CO-CREATION FOR TRANSDISCIPLINARITY

Adoption of participatory design and agile project management in collaborative research processes

Enric Senabre Hidalgo

PhD Dissertation

UOC R&I
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Information and Knowledge Society Doctoral Programme

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«You cannot understand a system until you try to change it»
Kurt Lewin

Abstract

This PhD project investigates co-creation methods applied to transdisciplinary research. In the context of the Network Society, research collaboration has grown in popularity among scientific teams, under many approaches and forms. Among them, transdisciplinarity represents a specific type of collaborative scientific activity. Transdisciplinary research goes beyond the collaboration of experts from different disciplines, and can also involve non-experts and non-scientific stakeholder communities for holistically addressing different problems and issues, as in the case of citizen science or action research. Transdisciplinarity involves complex research processes and new challenges, such as how to deal with diversity from participants, especially for planning and managing projects. This thesis, articulated around a compendium of publications, explores if and how far co-creation methodologies can contribute to addressing these challenges, in different contexts and phases of transdisciplinary research. The research focuses on the need to explore and analyse how transdisciplinarity can be influenced by co-creation at the practical and procedural level, particularly when adopted by scientific teams in the preliminary and day-to-day collaboration for research projects.

Among the various paradigms of co-creation, participatory design and agile project management represent two relevant methodological frameworks for articulating collaboration. Both originated outside of academia and are now progressively being adopted in a wide diversity of knowledge-related domains. With a potential for improving collaborative research processes, participatory design and agile frameworks represent innovative approaches to knowledge generation that require dedicated attention when adopted in transdisciplinary contexts. Co-creation, in this sense, is emerging in parallel to new approaches to scientific production like Open Science or Responsible Research and Innovation (RRI).

The central question is to what extent the current shift in different scientific domains to establish transdisciplinary processes, which increases the diversity of participants and perspectives, as well as complexity in the management of collaboration practices, could benefit from co-creation approaches for the participative ideation, planning and coordination of research. The aim of this thesis is, therefore, to develop a comprehensive understanding of key factors that connect co-design and agile practices to collaboration in transdisciplinary research projects. Among these key factors, consideration is given to aspects such as communication, visualisation, transparency, task distribution, trust building, engagement, quality of results and efficiency.

The study is based on three different case studies of transdisciplinarity in academia, that cover the contexts of citizen science, team science and action research. The methodology adopted combines quantitative analysis, via questionnaire surveys and

online content analysis, with a qualitative approach based on semi-structured interviews and participant observation. In parallel to the analysis of the case studies, the project has produced and tested a practical toolkit for the collaborative design, planning and management of transdisciplinary research. The originality of the project, in this sense, is twofold. On the one hand, it brings a common perspective of co-creation and its experimental application in transdisciplinary research (connecting previous knowledge from fields like design thinking, project management, organisational learning, public participation in research and science of team science). On the other hand, the study represents a novel approach in providing the mentioned toolkit as a practical copyleft material, for potential reuse by other research projects and co-creation practitioners.

The research results suggest that co-creation contributes to integrating diversity and managing complexity in several stages and types of transdisciplinary research collaboration. Especially in decision-making processes, thanks to visualization techniques, dynamic ways of communicating and generating discussion via specific facilitation approaches. Co-creation is also useful for improving transparency in workflows, contributing to engagement and trust building when facilitated in flexible, adaptive and scalable ways. In terms of efficiency and quality of results, data from the various case studies are less evident, and the indicators pertaining to the scope of the study less definitive in affirming such extent. However, both participatory design and agile project management seem to contribute to fomenting diversity in research, by enabling dialogic and visualization processes that represent a counterbalance to the usually isolated and asynchronous pace of research work. Additional data and observations gathered through this study have expanded the frame of the research to results related to the current context of structural changes in academia. This relates particularly to the complex balance between intellectual work and administrative tasks, in parallel to the accelerated pace and pressure derived from competition for research excellence and funding in scientific institutions.

In conclusion, the results of my overall research through this dissertation point not only to the coherence of applying co-creation methods to transdisciplinary research, but also to the need to consider it a key methodological requirement for properly articulating collaboration in this field.

Acknowledgements

I began this project by asking an apparently simple question: how can science be co-created today? But I was not alone when considering this, since I was sitting next to Mayo Fuster, the first person I wish to acknowledge and to whom I would like to convey my sincerest thanks. She gave me this opportunity and privilege to imagine, test and learn many things while working by her side, during the three first years of existence of the Dimmons research group. From this shared interest, soon I realised along the way, that, after all, scientific endeavours have always been co-created, and that diverse types of knowledge (not only scientific knowledge) are mostly generated collectively. This occurs incrementally through joint effort, since scholarship is a cumulative process, with questions, methods and discoveries built through a continuum of projects, paradigms, publications, schools, generations, and people, amongst others. In this collective sense, I want to recognise and thank my other colleagues in Dimmons Ricard Espelt, Vera Vidal, Núria Valero, Adrià Garcia, Melissa Renau, Jessica Agnel and Mireia Manjón for their warm support, wisdom and good karma. And to the fantastic people and professionals with whom I have had the privilege to collaborate on Dimmons' activity, at some point, through different projects: Núria Ferran-Ferrer, Guido Smorto, Thais Ruiz, Marc Rocas, Núria Reguero, Sergi Frias, Sara Moreira, Bruno Carballa, Natalia Andrea, Manel Rebordosa, Paola Imperatore, Elisabet Roselló, Eva Esteban.

From the co-authorship of papers and cooperation within university departments and research organisations (or even conferences, as temporary research ecosystems themselves), to academic networks and epistemic cultures across disciplines, collaboration lies at the center of scientific activity. I have also had the opportunity to learn about this type of collaboration through shared projects and conversations with other research groups and colleagues at the Internet Interdisciplinary Institute, who were generous and open to sharing their expertise with me. So, in this regard, I would like to express my gratitude to Antonio Calleja and Andreu Belsunces from Tecnopolítica; Jörg Müller, Julio Meneses and Lídia Arrollo from GenTIC; Ramon Ribera and Isabel Ruíz Mallen from TURBA Lab; Jordi Cabot from SOM Research Lab; and Daniel López from CareNet.

My question arose from a clear, relatively new and disruptive change in this perspective of co-creation and collaboration in science: nowadays the Internet and digital culture has radically changed the way researchers work and communicate, affecting in profound ways academia and science (as probably any other area of human activity). So, I thought a valid starting point would be to consider how new communication possibilities, in all periods of history, have always influenced the progression of human knowledge and, in several ways, our current opportunities for collaboration and co-creation. I consider myself a very lucky person in this sense, since during the last two decades I have been in touch with the human side of collaboration through many projects and initiatives. In between technological accelerations and personal changes,

collaborating with the following people represented a serious and fertile playground, full of important discoveries and great moments, so I wish to say thanks a million to Platoniq souls Olivier Schulbaum and Susana Noguero (brothers in arms in co-creation and in workshops across Europe); Mauricio O'Brien, Mercè Moreno, María G. Perulero, Javier Carrillo, Iván Vergés (and the rest of the great Goteo crew and history); Wouter Tebbens, David Gómez and Mónica Garriga (from FemProcomuns and writing collaboratively from Teixidora, and for our early co-creation adventures David); Paco González and Massimo Menichinelli (and our regular P2P mutual support!).

By having the opportunity to observe closely how a complex system of scholars, communities, questions, research methods, civic organizations and academic institutions are interrelated (especially in the field of social sciences), my question began to become more complex, as I started to look for practical answers for daily challenges in the "core" of transdisciplinary research processes. At this point I also need to acknowledge and convey my gratitude to Josep Perelló from Universitat de Barcelona, for his advice and insights, as well as the rest of the OpenSystems team Isabelle Bonhoure, Anna Cigarini, Julian Vicens and Enric Sanmartí (and to all the students and teachers involved in the great STEM4youth project), for their complicity and the early trust and confidence they gave me at the beginning of my study. The early support of Laura Forlano from the Illinois Institute of Technology was also key in making this dissertation project possible. I also wish to express thanks for their time, inspiration and patience to Nigel Gilbert, Alex Penn, Dione Hills, Ian Christie, Adam Hejnowicz, Ben Shaw, Jeremy Phillipson, Pete Barbrook-Johnson, Martha Bicket, Amy Proctor, Emma Uprichard, Frances Rowe and Lisa Fletcher, from the Centre for the Evaluation of Complexity Across the Nexus. At some point I was also very lucky to meet Eveline Wandl-Vogt, in the middle of a shared exploration process, and get to know and start to collaborate with her and Amelie Dorn, Renato Rocha, Thomas Palfinger, Jose Luis Preza and Barbara Piringer, from the great exploration space of the Austrian Centre for Digital Humanities. I must also express my thanks for the advice and insights of Adam Hyde from Collaborative Knowledge Foundation, Geraldine Henningsen from Technical University of Denmark, Ingrid Erickson from Syracuse University, Michelle Boath and Jonathan Hyde from Risk Solutions, Antonio Tenorio and Samer Hassan from Universidad Complutense de Madrid, Ferne Edwards from RMIT Europe, Simon Gough from The Data Place, and Carrie Yury from Beyond Curious. I am also very grateful to Enric Mor from UOC's Arts and Humanities to invite me to present some early results, and Susanna Tesconi, from the UOC's Computer Science, Multimedia and Telecommunications studies, for her feedback as an early adopter of the toolkit developed during this project. And I also convey a special thanks for Toni Cambra, who was always available to dispel doubts as a great UOC tutor.

At some stage my initial question branched into several areas of inquiry, related to ways for designing and managing research projects collectively. Recognising this, I moved on with the resolve of not "reinventing the wheel" nor complicating things even more, but instead going back to some solid things I knew first-hand, where similar questions and challenges in other fields around co-creation have experienced great advances. Working in a deductive and inductive way, from the privileged but challenging position as coordinator of the Dimmons action research group, on many occasions I had to

resort to my previous background as facilitator of collective work dynamics and knowledge management. In this sense, during many stages of this intellectual adventure I also recalled experiences when working at CitiLab Cornellà (so here are more thanks, in recognition of the great moments spent together with Ramon Sangüesa, Laia Sánchez, Artur Serra, Vicenç Badenes, Maria Josep Solé, Jordi Colobrans, Francisco Cobacho, Joan Güell, José García, and many more); as well as during the intense and fruitful experience of being part of the Observatory for CyberSociety (which also means gratitude for the early learning together with Joan Mayans, Ricard Faura, Nicole Etchevers, Francesc Balagué, Guillem Mundet, Josep Vives, Ana Esteban, Daniel Domínguez).

Exploring ways to co-create science, or more specifically, collectively ideate and manage research projects, has ended up taking shape in a series of concrete practices, where I had the opportunity (not always easy) of being a participant observer. Something that progressively allowed me to refine questions and collect empirical data, via diverse case studies, as well as an intense dialogue with the specific literature I found. Eventually, I was also able to adapt and even develop resources and tools for other researchers, who started to use them in similar contexts. But all this journey through collaboration, academia and knowledge, which I feel I'm not concluding but somehow starting with this dissertation (by perhaps adding more questions than answers to the point of departure), would not have been possible without the continuous support and encouragement of my family: from my parents Ana and Enrique, to my brother Miki, Maribel and kids, to Jordi, Micha and Montse (and Juanito, wish you were here); as well as my good friend in readings Ghislain, and Bruno and Marcos in the distance; tía Carmen, Juanan, Perico & María, Jordi and rest of Noel's Party Cerdanyola; and, of course, to Samuel and to Alba, sources of inspiration and lighthouses when the dark moments. Finally, especially to you Eva, I express my deepest gratitude, for supporting me and believing in me.

Enric Senabre Hidalgo
Barcelona, 3 July 2019

FIRST PART: OVERVIEW OF THE STUDY, DESIGN OF RESEARCH AND CONTEXT

1. Overview of the study

This dissertation investigates if and how co-creation practices and principles, from a methodological and managerial perspective, could contribute to improving the ways of designing and coordinating transdisciplinary research. Among the different paradigms of co-creation, participatory design and agile project management are two relevant methodological frameworks that constitute the focus of my research. It is within this perspective, related to the need to experiment co-creation and improve new collaborative ways for dealing with diversity and complexity, when implementing transdisciplinary projects, where I think lies the originality and importance of this dissertation.

In this first section I elaborate an initial approach to the basic areas of the study and the relevant concepts and challenges that have been the focus of my research, outline the rationale of its analytic framework and explain the value of my contribution. This first part also addresses the main research questions, and several key factors and concepts related to it, followed by a description of the methodology adopted for the different case studies. Some of the key concepts, discussions and perspectives addressed here at the theoretical level, however, are presented more extensively in the following chapter, which focuses on the context and state of the art.

1.1 Relevance of the project

In trying to describe the relevance of this dissertation, first it is important to frame this project within the concept of transdisciplinarity in research and some of the current challenges related to it. Particularly in relation to scientific collaboration, which is one of its key features (Lawrence, 2015). Nowadays, in different research domains there is an emergent dominance of collaborative teamwork for generating valuable knowledge (Sonnenwald, 2007). But at the same time, researchers who have looked at this subject have identified a lack of conceptual and practical approaches on how to effectively co-design and plan the day-to-day operations of research processes in more participative ways (Wilbon, 2012), and also a need of more evidence regarding successful research management practices (Derrick & Nickson, 2014). They argue that in contrary to the traditional context, where much research was conducted by lone researchers or by co-located teams, and where most team members had the same or similar disciplinary backgrounds, in recent decades there has been a clear shift to more diverse and regular collaboration in science and research (Katz & Martin, 1997). In parallel to the irruption of information and communication technologies (ICT) and its consequent culture shift for enabling more effective cooperation in the workplace (Zuboff, 1998), in online peer-production (Algan et al., 2013) and in research projects (Rogers, 2013; Fuster Morell, 2011), various scholars describe how research collaboration is a complex and ever-changing process (Ernø-Kjølhede, 2000; Stokols et al., 2008;

Jirotka et al., 2013). Debate centres on the issue of how collaborative research is dominant in science teams and team-based research, both in academic organisations and among large-scale international research networks (Cooke et al., 2015). In that sense, higher degrees of collaboration intensity and diversity seem to contribute to research quality (Liao, 2011) and productivity (Daradoumis et al., 2012), as well as bringing positive effects on participants commitment and knowledge integration (Polk, 2015).

Other potential benefits of collaborative research range from increased citations in the case of co-authored authorship of papers, which is one of the oldest scientific collaborative practices since the 17th and 18th centuries (Beaver & Rosen, 1978), to better use of existing resources (Ynalvez & Shrum, 2011), capacity to successfully manage large-scale projects (Bammer, 2008) or more opportunities for knowledge transfer and learning (Lassi & Sonnenwald, 2010). In this respect, finding more practical ways of developing collaborative research in team science is recognised as having a relevant effect on knowledge generation (Lee & Bozeman, 2005). Something that takes place in an emerging paradigm of different and changing collaboration practices in science, in a relatively new context of "increased complexity and scope of research problems requiring multi-, inter-, and trans-disciplinary approaches linking specialised expertise" (Katz & Martin, 1997).

In this sense, examples of collaborative research and the literature about the field usually appeal to the interrelation of disciplines and how they are combined. Rosenfield (1992) provided a clear distinction between unidisciplinary collaboration (where researchers from a single discipline work together to address a common research problem) and cross-disciplinarity (which includes multidisciplinarity, interdisciplinarity and transdisciplinarity), considering the latest being a progression of layers of practice and complexity in research collaboration, in line with other authors (Miller, 1982; Stokols et al., 2008). Whereas multidisciplinarity draws on knowledge from different disciplines, with each staying within their boundaries, interdisciplinarity analyzes, synthesizes and harmonises links between disciplines into a coordinated and coherent whole (Choi, 2006). Transdisciplinarity, on the other hand, can be summarised as eminently problem-centered (Leavy, 2016) and as a holistic and integrative process "in which researchers work jointly to develop and use a shared conceptual framework that synthesizes and extends discipline-specific theories, concepts, methods, or all three, to create new models and language to address a common research problem" (Rosenfield, 1992). This perspective takes into account how scientific collaboration within the academic context can challenge existing institutional structures and disciplinary methods of research, specially when they are not apt to deal with complex real world problems (Klein, 2015). In this sense, transdisciplinarity is also described by other authors as a form of research that can enable inputs and scoping across scientific and non-scientific stakeholder communities (Wamsler, 2017; Koskinen & Mäki, 2016), driven by the need to solve real-life problems by openly designing the phases or the research process in a recurrent order (Hadorn et al., 2008).

Transdisciplinarity, from that dual perspective, emerges as one of the basic attributes of collaborative work in scientific production, where according to the controversial but

influential “Mode 2” framework described by Gibbons et al. (1994), scientific knowledge (and innovation emerging from it) is context-driven, problem-focused and crosses disciplinary boundaries to create holistic approaches. As opposed to a “Mode 1” type of research, motivated by scientific knowledge alone (and not necessarily concerned with the applicability of its results), such Mode 2 is no longer isolated from its social contexts, either within or outside the boundaries of the academic institutions, and non-scientists under that approach can be more active in the processes of scientific knowledge production (Nowotny et al., 2013). Responsible Research and Innovation (RRI) is another relevant perspective in the scientific domain in relation to a change of paradigm in transdisciplinary collaboration, promoting the involvement of stakeholders and civil society in scientific activities for developing more inclusive innovation processes (Owen et al., 2012). So too Open Science, a series of principles and digital practices fostering a more transparent and accessible scientific culture and its connection with citizens (Fecher & Friesike, 2014).

