D. (2015). Designing for public sector innovation in the UK: design strategies for paradigm shifts. *Foresight, Vol.17 Issue: 4*, 332-348.

Schaffers, H., & Turkama, P. (2012). Living Labs for Cross-Border Systemic Innovation. *Technology Innovation Management Review*, 25-30.

Schön, D. (1973). *Beyond the stable state.* New York: The Norton Library.

Schön, D. (1982). *The Reflective Practitioner: How Professionals Think in Action.* New York: Harper Collins.

Sedini, C., & Cipriani, L. (2020, February 05). Polifactory Proceedings . Copenhagen, Denmark : Polifactory .

Shrage, M. (1996). Cultures of Prototyping. In T. Winogard, *Bringing Design to Software.*

Simon, L., & Cox, D. (2019, August 26). The role of prototyping in mathematical design thinking. *Journal of Mathematical Behavior*, pp. 1-14.

SISCODE. (2017). *SISCODE co-design for Society in Innovation and Science.*

ThessAHALL. (2020, July 15). Focus Group SISCODE Dialogue with Researchers and Practicioners . (A. Campo, Interviewer)

Tironi, M. (2018). Speculative prototyping, frictions and counter-participation: A civic intervention with homeless individuals. *Design Studies Vol 59*, 117-138.

Traces. (2020, July 15). Focus Group SISCODE Dialogue with Researchers and Practicioners . (A. Campo, Interviewer)

Underbroen. (2020, July 15). Focus Group SISCODE Dialogue with Researchers and Practicioners . (A. Campo, Interviewer)

van Buuren, A., Lewis, J., Peters, B., & Voorberg, W. (2020). Improving public policy and administration:exploring the potential of design. *Policy & Politics, vol 48, no 1*, 3–19.

Vettukattil, J., Samuel, B., Gosnell, J., & Kurup, H. (2017). Creation of a 3D Printed Model: From Virtual to Physical. In K. Majeed, *Rapid Prototyping in Cardiac Disease* (pp. 9-19). New York: Springer International Publishing.

Virzi, R. (1989). What can you Learn from a Low-Fidelity Prototype? *Proceedings of the Human Factors and Ergonomics Society Annual Meeting.* 224-228: Sage Publications .

Woodhill, J. (2010). Sustainability, Social Learning and the Democratic Imperative: Lessons from the Australian Landcare Movement. In C. Blackmore, *Social Learning Systems and Communities of Practice* . Springer.

Yang, J. (2018, December 20). *Creating certainty and embracing uncertainty*. Retrieved from Medium UX Collective: https://uxdesign.cc/creating-certainty-and-embracing-uncertainty-8cd0d6d19f5

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