On the other hand, an important area related to collaborative transdisciplinary research has to do with the tradition of action research and community-based research (De Santos & Hissa, 2011; Fuster Morell, 2009), where participants who are not professional or academic researchers can be fully involved in several aspects of an investigation process (Corburn, 2005). In that field, participants usually collaborate with researchers in relation to practical or pressing issues at the local level, representing the needs of different organizations and communities (Reason & Bradbury, 2001). Finally, in this respect a more recent collaborative research domain is the relatively new paradigm of citizen science, with volunteer citizens collaborating with researchers for digitally gathering or analysing scientific data (Bonney et al., 2009) and also engaging in other critical parts of the research process (Irwin, 2002; Wylie et al., 2017). Results from citizen science projects are already starting to appear in peer-reviewed journals, indicating that it constitutes an expanding palette of transdisciplinary practices with progressive academic acceptance (Follet & Strezov, 2015).

1.1.1 Challenges in transdisciplinary research

Although those collaborative practices in transdisciplinary research domains represent a wide corpus of academic literature and references, with specific methods for data gathering and analysis, there is a general lack of clear methodology and clarity on practical details about how to co-develop collaborative inquiry processes in participatory research (Frideres, 1992) as well as in cross-disciplinary contexts (Rosenblum, 1995). On the other hand, scientific teams and networks of large-scale collaborative research projects in many occasions require better approaches in applying existing project management techniques (Huljenic et al., 2005; Vom Brocke & Lippe, 2015). Given that, in some instances, complex and cross-disciplinary research projects seem to be repeatedly “re-inventing the wheel” for managing the production of results (König et al 2013), and the ideation and crafting processes behind different types of scientific production are currently in need to improve its sources of creativity (Wang & Hicks, 2015).

Evolving in parallel to the disruptive adoption of ICT in knowledge-intensive organisations (Powell & Snellman, 2004) and also to more interactive relationships

between society and science (Nowotny et al., 2013), transdisciplinary research practices face critical questions related to how to collectively produce relevant knowledge. Two of the most important challenges, in this sense, are related to integrating the diversity of participants and their perspectives (Cheruvelil et al., 2014), and the added complexity that this represents for project management (König et al., 2013), as reflected in Figure 1. This currently represents a wide and challenging field in continuous evolution at the methodological level, requiring analysis about how and when collaborative research is implemented (Katz & Martin, 1997; Jirotka et al., 2013). If we focus on the specific field of collaboration in transdisciplinary research, the same challenges arise when it comes to cooperatively developing effective project management (Hollaender et al., 2002), to co-designing research plans and approaches (Pohl & Hadorn, 2007) or, in general terms, to developing a culture of cooperation between experts in different disciplines and other stakeholders (Klein et al., 2012).

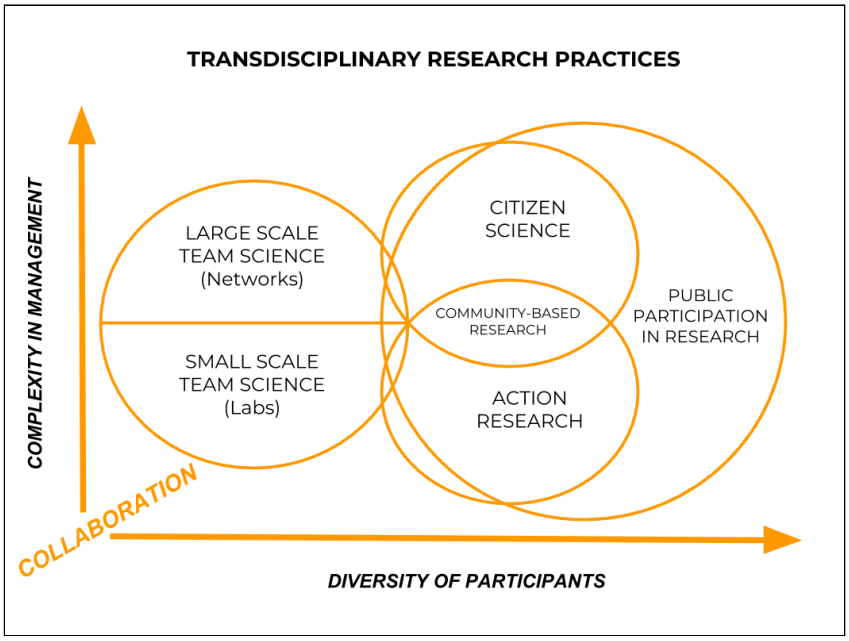


Figure 1: Complexity and diversity in transdisciplinary research.

In this sense, it is also important to refer in more detail to the work of Sonnenwald (2007) on scientific collaboration, which presents another set of key concepts addressed in the novel approach framing the analysis of this study. She establishes, on the one hand, a series of elements influential for the classification of scientific collaboration, such as: (a) its disciplinary focus (which coincides with the connection established here between transdisciplinarity and the involvement of multiple stakeholders, and hence the integration of diverse knowledge); (b) geographic focus (in other words, the extent to which collaboration is decentralised and distributed, or instead collocated); and (c) organizational and community focus (from collaboration with society to university-industry partnerships).

On the other hand, Sonnenwald also proposes a temporal view of four stages of scientific collaboration (foundation, formulation, sustainment and conclusion) which constitutes a complementary part of the analytical axis of my approach (Figure 2). Although she states in this respect that scientific collaboration is a non-linear, dynamic

process, in line with other authors (Hara et al., 2003), her classification describes how right after the foundation stage (with diverse social and intellectual factors existing before a research collaboration is formulated) and before the conclusion stage (final period of publishing findings, dissemination of results, etc.), there is the formulation and sustainment phases, which refer closely to the central focus of this dissertation.

	Stages of Scientific Collaboration			
	Foundation	**Formulation**	**Sustainment**	**Conclusion**
Factors	Scientific	Research vision, goals & tasks	Emergent challenges	Definitions of success
	Political	Leadership & organizational structure	Learning	Dissemination of results
	Socio-economic	Information & communications technology	Communication	
	Resource accessibility	Intellectual property & other legal issues		
	Social networks & personal			

Figure 2. Key factors of the scientific collaboration process (Sonnenwald, 2007).

The formulation stage represents a key moment for establishing the vision, goals and tasks of a given collaborative research project. This stage is characterised by the complexity of formulating research questions, and the importance of skills needed for facilitating the process, as well as the need of a clear definition of tasks, or the importance of a shared vocabulary and effective leadership. Finally, in relation to this formulation stage, the author also points to the key issue of ICT and challenges related to its adoption by team members. Regarding the stage of research sustainment, that phase is also relevant according for Sonnenwald for how it points to complex aspects in the organizational structure of scientific teams and project management practices, and the need to balance diversity with structured coordination. Factors like trust building and organizational learning (sharing explicit and tacit knowledge among participants) are also key at this phase, prior to concluding the research.

1.1.2 Co-creation methods for transdisciplinarity: participatory design and agile project management

In view of the challenges described in terms of diversity and complexity for enabling research collaboration practices, this dissertation explores and tests the implementation of transdisciplinary processes of, on the one hand, participatory design (or co-design), and of agile project management on the other one. I try to analyze in depth if adaptations of those two co-creation methodological frameworks (which were not originally developed in research contexts) can contribute to the dynamics of collaborative research. Especially for generating additional participative research design and planning (benefiting from diversity through co-creation), as well as for viable alternatives in the project management of transdisciplinary projects (dealing with the derived complexity in effective and meaningful ways).

In relation to research co-design, the literature and tradition of research design and scientific methods covers how to practically define a research project (Creswell, 2009) or how to implement for example more visual methods (Margolis et al., 2011; Latham, 2016), but usually from the perspective of the main researcher as the only decision-making actor. The same goes for scientific teams, where those crucial design steps are usually, if so, informally negotiated (Barab & Squire, 2004). While there have been increasingly more approaches addressing the need to rethink the methods of inquiry in the disruptive context of the digital domain, and its rich possibilities for changing the role and outreach of the researcher (Rogers, 2013), the design and planning of the research process and its details usually falls into decisions taken at the individual level, via non-explicit processes (Verschuren et al., 2010). In relation to strategic planning for research organisations, there is also scarce academic literature about it, with studies focusing on how it has gained some popularity in the general operation of universities (Srinivasa et al., 2015), as well as with openness and participative approaches (Amrollahi & Rowlands, 2017), or about its implementation for collaborative practices within scientific centers (Boardman & Gray, 2010) and for the administrative management of research (Drummond, 2003). Other studies reflect how the challenge for any research environment is that significative creativity is required to produce innovative results, considering creativity as something that is at the base of problem-solving and problem-finding activities (Amabile et al., 1996). In this sense, some research on innovation management argue that projects benefit from flexibility and enabling spontaneity (Kapsali, 2011).

The design thinking tradition, and its connection to specific methods for collaboratively integrating diversity and visual language, as well as co-creation for participative planning, could offer alternatives for this (Nagle & Sammon, 2016). Design thinking, particularly with co-design as it's more participative dimension (Manzini & Coad, 2015), represents a set of practical approaches for the creative definition and solving of problems (Cross, 2011). It offers a great variety of visual methods, procedures and techniques for collaboratively designing new projects in complex circumstances, as well as the simultaneous exploration of scenarios, user-centered and participatory approaches and the integration of many possible points of view and perspectives to a given situation (Blizzard & Klotz, 2012). In comparison to the main analytic approaches from the scientific method or engineering disciplines, with which it has a complex and rich dialogue in practices and foundations (Archer, 1979; Bannon & Ehn, 2012), design thinking allows the integration of diversity and more ambiguity in relation to research parameters, as well as flexibility in the generation of outputs (Cross, 2001), and even the iterative redefinition of initial contexts and problems (Jones, 2014). In this sense, the approach of this project is based on an important conceptual difference in design thinking between "co-creation" (the generic process of collective creativity and production) and "co-design" (a set of concrete participatory design techniques), the latter being a specific feature within the broader co-creation field (Sanders & Stappers, 2008).

In relation to agile management frameworks, a close look at the literature and state of the art in project management and collaboration in research projects shows also the relevance of my approach, which attempts to address some of the challenges in the

day-to-day of coordinating transdisciplinary processes. In this sense, Turner and Cochrane (1993) identify uncertainty about working methods and precise outcomes as the main characteristic of any research environment (especially for the key issues of defining methodologies and goals). Whereas any type of research project may or may not have a more participative dimension, this points to the key aspect of managing uncertainty and to the ability to re-plan or add new tasks to the research project roadmap with fast decision-making (Lenfle, 2008). When researchers and practitioners from different organisations and disciplines work together, some authors also point to the important aspect of managing stakeholder expectations, which sometimes can be different and contradicting (Vom Brocke & Lippe, 2015).

Other approaches related to collaborative research management deal with key factors such as levels of commitment, leadership, trust, clarity, transparency or communication and monitoring (Keraminiyage et al., 2009). Another important dimension addressed in literature about collaborative research management has to do with the role of the researcher as a manager, who according to some authors requires relevant dialogue skills in cooperative environments (Ruuska & Teigland, 2009) and a delegating and participative leadership style (Barnes et al., 2006), especially for the management of project-internal communication and participation (König et al., 2013).

Adopting and adapting agile methodologies for collaborative teamwork, which according to several studies improve flexibility, autonomy and effectivity in different informational tasks (Wysocki, 2011), could contribute to a shared and effective way of dealing with some of the challenges mentioned above. Agile co-creation practices usually make workflows more continuous and incremental, based on principles of adaptability, personal and group autonomy, modularity and self-organised collaboration, as defined in the Agile manifesto (Beck et al., 2001). Also representing a set of emerging co-creation practices, agile project management has recently expanded to other organisational contexts (Rigby et al., 2016). This is mainly due to its potential for optimising the operative capacity of teamwork in short cycles of implementation, for visualising and sharing the progress on tasks and for maximizing the possibilities for success of projects in complex and multidisciplinary environments (Cao et al., 2009; Ciric et al., 2018). A potential related to the fact that the roots and foundational theories for the agile methodological framework date back to empirical work in knowledge management, particularly with respect to lean production and the distinction of sharing of explicit knowledge or tacit knowledge in teamwork dynamics (Takeuchi & Nonaka, 1986).

1.1.3 Transversal key concepts derived from previous research

The analytical framework of this dissertation departs from an extensive literature review that has allowed for the identification, beyond the issues in diversity and complexity mentioned, of other transversal key concepts in previous studies about transdisciplinarity and collaborative research, in connection with similar ones in the different fields of participatory design and agile project management.

These factors (Table 1) were extracted by a clustering of concepts derived from results and discussions on different reference papers that guide my analysis (as widely

described in the state of the art in the second chapter of this compendium). In order to present them here, as a transversal analytical base that contributes to guiding this research, I classify and group them connected to collaboration practices at (1) the conceptual level (factors of visualization, communication, transparency), (2) the organizational level, of key aspects made possible by the previous ones (trust building, task distribution, engagement) and finally (3) aspects related to outputs of the process and its results (efficiency and quality).

Key concepts	Transdisciplinarity and collaborative research	Participatory design	Agile project management
CONCEPTUAL LEVEL			
Visualisation	Bennett & Gadlin, 2012	Sanders & Stappers, 2008	Cao et al., 2009
Communication	König et al., 2013	Bannon & Ehn, 2012	Hoda et al., 2013
Transparency	Jeffrey, 2003	Kleinsmann & Valkenburg, 2008	West et al., 2010
ORGANIZATIONAL LEVEL			
Trust building	Stokols et al., 2008	Björgvinsson et al., 2010	Cohen et al., 2004
Task distribution	Laudel, 2002; Delfanti, 2016	Cross, 2011	Hoda et al., 2013; Dybå & Dingsøyr, 2008
Engagement	Cheruvelil et al., 2014; Stokols et al., 2008	Manzini & Coad, 2015	Stettina & Heijstek, 2011
OUTPUTS LEVEL			
Efficiency	Lee & Bozeman, 2005; Ynalvez & Shrum, 2011	Cross, 2011	Fernandez & Fernandez, 2008
Quality	Liao, 2011	Sanders & Stappers, 2008	Serrador & Pinto, 2015

Table 1: Transversal key factors for analysing adoption of co-design and agile in transdisciplinary research, derived from the literature review.

This classification is consistent, as well, with the framework elaborated by Hoegl & Gemuenden (2001) for assessing teamwork quality for successful collaboration processes. The authors establish a series of key concepts from the field of project management in organizational studies, that relate with similar terminology to equivalent factors: communication, coordination, balance of member contributions, mutual support, effort and cohesion.

Summarising the justification and motivation for this dissertation: both participatory design and agile frameworks represent, until now, relatively unexplored principles and methods of co-creation for challenges on how transdisciplinary research collaboration takes place, between different areas of knowledge and also different levels and types of participation. The relevance of my contribution, in this respect, lies in the unique position as participant observer involved in several transdisciplinary research projects, from different academic institutions. From there, applying a deductive and inductive approach, I had the opportunity to analyse the adoption of various co-creation methods. My contribution can be considered also original in its combination of diverse theoretical perspectives from fields such as knowledge management, science and technology, organizational studies, design disciplines and sociology of science.

1.2 Research questions and analytic process

This doctoral study represents a meta-research project. That is, research about research practices, with the goal of exploring evidence-based improvements (Ioannidis et al., 2015). In this case, the analysis addresses collaboration practices in transdisciplinary research with a focus on the challenges related to the design, planning and management of projects in such context. Current studies about the benefits of collaborative teamwork in research, and the view that transdisciplinarity must address issues like social impact or responsible innovation (Ribeiro et al., 2016), are just starting to provide evidence in terms of quality of outputs, awareness or new methodological approaches. In this sense, this work has an explorative focus in order to cover a meta-research layer of analysis and potential improvements at the practical level, specifically for participative design and management of research. For that, a series of case studies allowed for experimentation and observation of circumstances and conditions under a deductive and inductive cycle.

My main claim is that, from scientific teams integrating experts from different disciplines, to action research or citizen science projects involving laypeople, the current increase of diversity and additional complexity in research planning and management, in such transdisciplinary contexts, suggests the need to experiment with the principles of co-creation. This goes from the usually fuzzy and unstructured early ideation stages of research design, to the incremental and cyclic stages of project development after planning (Figure 3).

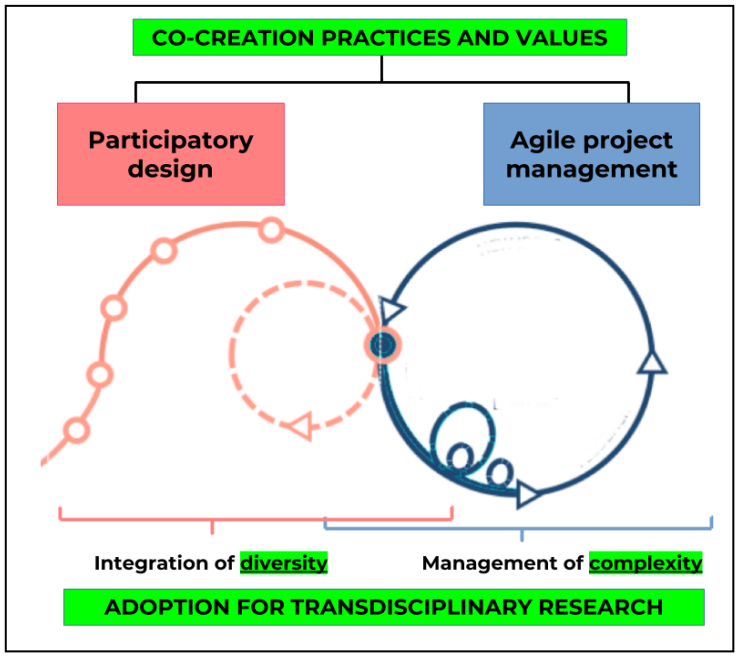


Figure 3: Overview of the study approach to co-creation and transdisciplinarity.

Although similar challenges can emerge in unidisciplinary contexts, or without the involvement of non-scientific knowledge and other stakeholders in research, the focus of this dissertation is specifically on transdisciplinary collaboration. It examines how this represents a paradigmatic and rich context in relation to the mentioned issues of collaboration, particularly in relation to the important concepts of diversity and complexity, and also for its parallelism with key factors and conditions for co-creation processes, as I will elaborate in detail in the following sections.

Therefore, the central issue of my study is if (and how) the relevant challenges of diversity and complexity in collaboration practices in transdisciplinary research could benefit from co-creation approaches for the participative ideation, planning and development of research projects.

There are three specific research questions which relate to this focus, connecting the specific and differentiated practices of co-creation through the various case studies and the academic publications that structure this compendium:

1. How can co-design help to integrate diversity for the collaborative ideation of research processes in transdisciplinary contexts?

2. To what extent is it possible to co-develop complex transdisciplinary projects following agile project management principles?

3. At the intersection between the ideation and the management of projects, how can both co-design and agile co-creation techniques be combined for the strategic planning of transdisciplinary research?

The sum of the different concepts, frameworks and elements detailed until this point configure the analytic approach of this study (reflected visually in figure 4). It considers the practices of participatory design and agile project management oriented to issues of diversity and complexity under the same conceptual umbrella of co-creation, despite their origin in different areas of knowledge and collaboration practices. Integrating the different transversal factors presented in table 1, according to the literature review, as well as the temporary perspective of Sonnenwald (2007) in figure 2 (about the stages of research collaboration), the diagram below reflects the incremental and iterative nature of co-creation applied to transdisciplinary research.

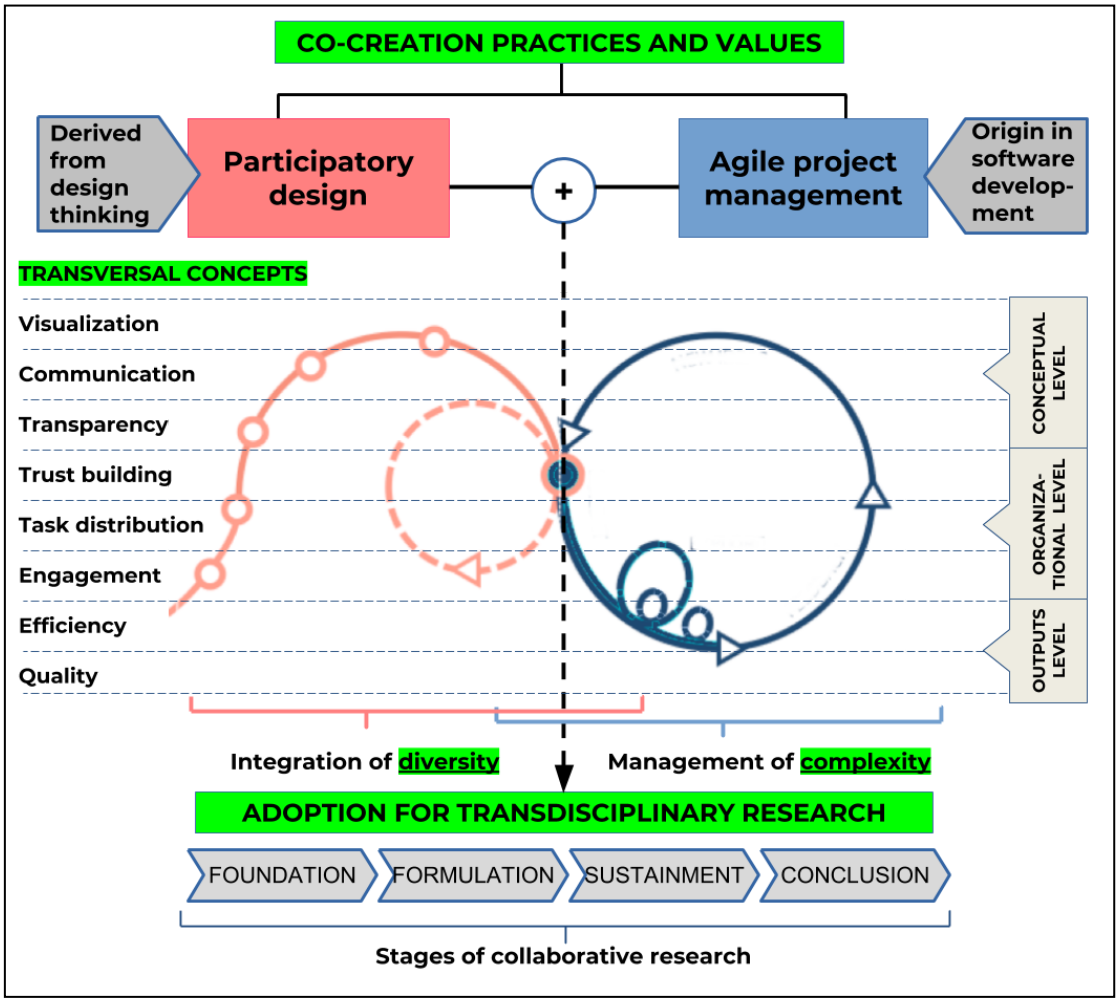


Figure 4: Concepts of co-creation applied to transdisciplinary research collaboration.

Therefore, the main contribution of the analysis of this project is:

- Firstly, to draw on the bodies of literature on research ideation and research management to develop a framework for adoption of co-design and agile management in transdisciplinary practices;
- Secondly, to illustrate the value of the framework by analysing examples of how these co-creation models could be implemented in specific projects, as well as impediments or failures during the process;
- Finally, to identify in this still unexplored approach to research collaboration the challenges to overcome and good practices to be adopted, regarding the key interrelations of diversity and complexity issues.

1.3 Research methodology

This PhD project is exploratory in nature (Babbie, 2015). It is based on three specific case studies of transdisciplinary research (see Table 2 for a summary of the overall approach). One case focuses on the co-design of research (for a citizen science project), another on agile project management for research (in the context of a distributed scientific network), and a third focuses on how to combine co-design and agile (through the strategic planning of an action research group, and some of its projects). The goal of pursuing different case studies is to understand real-life phenomena in their contextual conditions (Yin & Davis, 2007). Consequently, this exploratory research examines processes of collaborative planning and agile project management in different cases of transdisciplinary research, even if the differences in the nature of the contexts and the particularities of the institutions, teams and goals in each setting don't allow for a complete comparative approach between them.

Case studies	**Case study #1: STEM4youth project**	**Case study #2: CECAN center**	**Case study #3: Dimmons group**
Context	Citizen science	Team science	Action research
Research question addressed	How can co-design help to integrate diversity for the collaborative ideation of research processes in transdisciplinary contexts?	To what extent is it possible to co-develop complex transdisciplinary projects following agile project management principles?	How can co-design and agile co-creation techniques be combined for the strategic planning of transdisciplinary research?
Methods applied	Online surveys and interviews	Interviews and content analysis	Surveys and content analysis
Related publications	Publications 4.1, 4.2 and 4.5 of the compendium	Publications 4.4 and 4.5 of the compendium	Publications 4.3, 4.5 and 4.6 of the compendium

Table 2: Relation of the case studies with the corresponding research methods and questions.

1.3.1 Research methods applied

Results of the case studies have been obtained from triangulating quantitative and qualitative methods. Through such methodological pluralism I have been able to get access to diverse facets of the phenomena, adapting the use of different research techniques depending on the research questions and the specific conditions, timing, scale and participants in each of the three cases.

Data collection

In approaching the case studies this study combines quantitative analysis via questionnaire surveys and semi-structured interviews, and a qualitative approach based on field notes from participant observation during each case, as well as artifact

and document content analysis. All of these sources of evidence are widely recognised in case studies (Stake, 1995; Yin, 2013). Research protocols have been created for each case study regarding the documentation, surveys and semi-structured interviews. These three methods allowed me to capture information regarding perceptions, motivations and interpretations, while through participant observation I could actually be involved in the events being studied.

Recognising that there could be a bias in this process, three principles of data collection have been implemented: the use of multiple sources of data, the creation of databases for case study related materials, and the maintaining of a chain of evidence. This coincides with Yin's (2013) suggestion that multiple sources of information and triangulation of evidence, increases the reliability and the process of gathering data.

Data analysis

In total, between February 2016 and February 2017, the empirical base of this study comprises 26 semi-structured interviews, 4 surveys that in total were answered by 108 participants, minutes and notes from participant observation of 21 workshops (with a total of 219 participants), and content analysis of 45 digital kanban boards and 2 Telegram group chats. Attention to gender balance has been considered both in interviews and surveys (with just a slight majority of male participants registered, representing approximately 60%), while there has been no assessment of gender balance for participants in workshops.

The reliance of case studies on varied sources of evidence benefits from a previous theoretical development, as defined in section 1.2, which guides the data analysis. Data from surveys, transcription of interviews and content analysis was coded based on key concepts presented in table 1 (visualization, communication, transparency, trust building, task distribution, engagement, efficiency and quality), as well as on additional concepts depending on the case study. Among them, there were the following concepts also associated with the data analysis derived from the analytic framework:

- Motivation
- Involvement
- Trust and credibility
- Coherent sequencing
- Facilitation roles
- Quality of participation
- Decision taking
- Power relations
- Capacity for self-organisation
- Flexibility
- Adaptivity
- Incremental development
- Need for balance
- Offline vs online context
- Types of research

- Time and resources
- Institutional culture

Although not all of these derived concepts were considered for all the case studies, due to the differences in their characteristics, and the absence of a comparative approach in this study, they were present to a significant extent in each data analysis process.

1.3.2 Selection of the case studies

The rationale behind the selection of each case study was determined by identifying how they represent complementary approaches to transdisciplinarity, and also its early initial stage of development. Another factor for the selection was the extent to which the team composition and the rest of the participants in each case represented diversity of perspectives, while at the same time a perception of ambitious research goals and an interest to experiment with co-creation approaches in complex projects. Additionally, each case aligns with the following conditions for case study selection: a transdisciplinary framework and collaborative focus, at least one lead or main researcher, a predefined number of diverse participants, the intention to produce at least one academic publication as an output of the inquiry process, and to agree on engaging in research co-creation processes with the author as lead facilitator or at least participant observer.

Finally, for the selection of the three cases, consideration given to success according to academic, social and economic factors has also been important. For this, in all three cases, the various institutions have (1) demonstrated solvency in publishing in relevant academic publications and affiliation with prestigious universities; (2) a high level of online visibility and connections beyond the academic contexts (with public institutions, non-governmental organizations and media); (3) a record of public funding for sustainable activity in the mid-term (from EU funded projects, to specific schemes of national research bodies); and (4) a balanced gender composition between men and women in different positions, which in parallel to the previous quantitative indicators of excellence represents an alternative measure for research quality, promoting equality and well-being (Carpintero & Ramos, 2018).

Citizen science case study

The first case study focuses on the adoption of co-design techniques for the planning of different citizen science experiments, in the context of the European project STEM4Youth (http://www.stem4youth.eu/), in close collaboration with OpenSystems (http://www.ub.edu/opensystems/), a team of scientists from the University of Barcelona. It took place between December 2016 and June 2017, and it consisted in a collaboration for defining the materials and methodology that could allow students from three different secondary schools in Barcelona to engage in the participatory design and planning of three experiments about human behaviour, guided by their concerns and interests in a dialogue with the scientific team.

This case study represented an opportunity to address diversity in transdisciplinarity for the integration of non-experts in the co-design of research, during the foundation and

specially the formulation stages. This was not only for the need to adopt a visual language and develop a viable methodology and materials for co-creation, paying attention to a significant high number of participants, but also for the constant dialogue and implication with the scientific team behind the initiative. As a complex project, with the goal of developing new approaches to citizen science beyond its usual contributory paradigm (where participants are usually involved only for the data collection phases), this case study allowed for the iterative development and application of different participatory design techniques.

In terms of the methodology adopted, due to the total number of participants and the possibility of obtaining clear statistics about such experimental approach, I administered a broad survey covering perceptions from all the groups involved. This was afterwards contrasted with a series of interviews with the scientific team behind the initiative. Additional summary documents as evidence (pictures, completed canvas and minutes) resulting from nine co-creation sessions were also gathered and processed for this case.

Team science case study

The second case study analyses the adoption of agile project management in a wide distributed research center, with scientists from different disciplines self-organising for the evaluation of projects on public policy and environmental issues. In this case, thanks to a research Fellowship with CECAN, the Centre for the Evaluation of Complexity Across the Nexus (https://cecan.ac.uk/), led by the University of Surrey. CECAN is pioneering, testing and promoting innovative policy evaluation approaches and methods across Nexus domains such as food, energy, water and the environment, through a series of 'real-life' case study projects with co-funders (several UK government agencies). From April 2017 to March 2018, I participated in a series of CECAN activities (mainly workshops and internal meetings), had access to the different communication channels of the project and led the agile adoption of a specific research group.

In this case, the transdisciplinary nature of CECAN as a research network coincides with the perspective of novel strategies for integrating diversity of disciplines and stakeholders in team science, in order to generate new approaches in front of complexity. On the other hand, this challenging research setting had already started to experiment with agile project management for its general activity. This represented not only an opportunity for participant observation (through the specific research fellowship), but also validated the approach of this dissertation as a previously existing case. It covered the additional aspect of representing a wide, novel network of experts from different academic and governmental institutions, heavily relying on ICT channels for communication and coordination processes.

The methods adopted in this case were first preceded by an ethnographic approach joining the activities of CECAN, maintaining a database of observations. This was followed by adding several agile-related questions to a wide survey to its members (coordinated by other researchers). This approach allowed me to have a clear

understanding of the context and then, considering the stage and level of complexity of the project, to develop an interview protocol and interview members of that network with different roles and perspectives. Those interviews, on how participants experienced agile project management in CECAN, were contrasted with other interviews conducted with researchers who were familiar with agile from other institutions, as well as content analysis of the main online tool used.

Action research case study

Finally, the third case study concentrates around the day-to-day activities of the Dimmons research group at the Internet Interdisciplinary Institute of the Universitat Oberta de Catalunya (http://dimmons.net/), for several of its projects and internal activity, where both co-design and agile management have been applied since February 2016. In this case, I could apply in a deductive-inductive process a series of co-creation principles to teamwork. Especially for the strategic planning of the research group, which emerged as a key internal project once my research was initiated, and took place in a series of co-creation activities between November 2017 and February 2018.

This case study as a whole was the first one to start, taking place simultaneously to the other two ones, and it represented a long-term opportunity for participant observation from my role as Dimmons researcher and coordination manager. For this reason, the approach in this context addressed not only issues of diversity, from the perspective of action research as a paradigm of transdisciplinarity, but also the complexity of a new research group (which was constituted at the beginning of this dissertation) that develops in parallel, growing in members and projects. From the conception and refinement of co-design materials in specific research projects, to the adoption of different agile experimental approaches for the group's management, Dimmons as a case study represented a convenient context to put co-creation in practice at the strategic level.

The methods applied in this case, adapted again to the specific circumstances of the setting and its experimentation with co-creation practices, consisted mainly in the content analysis of the outputs of co-creation sessions, as well as the coordination and communication through digital channels (particularly kanban boards and Telegram group chats). Although some unstructured interviews and surveys were also used as methods at some stages during this case, as well as notes from participant observation, they were not the main source of empirical data in order to avoid potential bias derived from personal and professional relationships between the researcher and the objects of study, as colleagues in the same research group.

Additional data derived from other specific Dimmons co-creation sessions and workshops (not oriented to research design or research management), as well as interviews with participants from other organisations, have also been taken into account for the study, as reflected in some of the journal publications of this compendium. This additional contribution is mainly related to Dimmons as an action research organisation with a mission-driven agenda for research, where as part of its

methodological experimentation approach I was in charge of different participative sessions, mainly for studies around areas like the platform economy or public policy innovation[1].

1.3.3 Originality of the methodological approach

In this section I summarise the most relevant aspects related to the novel methodological approach of this project. First, it has to do with integrating a series of strategies for replication and dissemination, with the aim of developing useful outputs as open knowledge (Molloy, 2011). Secondly, in parallel to the triangulation of qualitative and quantitative methods, the innovative character of applying co-creation techniques to the different case studies is highlighted. Third, the whole process of this dissertation has been guided in addition by principles of action research. This represents departing from research questions that aim to inform action, and trying to apply practical solutions to specific needs and challenges beyond the gathering of data and observations. What guides me in this sense is the aim to contribute not only to academic literature and theoretical fields, but also to the projects and teams I have collaborated with (and particularly to apply these learnings to Dimmons, in my role as coordinator).

With the aim of adding value in parallel to the research methodology developed for each case study, supported by the observations and notes since the beginning of the project, I developed a practical toolkit (see Annexe section) which has allowed for alternative replicability, interactions and new cases of adoption in transdisciplinary projects (Figure 5). Based on an iterative elaboration process, this "Collaborative research design toolkit" was conceived as a meta-research tool and also a "physical knowledge artifact" (Holsapple, 2013). This additional output of the research, beyond being a driver for discussions and critical for co-design in the first and third case studies, has been an important element of observations and learnings for the dissertation, in parallel to the overall analysis.

[1] Some of these other co-creation projects have been reflected in different blog posts:
- http://www.share.barcelona/sharing-toolkit/
- http://howtowriteanacademicpaper.com/collaborative-writing.html
- http://lab.cccb.org/en/the-user-experience-in-platform-cooperativism/
- http://www.backlogs.net/testing-new-materials-and-dynamics-for-co-created-projects/

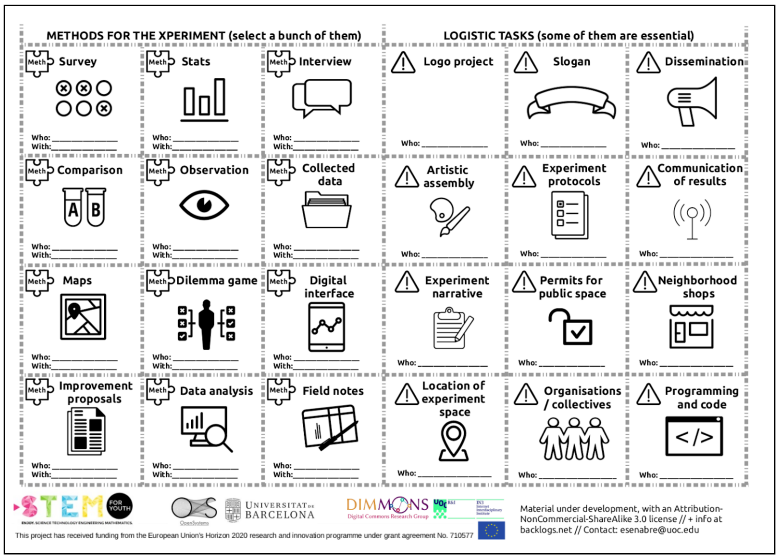


Figure 5: Sample of one of the canvas of the toolkit (version 2.0).

In order to achieve a wider impact under the key co-creation concepts of prototyping (Spinuzzi, 2005) and minimum viable product (Münch et al., 2013), the toolkit was early on shared online[2] under a Creative Commons Attribution 4.0 International license[3]. This allowed other researchers to adopt and tailor it for co-creation sessions (providing afterwards feedback and suggestions for improvement) that in beyond 2017 and 2018 took place in the Tabakalera International Centre for Contemporary Culture in Donostia (https://www.tabakalera.eu/), Centro de Estudios Fundación Ceibal in Uruguay (https://fundacionceibal.edu.uy/), Bau Escola De Disseny in Barcelona (https://www.baued.es/) and the Austrian Centre for Digital Humanities in Vienna (https://www.oeaw.ac.at/acdh/).

In relation to the agile project management of research, the methodology described also meant to apply an experimental approach, in this case in relation to content analysis. For this, two different open source kanban boards were adopted and tailored to the needs of the Dimmons research group. First, the Odoo agile project management platform (https://www.odoo.com/page/project-management) was adopted, followed by the Kanboard project management software (https://kanboard.org/). For this last one, several extensions for adopting the tool to the needs of the Dimmons research group were added and tested, and a novel approach to content analysis applied by combining task statistics to tags and categories for strategic planning (as described in the last publication of this compendium).

Finally, as another relevant element of innovative approach to some of the methodologies adopted for this research (in this case for the third case study related to Dimmons), it is also important to mention the use of the Telegram open source group chat (https://telegram.org/). This tool was adopted since the creation of the Dimmons for regular internal communication following agile principles, as the main channel for the daily "standup" meetings of the group. In this case the novelty, related in technical

[2] https://figshare.com/articles/Untitled_Item/5331190
[3] https://creativecommons.org/licenses/by/4.0/

terms to content analysis, also had to do, in technical terms, with the possibility of dumping and extracting to plain text the full history of the chat group for 28 months of activity, and afterwards combining it for massive computer-assisted text analysis and comparative visualizations.

It is also important to mention the regular dissemination effort to publish online several reflections and observations related to the PhD process, aligned with the mentioned approaches to openness and replication of the research materials and the tools derived from my methodological approach. This took place online by using a personal research blog (http://www.backlogs.net/) and the Dimmons website (http://dimmons.net/blog/) where information was regularly provided about progress with the theoretical framework of the study, as well as about co-creation workshops, publications, conferences and seminars attended. Additionally, for open documentation, the Open Science Framework platform was used to share document drafts in some areas (https://osf.io/zb9re/). For an online open access visualization of the main authors and theoretical frameworks I used the novel Onodo network mapping tool (https://onodo.org/visualizations/305/).

2. Context and state of the art

The bodies of literature that inform the theoretical framework and relevant practices for this study are drawn mainly from the fields of knowledge management, science and technology, organizational studies, design disciplines and sociology of science. First, an overview of how collaborative work in organizations has been influenced by ICT and digital networks, determining value and innovation related to knowledge generation, will be presented. The key issue of organizational learning is examined, as well as how it relates to action research and the differentiation between tacit and explicit knowledge, and how they are relevant for the thesis. Secondly, this chapter examines the state of the art of transdisciplinarity and collaboration in research processes. It focuses mainly on the research design and research management areas, establishing a classification of transdisciplinarity domains that distinguishes between professional, team science scales of scholarly activity, and in parallel the diverse domain of public participation in research. Finally, the last section focuses on the wide field of co-creation, describing and establishing the links between the two main practices for collaborative creation adopted in this study: participatory design and agile project management. It traces the distinct origins of both practices, and also connects some of its key values and principles with the tradition of action research, which represents a novel perspective in the field of co-creation studies.

2.1 Collaborative work in networked knowledge organisations

In the context of knowledge-intensive work that configures the Network Society (Castells, 2004), where wide access to information and the ability to transform it into value characterises the “knowledge worker” (Drucker, 1999), projects and tasks continuously develop under two key factors: new organizational logics and a myriad of technological changes (Spinuzzi, 2015). That applies to all types of organisations, from private companies to public institutions as well as social movements, given the palette of communication possibilities and the fast pace of global challenges, especially in economic, civic and technological environments (Castells & Cardoso, 2006). This results in new dynamics of decentralised management, beyond command-and-control approaches (Lauren, 2018), where hierarchy tends to work well for simple, stable tasks, but not for complex projects and unstable contexts (Bolman & Deal, 2017).

Although those new organizational logics relate to current processes of technological change, converging and interacting with ICT, they are not dependent upon it (Castells, 1996). As we will see in the following sections from the perspective of organisational development, the impact of low-cost digital technologies and communications in knowledge-intensive projects and teams can explain only part of the transformations in adaptability, autonomy and empowerment in group dynamics within organizations (Rigby et al., 2016), which historically developed in the 70s during the evolution from

mass production to flexible production (Bernard, 2000). Facing increasing change and complex environments in a global scenario, organisations adopt different digital but also non-computer mediated dynamics and methodologies for organizational learning, knowledge management and the transformation of production, constantly combined in a pursuing for innovation (Tuomi, 2002), which is considered the critical factor for value and productivity in the knowledge-intensive Network Society.

2.1.1 Innovation from collaborative networks

Regarding the question of innovation and organizational change mediated by informational technologies, from a general perspective, we can consider the impact of low-cost digital communications, has been key in terms of enabling wider possibilities for distributed and remote collaboration for knowledge-workers, within and between networked organisations (Castells, 2004), as well as communities of practice (Wenger et al., 2002). Again, the critical concept of innovation emerges here as a resulting value of effective, distributed collaboration and communication. According to Yochai Benkler, and his work on commons-based peer production, based on paradigmatic examples of distributed teamwork in open source projects one can view innovation as a collective phenomenon, as "it is a process of learning, and therefore depends crucially on communication" (Benkler, 2016).

Although we can agree that innovation depends on other factors like cultural creativity, institutional openness or labor autonomy in work processes (Castells, 2004), it seems that networked impact of informed, interconnected and more participatory individuals on organizational structures is what generates dynamics of value creation (Camargo-Borges & Rasera, 2013). This is possible due to a historical context characterised by a dramatic rise in the number of people employed in work which is largely information based (Powell & Snellman, 2004). From that point of view, the origins of innovation are usually generated in collaborative and networked contexts, as result of dynamic social cycles where knowledge reproduces knowledge, and then new competencies develop (Paavola & Hakkarainen, 2005). The more information and communication technologies penetrate layers of society and organisations, the faster and more far-reaching is the impact of innovations on human systems (Manzini & Coad, 2015). Whereas one can agree at the conceptual level on how this trend in our present society -a post-traditional one where everything becomes modifiable and experimental (Giddens, 2013), with a wide and continuous pursue in many cases of the latest innovation "per sé"- such trend constitutes a key shift where the organizational ability to increase sources of innovation, from all forms of knowledge, has become the foundation of competitiveness (Castells, 1996).

2.1.2 Knowledge generation in teamwork

Continuing this preamble on the importance of collective knowledge generation, and how it is transforming today's landscape of teamwork in a general sense, increasingly more scholars argue that it is something collaboratively designed and constructed, determined by continuous learning and innovation (Fischer, 2001), which points to the key aspect of project and knowledge management. That is, the effective administration

and sharing of organizational knowledge, and the way to operate and take decisions about it within organisations (Goh, 2002).

Shoshana Zuboff, in her early work, describes in depth how the impact of ICT in the workplace, with a shift from traditional to computer-mediated task environments, has progressively determined that relationships and informational processes in teams (parallel to the use of more effective tools for knowledge management), derived in less hierarchical relationships and more autonomy between individuals and teams (Zuboff, 1988). For Zuboff, among other important aspects in the relationship between information technology and work, at the level of managerial activity four profound organizational developments have been taking place simultaneously, determining the way organisations process information and generate knowledge: (1) the development of specific intellectual skills (involving "abstraction, explicit inference and procedural reasoning"); (2) the development of technology itself; (3) the development of strategy; and (4) the development of the social system of the organization (this last characteristic being also key for Checkland and Holwell, 1997).

Interrelating those aspects (skills, technology, strategy, relationships) in relation to the creation and flow of knowledge through projects at the core of productive organisations, some other key theories come from the work of Ikujiro Nonaka. Nonaka was influenced by the work of Michael Polanyi, who proposed the distinction between tacit and explicit knowledge (Polanyi, 1958), where tacit knowledge can be considered "action-oriented", while explicit knowledge "people-to-document approach", obtained with the help of written documents or other information sources that have been codified. Nonaka established a dynamic model to illustrate the co-creation of organisational knowledge in the late 80s and elaborated influential theories on how objective and transferable, explicit knowledge, differs from tacit knowledge (also defined as "know-how"), and the importance of routines and rituals between teammates in a spiral of sharing both types of knowledge (Nonaka, 1991). In this way, similar to how agile software development treats collective feedback when building pieces of code (as we will see in the corresponding section), sources of innovation can multiply when organizations self-organise to transfer tacit into explicit knowledge, and then explicit into tacit knowledge again. A type of virtuous circle of knowledge development and management which precedes the impact of ICT in the workplace as described by Zuboff, now expanded by new digital tools and information technologies (Castells, 1996).

In addition to the shift from a linear to a flexible, integrated approach of production, characteristic of post-Fordism, the dynamic explicitation of knowledge described by Nonaka encourages trial and error and challenges the "status quo" of top-down managerial practices (Takeuchi & Nonaka, 1986). In this respect, such formalisation of knowledge dynamism also transforms how authority flows through organisations (Zuboff, 1988), usually by more meritocratic ways or even forms of "hacker ethics" (Himanen, 2001). A systemic shift in knowledge-generation organisations that can stimulate new kinds of learning and thinking at different levels and for diverse functions (Rubenstein-Montano et al., 2001).

This foundation of Nonaka and Takeuchi's theory of organizational knowledge, based on the notion of 'knowledge conversion', is rooted in the key assumption that human knowledge is created and expanded through social interaction (in this case, between tacit knowledge and explicit knowledge). More specifically, they describe four modes of knowledge conversion, as steps in a cycle or spiral that can be adopted and managed: from tacit knowledge to tacit knowledge (socialization); from tacit knowledge to explicit knowledge (externalization); from explicit knowledge to explicit knowledge (combination); and from explicit knowledge to tacit knowledge (internalization), which represents the base of the "SECI model" (Nonaka & Takeuchi, 1995). A model that appreciates the dynamic nature of knowledge creation, providing an operational framework for the management of organisational processes.

The SECI model since its wide dissemination, study and practise has received criticism for being based originally on case studies related only to Japanese management cultural practices (Glisby & Holden, 2003; Andreeva & Ikhilchik, 2011), thus opening discussions about the need to understand it only as a framework (and because of that, the need to adapt it to other contexts). In other academic literature it is regarded as controversial for being too conceptual, needing more precise application as a model (Rice & Rice, 2005), for the implicit assumption that knowledge conversion needs the managerial role for taking decisions, in contrast to self-organized learning (Poell Van der Krogt, 2003; Gourlay, 2006), or for how it could work without the presence of appropriate and defined task characteristics, in situations when those are basically unknown (Becerra-Fernandez, 2001).

However, as a conceptual model and inspiration, Nonaka's theory of organizational knowledge creation has won paradigmatic status in organizational studies, setting the framework and basis for different knowledge management practices (Rice & Rice, 2005). And as mentioned before, the conceptual model behind the ideas of Nonaka and Takeuchi constitutes one of the foundational inspirations for the development of agile project management (Cervone, 2011), whose diverse origins and characteristics I will describe in detail in section 2.4.

2.1.3 Organizational learning, between explicit and tacit knowledge

Now that I have set a connection between some key aspects of organizational knowledge management and decentralized participation in this section, a deeper focus on some key issues related to organizational learning seems necessary. This will draw attention to important notions, at the same time, from the perspective of action research, on the one hand, and from some relevant topics in the field of design, on the other.

From the perspective of information technologies and processes in organisations, we can consider that somehow learning is never complete, as new data and new contexts constantly create opportunities for additional reflection, improvement and innovation (Zuboff, 1988). In parallel to the disruptive introduction of ICT in all areas of work and managerial processes, 'post-hierarchical' relationships require different types of organizational learning, where people in organizations continually construct the meanings that make sense of themselves and what they do (Checkland et al., 1997).

This is evident for example in the case of collaborative writing, where the possibilities of the digital text for gathering distributed knowledge from the organisation, or among networks of organisations, also facilitates distributed learning (Zuboff, 1988), apart from other benefits like socialization and the generation of new ideas (Lowry et al., 2004).

From the point of view of behavioural psychology and organizational development, the work of Donald Schön is also relevant here, since it represents a set of theories that connect the notions of tacit knowledge with the concept of "reflection-in-action". More specifically, in relation to how reflection-in-action can be understood and framed as "research attitude", Schön states "when someone reflects in action, he becomes a researcher in the practice context. He is not dependent on the categories of established theory and technique, but constructs a new theory of the unique case" (Schön, 1983). Adopting a role of social scientist as both researcher and actor, influenced by the foundational work of Kurt Lewin in action research (which was established also in contexts of studying organisational learning), Schön developed with the business theorist Chris Argyris the concept of "action science". This theory conceived individual learning as organizational learning, and the extent to which human reasoning (not just behaviour) can be the source for diagnosis and action, based on a concept of "double loop learning" and considering people as designers of their behaviour and their "behavioral worlds" (Argyris & Schön, 1978; 1989).

This perspective of continuous practical and emancipatory learning, rooted in the origins of action research, can be understood as a conscious personal design process, projecting mental frames onto the external world, thereby shaping this way relationships and personal contexts, where implicit individual theories interact continuously (Friedman & Rogers, 2008). This represents a link between the work of Schön and that of Nonaka and Takeuchi later on (and therefore the foundations of agile) that is usually missed in the literature. Something that was previously highlighted in relation to knowledge generation and the influence of Schön's theories, such as when the latter stated "how considered more broadly as an organizational learning system, the product development game determines the directions and the limit of reflection-in-action" (Schön, 1983).

It is also noteworthy that in order to make explicit individual and collective "theories-in-use" (described as theories derived from action), which could be critically examined and consciously changed, Schön paved the road for fundamental constructivist concepts in design thinking. Rather than scientific, rationale analysis, the reflective practice (for framing problems collectively, and react to them) represents "designerly" ways of doing based on intuition and creativity (Cross, 2001). In this respect, one can also consider learning within organisations not only as a dialogical process (Tsoukas, 2009) but also a design thinking process on its own, which can for example coexist in practice with the described virtues of the SECI model for organisational development (Dubberly & Evenson, 2011) as described before.

This constructivist perspective of organisational learning, proposed by Schön, connects with more recent approaches of knowledge for social change, favouring pluralism and diversity and the conditions for new meanings that can be co-created in the context of

organizational transformation (Camargo-Borges & Rasera, 2003). A complementary perspective to the pragmatic considerations around learning related to efficiency in Zuboff, from the point of view of the disruptive impact of ICT in the workplace: “learning is not something that requires time out from being engaged in productive activity; learning is the heart of productive activity. To put it simply, learning is the new form of labor” (Zuboff, 1988).

Both points of view, as we will see, connected to constructivism, autonomy and social change at the organizational and project level, on the one hand, and to improvements in productivity and efficiency in the same context on the other, are at the root of the values and concepts that need to be discussed in relation to the methodological frameworks that can be adopted in collaborative research. However, in the light of these key changes and challenges in networked organisations, it is also important to mention another critical perspective. This type of permanent and ubiquitous opportunity to connect online implies also that knowledge workers have to be permanently “on”, challenging not only work-life balance but also expectations around productivity and efficiency (Turkle, 2011). In this sense, “acceleration” in dealing with knowledge-related processes seems also one of the key attributes of digital capitalism (Wajcman, 2015).

2.2 Transdisciplinarity and collaboration in research

I described above how the emergence of new collaborative dynamics in teamwork derive from the irruption of ICT and from the strategic value of knowledge generation in organisations, and some opportunities and challenges derived from it in relation to knowledge management. In this section, rather than dive deeper into the different layers of types of research (experimental, descriptive, correlational, being of confirmatory or exploratory nature, etc.), or the extent to which any research project can follow the rich palette of qualitative, quantitative or mixed methods (which is mostly out of scope of this project), I will try to set the concept of collaboration around scientific knowledge production. This will set the path for addressing afterwards transdisciplinarity as the type of context where specific co-creation practices can offer solutions to complexity and diversity issues.

I will put the focus on relevant aspects of research activity when it comes to two general phases: research design, on the one hand, and, on the other, research management. I will highlight relevant issues from the fields mentioned in the introduction, considering the elements of transdisciplinarity and collaboration in four different but related domains: team science (at small-scale and also at large-scale levels), action research and citizen science. All of them characterised in one way or another by collaboration, as a process that can take place between individuals, between organisations or between individuals with organisations (Bozeman & Boardman, 2014). This covers the four mentioned areas, where evident elements of collaboration, in different degrees and shapes, are a prerequisite for carrying the research. Including methods that can be qualitative, quantitative or mixed, where I will describe basic assumptions trying to not confuse issues of epistemology with those of methodology or research technique (Della Porta & Keating, 2008). In all the cases and

approaches to transdisciplinary research, apart from some exceptions (Lang et al., 2012) there is still a relatively unrepresented and non-systematic field of knowledge about how to collaboratively design and manage projects. This points to more pragmatic and specific methodological and practical challenges for the "co-productionist framework" or "idiom of co-production", following the concepts and the influential ideas of Jasanoff (2004) in the field, and what she calls the "participatory turn" of science studies (Jasanoff, 2003).

2.2.1 Transdisciplinarity in research work

A basic definition of research, in the first term, could be: an enquiry project for addressing a defined question or hypothesis, producing novel results based on some type of evidence or data, and (importantly) "according to a given research design and following a systematic approach or research method" (Creswell, 2009). In relation to planning research outputs and results collectively, however, these are normally characterised with a high level of uncertainty about the degree of goal achievement and the best way or methods to succeed (Lassi & Sonnenwald, 2010).

Relevant academic literature about cases of research collaboration relate, from the field of science and technology studies, to the ethnographic description of "laboratory settings" and group dynamics in case studies of local, small-scale science teams, as in Laudel (2002), Latour and Woolgar (1979) or Suchman and Trigg (1986). For larger scale collaborative research practices (as opposed to the study of scientific teams as limited, collocated entities with intense face-to-face interactions) there is an increasing number of studies from the perspective of the Science of team science (Stokols, 2006) or e-Science (Jirotka et al., 2013), that explore the way wider distributed and networked research teams collaborate (Stokols et al., 2008; Bennett & Gadlin, 2012). Some of the reasons why team science is starting to be studied in recent times from diverse perspectives (Wang & Hicks, 2015), is that large-scale collaborative research programs are each time more encouraged by funding agencies, aiming at better use of existing resources or ICT tools (Fuster Morell, 2012), as well as for bringing prestige and building international reputation (Smykla & Zippel, 2010).

Apart from knowledge generation and teamwork, related to collaborative approaches, there are, as mentioned, two other domains of academic literature related to transdisciplinary research: action research and citizen science. On the one hand, there is abundant literature about the theories that underpin action research and its different types of practices, as a field oriented to solve immediate problems by reflective practise and iterative inquiry, with the participation of individuals and within communities of practice (Chevalier & Buckles, 2013). Here the focus is usually on describing research as a strongly participative and iterative approach, mainly in the field of social sciences (Della Porta & Keating, 2008). Authors describe action-oriented research as a dimension that combines theory with practise (Brydon-Miller et al., 2003), favouring a pluralist and instrumentalist view of knowledge (Gergen & Gergen, 2008) and strongly focused since its beginnings on action and change (Lewin, 1946). On the other hand, in relation to the relatively new practices of citizen science, the literature mainly describes the results of case studies and research where collaboration and participation (usually in experimental research) have the characteristic of direct implication of society for

actively and consciously gathering data for scientific projects (Silvertown, 2009), normally via the use of ICT and digital tools (Prestopnik & Crowston, 2012). Other relevant approaches in that area demonstrate how citizen science has been developed in different domains at large scale levels (Raddick et al., 2009), with varieties of this type of research across domains (Christian et al., 2012) and thematic areas (Dickinson et al., 2012; Theobald et al., 2015; Kremen et al., 2011). It has not been until recently that exponential progress has been made in new more participatory forms of citizen science (Kullenberg & Kasperowski, 2016), beyond that of data collection or for wider scientific communication, and in some cases with controversy regarding a precise definition of the phenomenon (Heigl el at., 2019).

Traditionally, examples of collaborative research and the literature about it usually appeal to the distinctions between disciplines and how they are usually combined in collaboration. Stokols et al (2008) provide for example, based on Rosenfield (1992), a clear distinction between unidisciplinary collaboration (where researchers from a single discipline work together to address a common research problem) and a progression of layers of complexity and potential in research collaboration, all characterised by cross-disciplinarity (this is, the combination of more than one discipline):

1. Unidisciplinarity
2. Multidisciplinarity
3. Interdisciplinarity
4. Transdisciplinarity

On the one hand, this distinction establishes the importance of considering unidisciplinarity, which relates to earlier and more basic research on stable teamwork (usually within the limits of a research institution, department or group), and cross-disciplinarity, on the other, as a set of practices which refer to higher and more complex scales of interaction between researchers, teams or institutions (Miller, 1982). The first type of cross-disciplinary collaboration would be multidisciplinarity, as a sequential process whereby researchers in different disciplines work independently, each from his or her own discipline-specific perspective to address a common research problem. Followed by interdisciplinarity, as a more interactive process in which researchers work jointly, each drawing from his or her own discipline-specific perspective. Finally, transdisciplinarity would represent the most complex degree of cross-disciplinary collaboration, with the greatest potential for developing and producing innovative and generative scientific outcomes (Stokols et al., 2008), and the possibility of integrating extra-academic participants and perspectives (Wamsler, 2017; Koskinen & Mäki, 2016).

Related to any combination of disciplines, usually a key argument to justify and highlight the importance of collaborative work in research, relevant for the present purpose, is the need to surpass the tendency to isolation from individual scientists, and to some extent the general tendency of the academic world to work apart from the industrial and social worlds (Ota, 2010). In this respect it seems that, generally, researchers in the humanities and the social sciences tend to collaborate less than those in physical sciences (Becher & Trowler, 2001), where experimental research

disciplines have been traditionally more regularly driven by collaboration than theoretical ones (Katz & Martin 1997). In this respect, Coccia & Bozeman (2016) argue that currently there's an acceleration of collaboration patterns in medical sciences, social sciences, geosciences, agricultural sciences, and psychology (predominantly applied fields), while basic fields like physics or mathematics would experience in contrast lower levels of growth in scientific collaboration. On the other hand, some authors link collaboration with productivity (Barjak, 2006; Daradoumis et al., 2012) as well as with quality of results (Rigby & Edler, 2005; Liao, 2010), while other scholars describe how collaboration is a difficult and ever-changing process, and even more so when it comes to collaboration across distance via remote teams (Eccles et al., 2009).

2.2.2 Beyond co-authored articles as scientific collaboration

One of the main strands of literature about research collaboration consists on the study of co-authored articles as an indicator and measure of collaboration (Birnholtz, 2007), which analyses collective production of scientific knowledge based on scientometrics (Tsai et al., 2016) and bibliometric footprints of clusters of authors signing academic papers (López-Ferrer, 2012). This focus on research groups as the basic unit of scientific cooperation, contrasted with shared publications, allows for visualizing collaborative networks (Perianes-Rodríguez et al., 2009). Approaching the concept of scientific productivity according to the factor of co-authorship is considered in those studies the most relevant indicator, among others such as academic rank or job satisfaction (Lee & Bozeman, 2005).

However, in this respect there are limitations to the use of co-authorship as a single measure of scientific collaboration, which can represent a way to visualize and understand collaboration patterns but usually as a partial indicator (López-Ferrer, 2012; Laudel, 2002). In this respect, other studies pay attention to time factors, such as the percentage of research-related work time that scientists allocate to collaborative research (Boardman & Corley, 2008) but many of the more qualitative and descriptive approaches to other scales or practices of collaborative research are unrepresented by such quantitative approach (Katz & Martin, 1997).

2.2.3 Collaboration in small-scale science teams

As mentioned in the introduction, one of the fields where it is important to consider research collaboration and the way it takes place is in science teams. That is, inside and among research groups, usually in universities, laboratories and research centres, taking into account the emerging discipline since the 90s of Science of team science (Falk-Krzesinski et al., 2010). From this area of “research about research”, collaboration can be understood from the perspective of interactions that take place in small research teams among a few individuals, inside a single organisation and at low intensity levels or “micro-levels” (Börner et al., 2010), up to significant levels of coordination and integration in large-scale groups, when composed of different research departments or institutions (Bennet & Gadlin, 2012).

However, from that field of the Science of team science, the perspective usually focuses on the latter, covering primarily the way collaboration takes place in large-scale,

cross-disciplinary collaboration in research and training (Stokols et al., 2008), as determined by the impact and new possibilities of ICT for distributed teamwork (Bukvova, 2010). But there are also important considerations and previous theoretical contributions from the perspective of collaboration in small groups and projects, which is important to take into account, where research on scientific teams has a long tradition in the social psychology literature (Levine & Moreland, 1990).

In this sense it is important to consider the qualitative study at the scale of single, unidisciplinary science teams collaborating in daily tasks, as in the case of Latour and Woolgar (1979), from the perspective of "laboratory studies". Their pioneer anthropological inquiry about the routines and construction of facts between scientists in laboratory settings, *Laboratory life*, was also an influential work in social sciences and the Actor-Network Theory (Latour, 1996). There, through participant observation authors describe the social nature of the construction of ideas and the tacit knowledge processing that usually characterises research design (Latour & Woolgar, 1979). Confirming previous studies about the social fabrication of science (Knorr-Cetina & Knorr, 1978) and how communication of scientific information usually takes place through informal rather than formal channels (Garvey & Griffith, 1971), they analyse the way in which research is formalised, and the complexity of communication processes and meaning at several layers of human interaction in a research process. Followed by other works of ethnographic approach to epistemic cultures from a science and technology perspective (Latour, 1987; Knorr-Cetina, 1999), this first systematic and in-depth approach to the routines and collaboration processes between researchers detailed how scientific practices are characterised by networks of "local, tacit negotiations, constantly changing evaluations, and unconscious or institutionalized gestures" (Latour & Woolgar, 1979). This perspective was followed by other authors who conducted ethnographic studies on "expert systems and processes" in science, as in the case of Knorr-Cetina (1999) who also stated the transition from the individual to the collective agency in research collaborations.

Another relevant reference in this respect, also from the field of science and technology studies, is the early work of Lucy Suchman (Suchman & Trigg, 1986), which established a framework for collaborative research in the definition of the software requirements for the design of computer support (while, on the other hand, relating to the field of participatory design for software, as we will see). Providing an overview of the domain of scientific activity, as a set of professional and procedural practices and processes that involve activities at the everyday work of a laboratory, where the research was set, the focus of collaborative relationships were identified around four areas: (1) design activities (in this case of research-related software); (2) collaborative writing (from early discussion to draft-passing and feedback); (3) research discussions (usually via regular meetings) and (4) finally administrative tasks (from day-to-day coordination to management strategies).

More specifically, various issues identified transversally in that research had to do with the progression and characteristics of research across the four mentioned areas, all determined by the key human factor of productive and trusty personal relationships

(Kraut et al., 1987). These issues add important notions about the evolution of collaborative research in six interrelated steps (Suchman et al., 1986):

1. The emergence of collaborative relationships (or how collaborations typically emerge out of informal discussions on a particular topic).
2. Differences and syntheses (where synergy develops from the dialogue afforded by interaction).
3. Role specialization and interchangeability (prior to or once collaborating, roles may be relatively fixed, either institutionally or according to personal expertise).
4. Technologies and shared resources (from whiteboards to software, where participants communicate and through which they document work).
5. Forms of communication (substantive, annotative or procedural communications during the process, seeking coherence out of the developing interaction).
6. Products (final artifact, document or other demonstrable product of the collaborative work).

From the literature on participatory design for ICT tools for the support of knowledge-based teamwork, as in the case of Suchman et al., another relevant contribution to the field representing the process of collaborative research in scientific teams comes from Kraut et al. (1987), who defined it broadly at two levels: relationship and task-oriented (Figure 6).

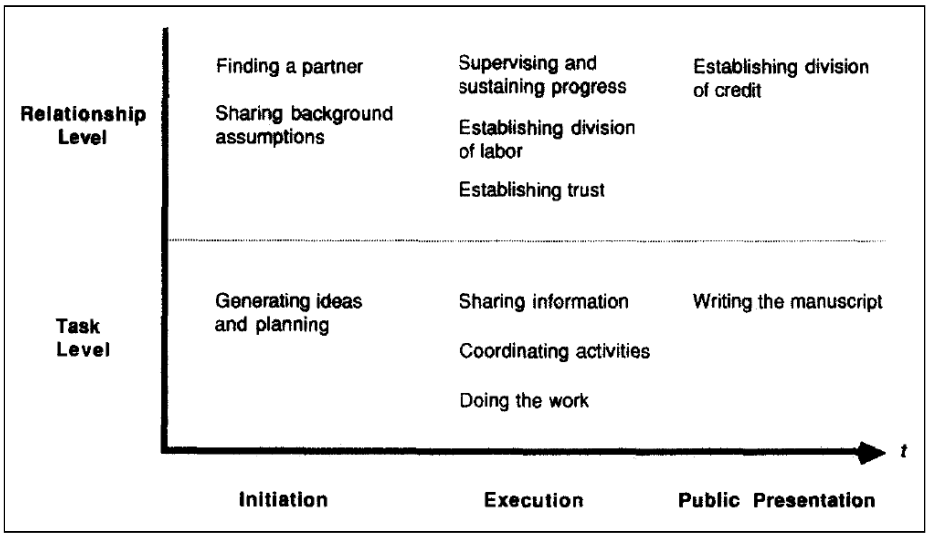


Figure 6: Model of research collaboration (Kraut et al., 1987).

This model offers a transversal view of the different tasks, as well as the informal steps that take place during research activity, all of which are usually developed in a collaboration involving two or more researchers.

Based on semistructured interviews with researchers in social psychology, management science and computer science, Kraut et al. (1987) describe the process of scientific collaboration starting with interpersonal relationships, based on shared interests, identifying commonalities, as well as agreements about research objectives.

This coincides with other literature that highlights the transversal importance of trust and shared vision in initiating collaborative research efforts (Bennett & Gadlin, 2012). Kraut et al. also consider how the nature of research activities involve plans that progressively become more detailed and specific, but that can be often revised and even abandoned without the research collaboration necessarily disintegrating. Other complexities at the relationship level coincide also with relevant research in this field, such as developing an equitable division of labor (Laudel, 2002), the need for supervision and coordination with peers (Delfanti, 2016), or for coordinating activity that is continually evolving (König et al., 2013).

Laudel (2002), from her research based on the analysis of interviews with experimental research group leaders, identified six types of research collaboration (Figure 7). In this case the framework considers horizontal specialisation as well as non-specialised contributions, both at the level of theoretical-conceptual tasks (usually by group leaders) and at the experimental level (usually by doctoral students). These six types are: (1) collaboration involving division of labor (characterised by formulating a shared research goal, and other creative tasks in the definition of a project); (2) service collaboration (where contributions comprise the completion of tasks on demand, providing knowledge to a request from a research partner); (3) transmission of know-how (interchange of tacit, procedural knowledge about practical issues); (4) provision of access to research equipment (sharing a resource and its maintenance); (5) mutual stimulation (extrinsic to a given research project, but consisting of dialogues relevant for fostering new ideas and identification of problems); and, finally, (6) trusted assessorship (knowledge interchange and feedback, reviews and proofreading of drafts and papers).

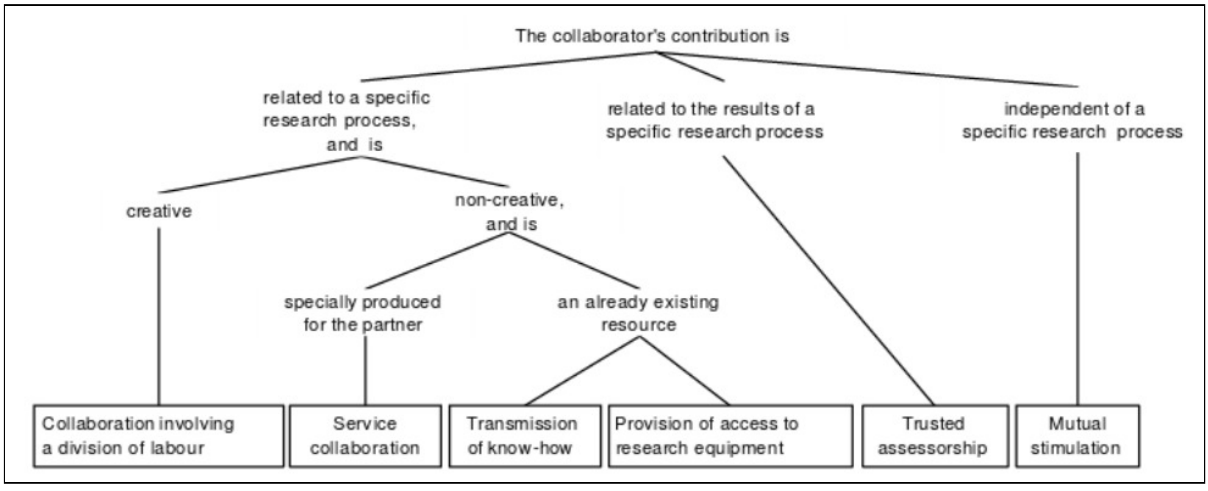


Figure 7: Types of research collaboration (Laudel, 2002).

Another key reference for framing and understanding how collaborative research occurs in scientific teams is the work of Bennett and Gadlin (2012), who describe and analyse highly integrated and interactive collaborative organisations in research, with these recurrent characteristics:

- Researchers with diverse backgrounds and different areas of expertise
- Defining a vision and setting goals shaped by a central scientific idea

- With common objectives according to that shared vision
- A shared agenda of activities directed toward achieving objectives
- Some level of coordination around the needed resources
- Meeting regularly, physically or virtually, and communicating effectively
- Encouraging intellectual disagreement
- Obtaining and keeping a high level of trust
- Sharing both data and credit for accomplishments
- With a principal leader or co-leaders (that can emerge during the project)

Among these factors, they also consider trust to be the most critical element, which, in line with other authors, clearly determines team cohesion and project development in research settings (Bennett & Gadlin, 2012; Keraminiyage et al., 2009).

Considering again the conditions for all these patterns, as in the case of Laudel (2002), Latour and Woolgar (1979), and Suchman and Trigg (1986) concerning collaboration in small-scale teams, one important question, at this point, is the extent to which these phases and pre-conditions scale to more complex levels of scientific collaboration. Whereas the motivations can be the same for doing it so (Fiore, 2008), is important now to address the key issue of how large-scale collaboration takes place, in this case with more frequency of ICT use and within wider institutional networks.

2.2.4 Collaboration in large-scale research networks

As opposed to the study of scientific teams as small, collocated entities with intense face-to-face interactions, there is increasingly more literature from the field of the Science of team science (Stokols, 2006), exploring the way wider distributed and networked research teams collaborate, at usually big scales. Some of the reasons behind that type of cross-disciplinary research, and the reasons why it is being studied in recent times from diverse perspectives (Wang & Hicks, 2015), is that large-scale collaborative research programs are being promoted more and more by funding agencies aiming for better use of existing resources, instilling prestige and building international reputation (Smykla & Zippel, 2010). In this respect, we can consider this type of research collaboration from the perspective of self-assembling entities, with usually fuzzy boundaries and the tendency to function as networks (Wang & Hicks, 2015). These involve not only different research institutions, but also expanding its activity to collaboration with the industry, governments or civil society. That is, across sectors and across types of organisations (Bozeman & Corley, 2004), for example in government-based research programs, which usually emphasize cross-disciplinary and applied research (Gray et al., 2001). Or in the case of collaboration with industry, usually bypassing the confines of conducting research for the sake of academic publishing, looking for additional utility for the non-academic partners (Perkmann et al., 2013).

In this sense, in relation to large-scale research collaboration we must also consider in parallel the key area of collaboration of universities and research centres with commercial firms and industries, sometimes involving public administrations, usually oriented to research and development for fostering product or service innovations (Perkmann & Walsh, 2007), or different ways of knowledge and technology transfer (Santoro & Gopalakrishnan, 2001). A field where researchers and professionals from a

given industry or sector collaborate with common goals, in a two-way exchange where basic projects usually lead to scientific output, while more applied projects involve high degrees of collaboration (Perkmann & Walsh, 2009).

Large-scale research collaborations, in scientific networks or with other stakeholders, can be described as temporary organisations "that exist for the purpose of building and evaluating novel results under a predefined research objective and with constraints on resources, costs, and time" (Vom Brocke & Lippe, 2015). Although large-scale team science initiatives can be considered from the different characteristics summarised in the previous section for small-scale collaborative research, they usually face other levels of complexity and dependencies (Cooke & Hilton, 2015). That complexity normally refers to the need to incorporate more ICT and digital channels for communication (Lassi & Sonnenwald, 2010), not only for effective development of tasks, but also for the key aspects of personal relationships (Kraut et al., 1987). It refers also to the volume of data that can be generated for analysis when there is a significant number of teams, departments or institutions gathering information, especially in cross-disciplinary approaches, where triangulating between quantitative and qualitative methods means more complexity for successful interpretation of results (Cummings & Kiesler, 2005). Another aspect relevant in this study refers to complexity in project management, where large-scale research projects usually imply more dedication to leading and coordinating each process, from research design to collaborative authorship of papers and reports (Bozeman & Corley, 2004).

As Wang and Hicks (2015) observed, these everyday, usually large, collaborative research teams are not only "self-assembled and fluid", but also composed of the mentioned network characteristic, that makes participants (specially main researchers) also part of other networks of scientific collaboration, adding layers of projects with different goals and participants. With regard to the interpersonal factors of large-scale research collaboration, there is also an extensive amount of literature on the challenges faced in these types of collaborative research arising from the wide diversity of participants, particularly with respect to professional backgrounds, culture, defined roles or expertise and skills (Barnes et al., 2002; König et al., 2013), as well as the key need to establish philosophical dialogues for cross-disciplinary integration (Eigenbrode et al., 2007; O'Rourke & Crowley, 2013). Although diversity in research teams is discussed by some authors as a positive factor for research quality (Liao, 2011), at the interpersonal and institutional level a total lack of access to knowledge from different research cultures seems to be detrimental when it comes to quality of results (Barjak, 2006).

2.2.5 Action research and citizen science as transdisciplinary collaboration

Until now, I have been describing the context for knowledge generation and collaborative teamwork in transdisciplinary research focusing on different practical aspects, mainly related to size of research teams or networks, steps of the design and development of collaborative inquiry processes, as well as key issues pertaining to the complexity surrounding these practices in the context of scientific institutions. I have also mentioned relevant aspects of diversity, cross-disciplinarity and relationships, following academic literature on the subject of collaborative research. At this point, it is important to bring an additional perspective, as I mentioned early on, since there are

two more relevant approaches related to the diversity of participants in research collaboration which are intrinsically transdisciplinary, which in this case connect to the wider paradigm of public participation in research (Shirk et al., 2012).

On the one hand, action research and its different types of practices are oriented to solving immediate problems by reflective practice and iterative inquiry, with the involvement of individuals and communities of practice (Chevalier & Buckles, 2013). On the other, the relatively new practices of citizen science, where collaboration and participation, usually in experimental research, has the characteristic of direct implication of society for actively and consciously gathering data for scientific projects (Silvertown, 2009), normally via the use of ICT (Prestopnik & Crowston, 2012). Both cases, which I consider to be also transdisciplinary practices, this represents a shift of the collaborative paradigm in research described until now, which has to do with the direct and active implication of individuals who are not "professional", "expert" or "trained" researchers in scientific work, in many cases generating a bottom-up or community driven process, rather than a top-down, scientist-driven one (Danielsen et al., 2009). Prior to describing both approaches, some framing of epistemological and even political implications is required, as summarised by Gibbons (1994) in reference to the Mode 2 of science, and the traditional norms that govern the production of scientific knowledge:

> "Many argue that knowledge cannot qualify as scientific if it is produced outside its legitimating structures. A tension with established structures will arise when any scientist acts in a manner different from that prescribed by their specific set of technical and social norms. But as long as the numbers of such deviants are not significant, no threat is presented to the social control of knowledge production. However, when significant numbers of scientists choose to work on problems that lie outside their specialisms, when they form learns with other specialists to work on complex projects, when in doing so they enter into arrangements with other social institutions which broaden the constituency of interests involved in setting agendas and priorities, and when performance is evaluated by an expanded peer group, then the legitimacy of outputs may be called into question".

This echoes tensions and wide discussions in the production of scientific knowledge beyond its academic or "classic" limits that seem recurrent in the critique of both action research (Frideres, 1992) and citizen science (Riesch & Potter, 2013). A shift that moves between the theoretical and the practical, in close relation to knowledge and practice through design, then absorbed into larger collaborative communities by a process of professionalisation and institutionalisation (Gibbons et al., 1994). Although the normative approach of this theory is criticised for being biased toward political ideology (Godin, 1998), or for missing questions about power relations between society, institutions and policies (Linder & Spear, 2003), it is relevant for focusing on aspects of transdisciplinarity and its connection with broader levels of participation in scientific activities.

2.2.6 The collaborative tradition of action research

Action research can be understood as a strongly participative and iterative approach to research, mainly in the field of social sciences, which combines theory with practise (Brydon-Miller et al., 2003), favoring a pluralist and instrumentalist view of knowledge (Gergen & Gergen, 2008). Strongly focused on action and change (Lewin, 1946), among the various formulations of action research it can be described as the collaborative analysis of problems by affected participants (who look for the consequent formulation of a theory), followed by the generation of a change in their situation while studying its results (MacColl et al., 2005). Action research is currently experiencing an increase in academic literature, especially with a focus on collaborative and participatory action research (Chen et al., 2017).

Although in recent times there has been some approaches from a digital and network perspective (Foth, 2006), action research characteristically takes place in particular, local practice contexts, where it builds descriptions and theories based on practitioners' perceptions (Argyris & Schön, 1989). A more extended definition of the basic features of action research can be found in Reason and Bradbury (2001), who state that it:

- Is a set of practices that respond to people's desire to act creatively in the face of practical and often pressing issues, in their lives in organizations and communities;
- Calls for engagement with people in collaborative relationships, opening new 'communicative spaces' in which dialogue and development can flourish;
- Draws on many ways of knowing, both in the evidence that is generated in inquiry and its expression in diverse forms of presentation as we share learning with wider audiences;
- Is valued oriented, seeking to address issues of significance concerning the flourishing of human persons, their communities, and the wider ecology in which we participate;
- Is a living, emergent process that cannot be predetermined but changes and develops as those engaged deepen their understanding of the issues to be addressed and develop their capacity as co-inquirers both individually and collectively.

Another useful definition, from Altrichter et al (2002) reinforces the aspects of self-reflectiveness and pragmatic approach of action research as: "a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices". In this sense, action research represents a shift to a collectivist orientation of research, in harmony with the constructionist perspective of knowledge formation, and involves dialogical processes that recognize participants as "co-researchers" (Gergen & Gergen, 2008).

The origins of action research are broad, but there is agreement that its foundation lies in the work of Kurt Lewin and other social science researchers at the end of the Second World War (Adelman, 1993). Lewin, who coined the expression "If you want to truly

understand something, try to change it" (Burnes, 2004), is also considered the father of social psychology and the concept of field theory, which explains human behaviour based on patterns of interaction between the individual and his or her environment. What seems relevant for the purpose of this thesis, is that already in the origins of action research, observing how workers in a mine self-managed to improve work conditions and more effective teamwork by sharing tacit knowledge (Trist & Bamforth, 1951), there is already a mutual connection with organisational learning (Murray & Moses, 2005), and therefore with basic principles of design thinking and agile development, as I will elaborate later on.

Lewin also refers, at the origins of the discipline, to its problem-solving orientation involving cycles of action and reflection, noting that: "It proceeds in a spiral of steps, each of which is composed of a circle of planning, action and fact finding about the results of the action' (Lewin, 1946). Such circularity of knowledge sharing at the core of the collaborative inquiry, for generating change by activating empirical and logical reasoning (Reason & Bradbury, 2001) is also a relevant aspect of how action research is formulated. For other authors, action research can be defined as "spiral processes of taking action for change and improvement, to achieve research at the same time for understanding and knowledge" (Dick, 2002).

The intellectual and applied spreading of action research generated other theories like the usually more education-oriented Participatory Action Research (PAR), based on a liberationist perspective from Paulo Freire in the 70s (Reason & Bradbury, 2001). The PAR approach also stresses the aim of social change (Stoecker, 1999) and empowerment (Arnstein, 1969), as well as the importance of creating an enquiry environment where practitioners are both subjects of the research and co-researchers (Argyris & Schön, 1989; Whyte, 1990), usually in the context of the social sciences (Greenwood et al., 1993). Action research is also behind subsequent theories and models of community-based research, characterised as well by the community being involved as a partner in proposing and designing the research (Halseth et al., 2016). In this sense, another theoretical framework derived from action research is action science, formulated by Chris Argyris and Donald Schön in the late 70s and early 80s, which establishes a clear conceptual bridge between action research and the field of organizational learning.

These perspectives derived from action research, which I include in the broader field of transdisciplinary research, have in the last decades spread notably not only in the field of organizational development, but also in other ones like education, health and care provision, and community development (Reason & Bradbury, 2001). In all cases a critical aspect relates to the special role of the researcher, or action researcher (O'Brien, 1998), who puts great emphasis on the knowledge base that exists within the participant group, and is immersed in relationships and facilitation processes strongly based on collaboration. As Gergen and Gergen (2008) observed: "they do not work in separation from others, but with them. Their efforts are fundamentally collaborative. They recognize the essential condition of interdependence for the success of their work. Second, they do not sustain the traditional separation of communities between the professional community and those they study. Rather than creating barriers of

incomprehension, they conjoin community and professional interests". In these contexts, partnering researchers from universities are committed over the long term, where each stage of the collaborative inquiry process is part of an interactive relationship (Halseth et al., 2016). This fundamental aspect, that relates to who takes responsibility for bringing forth a researching system in this kind of participative inquiry (Ison, 2008), articulates "pattern theories" rather than the deductive form found in quantitative studies, where generalizations represent interconnected thoughts or parts linked to a whole as the output of research (Creswell, 2009). In this context, another relevant conceptual contribution derived from action research is the Soft Systems Methodology (SSM) developed by Peter Checkland in the late 60s, which is focused on problem solving, and of the many research techniques for dealing with complexity, the methodology utilises pictures and diagrams to describe problem situations (Checkland & Holwell, 1997).

None of these fields of action research, however, has to do with the "mainstream objectivist, hypothetico-deductive research, which retains a dominance" (Reason & Bradbury, 2001) with an emphasis on the representation of the world rather than action within it (Levin & Greenwood, 2001). However, action research can be also understood as a collaborative inquiry that collects data expressly to guide the future (Salehi & Yaghtin, 2015), guided by the critical aspects of social impact of science (Rowell & Hong, 2017) and democratization of knowledge (Santos et al., 2007).

Another defining aspect of action research is that it usually provides participants with a more comprehensive exposure to scientific methodology than research projects operated exclusively within science institutions (Bonney et al., 2009b). In most participative action research, depending on the established process, laypeople can help by framing the research questions, by designing parts of the study, and by interpreting results in addition to collecting data (Elden & Chisholm, 1993).

2.2.7 The emerging domain of citizen science

Citizen science is the third relevant form of research collaboration considered for this study, after team science and action research. In this case, it involves the public or "amateurs" (Gura, 2013) in distributed and usually empiric scientific projects to address real-world problems with the primary task, usually, of collecting scientific data (Cohn, 2008). While there's currently a rapid growth of all types of citizen science projects and diversity of approaches (Parrish et al., 2019), and the concept raises controversy when trying to establish a common definition (Heigl et al., 2019), the majority of well-known citizen science projects consist of digital ICT infrastructures (Prestopnik & Crowston, 2012), where geographically dispersed participants could coordinate and centralise tasks of data harvesting (Wiggins, 2010). Although as a collaborative type of organizational design based on volunteering rather than research as a paid profession, citizen science is not new to science (Silvertown, 2009), the concept has grown in academic literature in recent times (Dobreva & Azzopardi, 2014) and has expanded to different domains on a large scale (Raddick et al., 2009). Precursor examples of citizen science, previous to ICT technologies, can be considered dating back to 1900, like participative birdwatching ones (Butcher et al., 1990), while current popular types of projects like volunteer galaxy classifications are also considered citizen science (Haklay,

2013), in some cases with hundreds of thousands of participants engaged in data-gathering related tasks (Raddik et al., 2009; Hand, 2010).

Also defined as "crowdsourced science" (Prestopnik & Crowston, 2012) or "P2P science" (Delfanti, 2016), the majority of widely studied and known projects of citizen science relate to astronomy (Christian et al., 2012) or address ecological problems (Dickinson et al., 2012), such as the consequences of climate change (Theobald et al., 2015) or the population of bees (Kremen et al., 2011). A significant number of citizen science research projects are related to science and engineering (Spiers et al., 2019; Franzoni & Sauermann, 2014), and until relatively recent years they were are almost non-existent in the areas of humanities or social sciences (Ferran-Ferrer, 2015). However, recent projects are starting to address other fields like computational social sciences (Sagarra et al., 2016), human behaviour (Vicens et al., 2018); public health (Den Broeder et al., 2016; Cigarini et al., 2018), digital arts (Perelló et al., 2012) or cultural heritage (Dobreva, 2016). In this sense, recent advances and analyses cover new epistemological perspectives regarding the social sciences (Purdam, 2014; Kythreotis et al., 2019), the potential of citizen science for policy innovations (Hecker et al., 2018) or also critical approaches about the traditional scientific discourse (Peters & Besley, 2019).

According to a popular classification by Follet and Strezov (2015), citizen science projects can be considered based on the type of volunteer involvement in three main categories, that also match others based on progressive levels of involvement from participants (Delfanti, 2016):

- Contributory projects: participants contribute to data collection, and sometimes help to analyse data and to disseminate results.
- Collaborative projects: participants also analyse samples, data and sometimes help design the study, interpret the data, draw conclusions and disseminate results.
- Co-created projects: participants are involved at all stages of the project, including defining the questions, developing hypotheses, discussing the results and answering new questions.

Wiggins and Crowston (2011), from a complementary perspective, suggested previously an alternative classification based on the goals of the type of project:

- Conservation projects: addressing the environment and natural resource management goals.
- Investigation projects: focused on scientific research goals in a physical setting.
- Online projects: also with scientific research goals, but entirely based on ICT for data collection.
- Education projects: often performed in the classroom or school.
- Action projects: initiated by volunteers designed to encourage intervention in local contexts.

The most common model of large-scale collaboration in citizen science is the contributory participation model (basically for collecting data via online platforms),

which for some authors also has an economic motivation behind, as a free source of labour, skills or computational power (Cohn, 2008). There is also another important factor in the recent popularisation of this type of projects, consistent in policies and institutional strategies to expand the outreach of science among society (Silvertown, 2009), and especially to connect it to more public engagement (Dickinson et al., 2012), usually via education and learning processes (Bonney et al., 2009b).

But behind that pluralistic view of citizen science, as a field where the number of projects from other scientific domains is currently growing, and with results starting to appear in peer reviewed publications as a sign of academic acceptance (Follet & Strezov, 2015), the potential of open and reusable data generated via this type of collaborative research is still not fully integrated into established modes of inquiry, because there's also a palette of controversies and issues regarding its legitimacy (Theobald et al., 2015). One of the main areas of discussion in the literature about this specific field of transdisciplinary collaboration concerns the objectivity of citizen science from an empirical point of view, focusing on the quality and rigour of obtained data (Mueller & Tippins, 2012). Another discussion is the lack of neutrality from citizen-researchers as too much involved in their own problematics (Riesch & Potter, 2013), which is a recurrent issue also in other community-driven research processes derived from action research (Halseth et al., 2016). Other criticism has to do with levels of implication, when dedication or time availability is not the same for volunteers and professional, dedicated researchers (Riesch & Potter, 2013), or the extent to which the latter perceive this collaborative model as a way of losing control of the research (Hand, 2010). In addition, an important question related to the dilemma or problem of extension is under which circumstances and criteria can "lay people" join citizen science projects as co-researchers, and who, specifically (Dickel & Franzen, 2016).

On the opposite side of the discussion, a recurring question from other authors in relation to citizen science has to do with the extent that such research collaboration model usually serves to collect data in different ways -namely that contributory mode defined by Follet and Strezov (2015)-, but until very recently not for the other two deeper levels of collaboration with scientists (collaborative and co-created modalities). Although there are a growing number of cases where a more participative type of collaboration in research activities leads to common knowledge and community awareness (Cooper et al., 2007; Ruiz-Mallén et al., 2016; Vicens et al., 2018), or where non-expert participants develop new questions aided by data visualization so scientists can identify unexpected challenges (Goodchild, 2007), still the most habitual forms of citizen science are considered "contribution systems" (Wiggins & Crowston, 2014). That is, initiatives that crowdsource specific data-collection with detailed closed tasks, following the model of accessing a portal or website of scientist-driven research, which is a technical field in continuous evolution (Prestopnik & Crowston, 2012). A vision of citizen science that, simplified, could be summarised as this: participants register, join one or more projects, and become *de facto* members of research project teams (Newman et al., 2012), and where other authors point recently to how high-quality data can be successfully produced by appropriately designed citizen science projects (Parrish et al., 2019).

Literature addressing both types of issues point to the need to generate citizen science projects according to more deliberate and co-created research designs, that pay attention to diverse interests in order to achieve both social and scientific objectives (Bonney et al., 2014). Especially when defining research questions, these can be formed in a top-down approach (scientific-driven) but also in a more bottom-up way, as a community-driven process (Newman et al., 2012). Given the inherent complexity of those types of projects in relation to how they integrate diversity (Wiggins & Crowston, 2014), the aspect of effective community management also gains importance here (Gura, 2013). In this respect, in order to advance to more collaborative modalities of citizen science, authors like Bonney et al (2009a) point to the need to involve participants in the research design process in more deliberative and facilitated ways. This relates to the importance of determining collaboratively clear and project-specific goals, identifying through iterative periods of design the outcomes, tools and features of the research (Dickinson et al., 2012).

2.2.8 Acceleration of science, neoliberalism and academia

Prior to finishing this section on team science collaboration and transdisciplinary research it is also important, in describing the context in which all these changes and challenges take place, to consider the perspective of neoliberal transformation of universities and scientific organisations (Mountz et al., 2015). I started this discussion on the state of the art with a general focus on the micro-level of teamwork in networked organisations and the role of the knowledge worker, but in the case of research this also requires to critically addressing issues of productivity and timing for scholarship tasks (related to thinking, reading, writing, discussing, etc.) as key intellectual activities ahead of administrative ones. In what has been called “academic capitalism” (Slaughter & Leslie, 1997), or as “accelerated academia” by other authors (Vostal, 2016), there is different evidence of increased pressure on research teams for producing results, in parallel to a “projectification” of university research in relation to performance (Fowler et al., 2015).

This development has resulted in increased emphasis on formalised project management methods to conduct scholarly work, and in a myriad of strategies for adopting tools and practices depending on issues of power, hierarchy and control of expert labour (Hodgson, 2002). Here it is also important to consider how demands for publications and other types of academic impact are usually tightly connected to the economic sustainability and funding of research groups, in a quest for competitive excellence (Sørensen et al., 2015). This predominant research model has given rise to tensions and structural challenges related to the pace of doing academic work (Vostal, 2015), on the one hand, and on the other one to consider strategies and approaches against the individualization of researchers as a consequence of neoliberalism (Gill, 2017; Aibar, 2018). Also, these new managerial practices in academia, related to austerity politics in Western countries, have particularly highlighted the issue of research institutions as gendered spaces, affecting well-being and care issues (Carpintero, 2017).

It is in relation to this second perspective, aligned with the need to open the practice of research to social processes related to community empowerment and civic struggles beyond academia (Lafuente & Estalella, 2015) that the question arises of whether to

place co-creation principles at the core of transdisciplinarity, in parallel to the values of Responsible Research and Innovation or Open Science previously mentioned.

2.3 Co-creation as an emerging paradigm: participatory design and agile project management

There is currently a significant corpus of literature about co-creation associated with many diverse topics and application areas. A prevalent one is eminently market-oriented, with a large body of papers that use the term “value co-creation” from the perspective of customers or clients engaging in the identification and even co-production of new goods and services (Ranjan & Read, 2016). However, another approach to co-creation that seems more relevant in this case is that of “collaborative creation” as defined in the context of design thinking, and focusing among other things on its social value (Sanders & Simons, 2009). My research is closest to that perspective that considers the important conceptual characteristic of “co-creation” as the generic process of collective creativity (Sanders & Stappers, 2008). In that approach, both participatory design and agile project management, which require different techniques and principles combined for the effective collaborative development of ideas, plans and projects between diverse participants, are in the next sections presented and analysed, in order to establish afterwards the necessary connection with transdisciplinary research challenges and collaboration in science.

2.4 The field of co-design

2.4.1 Origins of design thinking and relation to fields of knowledge

There is relative controversy as to whether design thinking can be recognised as a design sub-discipline or set of practices with enough empirical validation and scientific recognition, especially when it comes to management practices and literature related to innovation (Johansson-Sköldberg & Woodilla, 2011). Following this question, Johansson-Sköldberg et al. (2013) offer an exhaustive literature review comparing the emergence of publications related to design thinking, first of all noting its exponential growth, particularly between 2004 and 2009. The authors contribute to clarifying the main question of rigour and academic approaches to design thinking, by confirming the use and abuse of the concept in innovation management literature. At the same time, however, they describe the more vast and solid domain of design thinking (“designerly thinking” in their words) in the field of design studies, with a clear classification in five main areas of theory (or sub-discourses):

1. Design thinking as the creation of artifacts (based on the foundational work of Herbert Simon around design science in the 70s, with design as a key element for the creation of technology and systems).
2. Design thinking as a reflexive practice (according to theories of Donald Schön, which have already been presented there around reflective practitioners and organisational learning).
3. Design thinking as a problem-solving activity (or how by recurrent contextualisation, a problem formulation and solution take place simultaneously,

according to theories from Richard Buchanan, who was inspired by the concept of "wicked problems" by Horst W. J. Rittel and Melvin M. Webber in the 70s).
4. Design thinking as a way of reasoning/making sense of things (mainly by extensive observational research, started in the 90s by Nigel Cross and Bryan Lawson, focused in the methods and techniques of designers).
5. Design thinking as the creation of meaning (a discourse mainly articulated by Klaus Krippendorff, defining design and designers' work as a matter of creating meaning -rather than artifacts, as in Simon's notion).

Rather than deepening in these five clear domains and authors in the same strict order, I will elaborate more references to them by following some key chronological evolutions of design thinking. Starting from Simon's legacy, focusing in parallel on important aspects related to other authors when they connect with matters of collaboration, knowledge and research, and with particular attention to co-design techniques.

2.4.2. Evolution of design thinking

Simon was one of the first contributors to design thinking (although there's no evidence that he used the term as such) with his key notion that design practices could be based on a rational theory of problem solving, inspired by the scientific method, for managing complex systems. For the Nobel-laureate author, and father of artificial intelligence, human behaviour at the individual and organisational level was characterised as being goal-seeking, and design was seen as an activity to achieve its "preferred conditions" (Simon, 1996). Although suggestive in its connection with epistemic principles of science, this approach to design as consistent with the field of scientific and engineering practices, as a systematic mindset of the designers, was later rejected by other authors like Donald Schön or Nigel Cross (more focused on attributes like intuition or socialization).

The vast theoretical and applied work of Schön, which I have taken into account because of his influence on action research through his book *The reflective practitioner - how professionals think in action* (1983), in parallel to contributions to the field from Chris Argyris (Argyris & Schön, 1989), refers to organizational learning in terms of tacit and explicit knowledge transfer processes (key aspects also for agile frameworks, as I will defend later on). In specific reference to design disciplines, Schön's perspective is relevant in the way he challenged previous positivists doctrines behind much of the 'design science' movement influenced by Simon, offering instead a constructivist and more intuitive approach (Cross, 2001), based on his elaboration on tacit knowledge and theories-in-action. In Schön's words (1983), design can be considered more as: "an epistemology of practice implicit in the artistic, intuitive processes which some practitioners do bring to situations of uncertainty, instability, uniqueness, and value conflict".

This connects with the key assumptions of design thinking as a problem-solving activity, but in latter theories with little in common with Simon's epistemology or scientific methods, where later on Buchanan (1992) proposed it as a new discipline of practical reasoning and argumentation (in areas like communication, construction,

strategic planning, or systemic integration). Based on the notion of “wicked problems” (Rittel & Webber, 1973) this characterisation of design thinking for solving complex system problems was based on the notion that they may be addressed by the intuitive and abductive approaches implicit in design thinking (Jones, 2014). This links design thinking, according to other authors, with the wider and more consolidated academic field of systems thinking (Mugadza, 2015).

Another key discourse and theoretical contribution in the field of design thinking can be found in the work of Nigel Cross, who mainly by direct observation of designers’ activities deepened in assumptions such as the difference between design, as a practice for initiating “novel forms”, as opposed to science, concerned with investigating “extant forms” (Cross, 2011). This highlights the different modes of reasoning between both domains, and also to what extent design rather than a process itself can be understood as a way of “shaping processes” (Lindberg et al., 2010). It is from this perspective of processes that need to be designed, by teams or groups rooted in diversity, that the field of design thinking has currently expanded to innumerable areas and practices, such as policy innovation (Howlett, 2014), learning and education (Scheer et al., 2012), business and management (Dorst, 2011) or sustainability studies (Garcia & Dacko, 2015), among others.

Without deepening on the fifth sub-discourse of design thinking according to Johansson-Sköldberg et al (2013), which contains the scholarly evolution of Krippendorff’s concepts, defining design and designers' work as a matter of creating meaning (rather than artifacts as in Simon's notion), it is important at this point to mention the key field of participatory design, which develops in parallel to design thinking, with mutual influences in the field of information systems.

2.4.3. The emergence of participatory design

With its roots in Scandinavia in the 70s, and afterwards expanding to other countries and technology research and engineering disciplines, the original conceptualisation of participatory design was intended to empower the users of computer systems to play an active and creative role in designing them (Bødker, 1994), based on principles of curiosity, creativity and empowerment (Steen, 2013). While Scandinavian participatory design projects developed an action research approach (Spinuzzi, 2005), emphasizing active collaboration between researchers and workers within organizations to help improve work situations (Schuler & Namioka, 1993), in countries like the United States (where debates about industrial democracy were not as prevalent) researchers and software systems engineers took more pragmatic and progressively apolitical approaches (Kensing & Blomberg, 1998).

The latter influenced that technological developments during the end of the 70s, which saw participatory design shift from a social to a technological method, to become synonymous with the emerging field of interaction design (Di Russo, 2016). This meant the generation of different co-design methods such as prototyping, mock-ups or scenarios (Kensing & Blomberg, 1998) as well as usability testing methods, sometimes inspired by scientific methodologies (Johnson et al., 2007). This coincides with the observations in other fields related to design thinking from Cross (2011), who stated that

design experts use also sketching, prototypes and scenarios in participatory settings for "inquiry into the future situation of use, when abstract thought alone cannot guide design".

On the one hand, the evolution of the user-centred design approach (that is, with the 'user as subject') was primarily a US-driven phenomenon, where according to the key contribution of Norman (1988) around the needs and interests of the user, laypeople were given more influence and room for participating in the informing, ideating, and conceptualising activities in the early design phases of software and information systems (Sanders & Stappers, 2008). On the other hand, the participatory approach (that is, the "user as partner") was more led by Northern European designers, although the two approaches ended up influencing one another (Holmlid, 2012), configuring in this way current practices of co-design.

Through this conceptual confluence between participatory design and collaboration, several areas of practice linked to the field of science and technology studies have emerged and progressed, evolving into the cross-cutting concept of community-based Participatory Design (DiSalvo et al., 2012; Dantec & DiSalvo, 2013). For example, broadening the concept of the public and expanding the inclusiveness of design at the margins of society (Dantec, 2012), opening the field for a human-computer interaction design that includes alternative identities (Light, 2011) or the resurgence of economic models such as cooperativism (Fedosov et al., 2019). This is a clear example, again, of how design as a field of study and practice, situated in its contemporary reality, is able to unite the epistemological tradition of action research with alternative world views, from feminist theory (Agid, 2012) to the contribution to urgent problems such as global immigration (Brown & Choi, 2018) or the aging of population (Botero & Hyysalo, 2013).

2.4.4 Characteristics of co-design

Evolved in its latter practices to other related sub-fields, which denote design thinking as a transitive paradigm which differs depending on the context in which it is applied (Di Russo, 2016), authors like Manzini and Coad (2015) consider co-design an open-ended culture and practice of co-creation, with the main characteristic of involving all actors in the process, with the key role of the design expert as facilitator. For Kimbell (2011) co-design in this context is an exploratory process for new kinds of value creation between diverse participants, as a process of "constructivist enquiry". Again, it all resonates with Cross (2011) echoing Schön, who through his studies of design in action considered: "there is the need to tolerate and work with uncertainty, to have the confidence to conjecture and to explore, to interact constructively with sketches and models, and to rely upon one's 'intuitive' powers of reflection-in action". For other authors, the evolution of this type of participatory design clearly resonates with values and essential practices related to the Commons (Marttila & Botero, 2017).

But what are some of the main characteristics of co-design, in terms of techniques and methods? In this case the evolution of the field, as opposed to the semi-absence of described collaborative research methods in academic literature (as I stated in the previous section), tends to be usually more prolific in researchers and designers producing facilitation materials and receipts (Sanders & Stappers, 2008). This connects

broadly to the concept of “placements” (Buchanan, 1992) and “thinging” (Binder et al., 2011), as well as the spread of practical and visual materials for enabling co-creation, for example for activating “what if” conjectures as propositive outcomes (Cross, 2011).

Once again, this connects with Zuboff (1988) and her field work on knowledge-generation companies, where despite the irruption of ICT for informational tasks, workers also appreciated the physical interaction with text notes as written artifacts. In the emerging practices of co-design, according to Manzini & Coad (2015), design knowledge accumulated within the tacit knowledge of design experts: “must be clearly expressed (by whoever produces it), easy to discuss (by many interested interlocutors), and easy to apply (by other designers), so that other researchers can use it as a starting point for producing further knowledge”. This explicit, discussable, transferable and accumulative knowledge can be dynamically generated in co-design sessions taking into account both the notions of user-centered and collaborative design, in detailed stages and techniques such as those described by Naranjo-Bock (2012):

1. Self-reflection of research methods, focusing on research goals and questions, who the audience is and what tools they can use, and the stage of the project;
2. Running co-design activities onsite, with techniques and “placements” like collages, context mapping, storyboards, inspiration cards, modelling, paper prototyping or games; and finally,
3. Pilot testing and results, where the data obtained is generally visual and tangible, accompanied by the important debrief of the results of each co-design session or process.

Another detailed methodological approach of sequences comes from the mentioned field of participatory design research (Spinuzzi, 2005), where similar stages of co-designing processes can be summarised as: (1) Initial exploration of work, where designers meet the users (using workflow and work procedures, routines, teamwork); (2) Discovery processes, when designers and users employ various techniques to understand and prioritize work organization, clarifying the user’s goals and values and (3) Prototyping, final stage when designers and users iteratively shape technological artifacts. These three stages should be iterated several times, thereby providing an iterative co-exploration by designers and users.

2.4 Agile project management

2.4.1 Origins and adoption of agile principles

Originally, the term agile was used in reference to a software programming methodology and set of co-creation principles based on iterative development, with requirements and solutions evolving through the collaborative work of cross-functional teams who are self-organized (Hoda et al., 2013). In this sense, agile characterises a development process that promotes adaptive planning, continuous improvement, frequent consultation with the end-user, small and frequent releases for early delivery, and rigorously tested code (Cao et al., 2009). Other definitions (Abrahamsson et al.,

2003) characterise it as follows: “incremental, cooperative, straightforward, and adaptive. Incremental refers to small software releases, with rapid development cycles. Cooperative refers to a close customer and developer interaction. Straightforward implies that the method itself is easy to learn and to modify and that it is sufficiently documented. Finally, adaptive refers to the ability to make and react to last moment changes”.

Compared to other project management methods, agile frameworks place greater emphasis on teamwork and people, by putting the focus on the social aspects of software development (Rosenberg & Stephens, 2003). That is, channeling social interactions between programmers and other types of participants, with collective ownership and shared responsibility as key features of teams adopting it (Robinson & Sharp, 2003). The core principles of agile were defined in 2001 by a group of software developers as a reaction to the weaknesses and rigidity of popular plan-based methodologies of software production, such as the previously influential waterfall method, mainly for its lack of responsiveness to change (Cockburn, 2002). In this sense, the early conceptualization of agile connects with the tradition of other human-centered approaches to workplace design, specifically participatory design (Spinuzzi, 2005) as I described in the previous section.

For other authors, the popularity of agile methods over plan-driven methods mirror the increasing popularity of non-Taylorist job designs over Taylorist job designs in the 80’s, when different types of jobs were transformed by adopting self-managed teams (Kakar, 2012). Followed by 12 detailed principles, the fundamentals of the Manifesto for Agile Software Development (Beck et al., 2001) consists of these four statements, which address the value of:

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan

Besides these key statements underlined in the manifesto, some of its detailed principles are described in that seminal online text as: “early and continuous delivery of valuable software; deliver working software frequently; build projects around motivated individuals; best architectures, requirements, and designs emerge from self-organizing teams; at regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly” (Beck et al., 2001).

However, some of the foundational principles of agile that I will describe and discuss in this section have an origin in previous practices and frameworks of software engineering (Abbas et al., 2008). As with the emphasis on iteration, which is rooted in the field of incremental and iterative development (IDD) as it was originally practised in the 40s at Bell Labs (with a “plan-do-study-act” approach) or in cycles of software quality improvement in the 50s at IBM (Victor, 2003). Another agile key principle, the focus on early and continuous delivery, was already practised under the principle of

"release early and often" by open source communities of developers (Koch, 2004; Senabre Hidalgo, 2005; Harzl, 2016).

Although according to some authors (Conboy & Fitzgerald, 2004) the agile manifesto principles are insufficiently grounded in theory, they have gained exponential popularity since its publication, as a generic approach to alternative job design with a focus on the social aspects of work (Kakar, 2012). Comprising different frameworks, sub-categories and practices, agile methods have increased in adoption from IT organisations since its conceptualisation in 2001 (Papatheocharous & Andreou, 2013). According to an extensive study by Sheehan (2015), based on a survey administered to 401 developers and 200 IT professionals, two thirds of organisations were applying some of the agile frameworks on a regular basis, while 24% were doing some type of hybrid adaptation. The ratings from the same study indicated that the primary motivations for agile adoption were associated with need of improving team collaboration and of improving software quality.

Apart from the claim that agile lacks solid theoretical foundations, which is an argument I will contrast in this section, agile practices and principles have received other critical opinions and perspectives in some research studies, mainly from authors referring to its lack of focus on software architecture (Rosenberg & Stephens, 2003) or its suitability only for small teams, but not larger projects (Cohen et al., 2004). Despite the critiques, even in extensive research on the approaches in the literature on agile software development (discarding articles or gray literature of practitioner's success stories), the majority of peer-reviewed papers and other empirical studies demonstrate the benefits of adopting agile. These range from positive attributes of easy adoption, as well as improvement of teamwork and outputs by its focus on human and social factors (Dybå & Dingsøyr, 2008), to the possibility of being a more inclusive framework in terms of gender balance for those values in software development (Judy, 2012).

2.4.2 Two main agile practices: Scrum and Lean-Kanban

For the purpose of this study, among the different variations and practices related to agile, I will describe the two most adopted ones: Scrum and Lean-Kanban (VersionOne, 2018), both agile processes of software co-creation based on incremental development and feedback loops (Cocco et al., 2011). Other relevant agile frameworks for software development are Extreme Programming (based on similar principles, but using an operative approach to software development in pairs, as well as test driven iterations) or Crystal Clear (similar to Extreme Programming, but less disciplined and much more tolerant in comparison), which are usually considered agile but with much less levels of adoption and not tailored to other domains of product or project management (West et al., 2010).

Scrum is a sequence defined by iterative steps (Figure 8), which in some rigorous, exhaustive and detailed interpretations of the framework can incorporate additional materials, phases or interaction in search of more efficiency (Marcal et al., 2007). These steps are usually followed in this order:

1. All participants (development team, the “Product Owner” and the “Scrum Master”) meet for a first high-level vision of the product or system to be developed.
2. A “Product Backlog” (usually a column of post-its) is co-created containing a list of known requirements.
3. Items of the Product Backlog are prioritized and divided into small time-boxed iterations called “sprints”. This is done mainly from the perspective of the Product Owner (main role in touch with the customer’s or stakeholder’s needs) and with coordination help from the Scrum Master (as main process facilitator).
4. Every task in scrum is carried out through development sprints (a 20/30-day average period of work time). Each sprint is initiated with a sprint planning meeting, where the Product Owner and the rest of the team get together to collaborate about what will be done.
5. After deciding what has to be done in the next sprint, the team develops the “Sprint Backlog”, a list of tasks that must be performed to deliver a completed increment of potentially shippable product functionality, by the end of the sprint. During the execution of each sprint, the team meets daily in short meetings to track work progress and solve blocked tasks, if necessary (this is called daily “standup”).
6. At the end of each sprint, a review meeting called “retrospective” is held, at which the team presents what was developed during the sprint to the Product Owner and to any stakeholders who wish to attend.
7. After the sprint review, and prior to the next sprint planning meeting, the Scrum Master also holds a sprint retrospective meeting, in order to encourage the team to revise its development process to make it more effective and enjoyable for the next iteration.

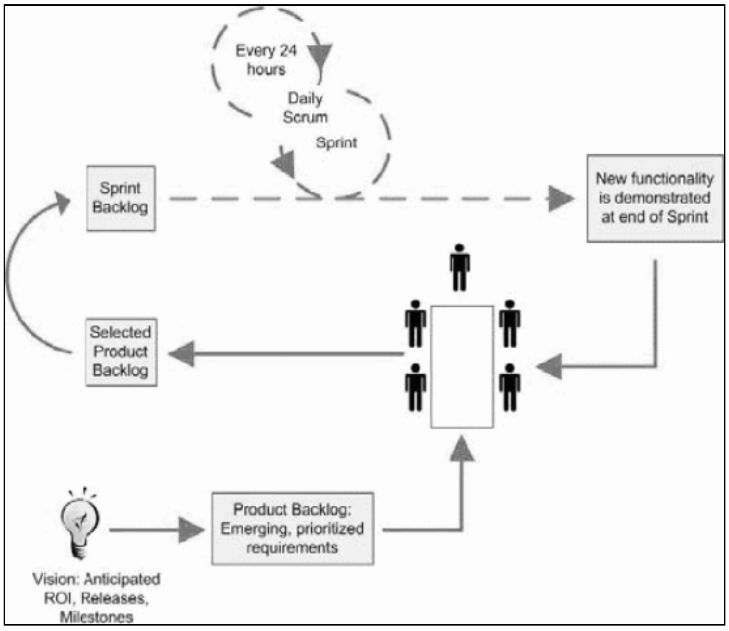


Figure 8: Diagram showing the basic workflow of scrum (Schwaber, 2004).

The inspiration and first reference to the term “scrum” appeared in an influential article that Nonaka and Takeuchi wrote in the 80’s, “The New New Product Development

Game" (Takeuchi & Nonaka, 1986), where a holistic approach to flexible, autonomous and dynamic teamwork was defined with six main characteristics: "built-in instability, self-organizing project teams, overlapping development phases, 'multilearning', subtle control, and organizational transfer of learning". Nonaka's concepts are also fundamentally connected to lean product manufacturing, the other field of methodological and managerial framework related to agile (Lindlöf et al., 2012), that stresses as well the importance of cyclical knowledge sharing and of focusing on value, in this case minimizing waste (Krafcik, 1988).

Lean software development, on the other hand, can be described as a translation to the software development domain of lean manufacturing (Shah & Ward, 2003). Lean manufacturing had its core principles popularised by Toyota workers on the production department, making decisions and solving problems autonomously, building trust with suppliers, and supporting a "culture of continuous improvement of both process and products" (Cohen et al., 2004). As first described by Mary Poppendieck and Tom Poppendieck in 2003, lean in the context of software development emphasizes improving the value given to the customer, eliminating waste and considering the project as a whole, based on the following principles (Poppendieck & Poppendieck, 2003):

- Amplify learning
- Decide as late as possible
- Deliver as fast as possible
- Empower the team
- Build integrity in
- See the whole

Rather than going deeper into the similarities or differences between scrum and Lean-Kanban, is important to consider here that for the practical and daily implementation of both agile frameworks, one of the main needs is to also adopt a "Kanban" board (Anderson et al., 2012). Kanban is a Japanese word that translated literally means *visual* (Kan) and *board* (Ban), hence adopting Kanban means to break the overall work into task items, writing their description on sticky notes or virtual online cards, and placing them on a shared board (usually with different columns to reflect the process), so workflows are visible to all members of the team. The Kanban board provides a high visibility to the agile process, because it shows the assignment of work to the team, communicates priorities and highlights bottlenecks, helping to keep efforts optimized (Cocco et al., 2011).

In the same way as with co-design principles, this key aspect of shared visibility and dynamism in the coordination of teamwork, both in scrum and lean-kanban, which is focused on doable and transparent tasks, is one of the basic elements of agile adoption in other collaborative organizations and teams (West et al., 2010), especially when adapted outside software development organisations.

2.4.3 Applicability of agile outside software development

Various pieces of evidence and empirical research point to the adoption of agile methods outside the field of software development, in seek of more effective project management in organizations (Ciric et al., 2018; Wysocki, 2011; Cao et al., 2009). There's no more specific or clear definition, nor manifiesto as such of the agile principles translated to other type of processes or organisations (Conboy & Fitzgerald, 2004), and in some cases it is presented more as an organisational "mindset" with vague indications for implementation in standardised ways (Denning, 2016). However, different studies have concluded that agile management practices are expanding to other domains at a considerable rate. A large survey in 2014 to companies in different sectors (PMI, 2015) pointed to 38% of frequent use of agile in project management activities, 8 points above results compared to the previous year, and with indicators showing a growth revenue 37% faster than competitors with other management practices. Another confirmation of agile adoption in management practices beyond software was made by the findings of a Learning Consortium study, comprising leading companies in banking, telecommunications and videogames, which found that several large-size corporations are implementing agile goals, principles, values and practices at scale (Denning et al., 2015).

According to specific case studies, the implementations of agile management has been analysed in educational projects (Salleh et al., 2010), construction projects (Georgy, 2016), venture capital groups (Sutherland & Altman, 2009), mining and metallurgical industry (Conforto et al., 2014) or banks (Niclasen & Stoklund, 2016). As in the case of software development, usually adoption needs to be tailored and addressed only to some teams or parts of the organisation(Campanelli & Parreiras, 2015). Ideally with complicity from the direction and top-management positions (Kuusinen et al., 2016), with most success cases based on the spirit of starting small before trying to expand to other areas of the organisation (Rigby et al., 2016). Another key aspect seems in these cases to establish effective coaching and training support prior to the implementation of agile, with the critical aspect of facilitation as a requisite for the appropriate propagation of the frameworks outside software development teams (Senapathi & Srinivasan, 2012).

In addition, with some authors pointing to the evidence that agile methods can lead to a more agile organizational culture (Küpper, 2016), there have been some recent studies describing how agile project management has been adopted in academic settings for research-related processes: experiences adapting scrum for academia-industry collaboration (Sandberg & Crnkovic, 2017; Santos et al., 2016; Ota, 2010); using agile practices to bridge the gap between research and practice in the management of case studies (Barroca, Sharp, Salah, Taylor, & Gregory, 2016) or to enable collaboration when working with and mentoring PhD students (Hicks & Foster, 2010). Also to develop prototypes in "Action Design" research projects (Keijzer-Broers & de Reuver, 2016); to coordinate a large-scale European research project with distributed teams (Marchesi, Mannaro, Uras, & Locci, 2007); to manage a research and development laboratory (Lima, de Castro Freire, & Costa, 2012); for experimental ethnography approaches in the workplace (Mara, Potts, & Bartocci, 2013); for evidence-based projects

for behavioural interventions (Hekler et al., 2016); and for adapting lean principles in the biopharmaceutical sector (DeWit, 2011) or in human-centred research practices (Armstrong et al., 2015).

2.5 Main contributions to the state of the art

As I initially described regarding transversal concepts in the fields of transdisciplinarity, co-design and agile management (in section 1.2.1), a relevant contribution of this part of the thesis has to do with a novel analytic framework connecting key co-creation factors to collaboration practices (Table 3) at: (1) the conceptual level (factors of visualization, communication, transparency); (2) the organizational level, of key aspects made possible from the previous ones (trust building, task distribution, engagement), and finally; (3) aspects related to outputs of the process and its results (efficiency and quality). This represents a theoretical contribution that can be useful for further investigations about co-creation and collaboration in research, approaching issues beyond diversity and complexity, as it is based on this extensive cross-disciplinary literature review and state of the art, in parallel to the case studies and data gathering phases of this project.

Key concepts	**Transdisciplinarity and collaborative research**	**Participatory design**	**Agile project management**
CONCEPTUAL LEVEL	Visualisation		
	Communication		
	Transparency		
ORGANIZATIONAL LEVEL	Trust building		
	Task distribution		
	Engagement		
OUTPUTS LEVEL	Efficiency		
	Quality		

Table 3: Summary of key factors for analysing co-creation in transdisciplinary research.

Additionally, when analysing the context and foundations of co-creation in this part of the dissertation, the development of the review and state of the art has also led to a series of considerations that seem relatively unexplored across academic literature. With a focus on challenges in transdisciplinary research and the key areas of participatory design and agile project management, they relate, on the one hand, to the extent to which co-design and agile have a in different ways a wider connection in values and practices. On the other hand, my contribution at the theoretical level has to

do with the consideration of action research as a clear precedent of the main concepts of agile project management[4].

2.5.1 Co-design influence in the concepts of agile

The characteristic of promoting effectively shared understanding and vision (Fischer, 2001) is probably one of the reasons why agile has been widely adopted, also from the perspective of its theoretical foundation in systems thinking (Mayer, 2013). Apart from the theoretical relationship I mentioned in the previous section between systems thinking and co-design, examples of agile frameworks like scrum connect clearly and fit naturally with the latter, for example in terms of incorporating early end-users' feedback and requirements focusing on them (Benefield, 2008). Serving as a guiding principle for IT development, agile has been widely applied in combination with participatory design in software production (Nerur & Balijepally, 2007), but also both as combinable co-creation practices in other knowledge-intensive contexts like policy innovation (Williamson, 2015; Kimbell & Macdonald, 2015) or business innovation (Novais & Konomi, 2016).

User-centered feedback characterises both agile frameworks and participatory design, following trends in more humanised and participatory design methodologies, such as those that promote user experience (UX) as a key perspective, a transversal method borrowed from the domain of behavioural science (Di Russo, 2016). In this respect, is also possible to track agile's theoretical foundation to the intellectual roots of participatory design and prototyping, as seen in this section about collaborative research practices, as in the context of software design for teamwork (Blomberg et al., 1996).

The focus on team collective intelligence of agile practices usually requires facilitation roles as well (the same as described for co-design processes), to continually improve teamwork and motivation by clarifying who's doing what, helping with conflict resolution techniques, and ensuring that team members contribute equally (Rigby et al., 2016). This facilitator, who can be an experienced colleague but is more usually a professional (like in the case of the Scrum Master) works like the rest of the team around kanbans, which somehow are designed artifacts where the flow of interactions and discussions of the group get reflected. These "agile artifacts" have the double function of anotational elements and enablers of social perspective over tasks (Sharp et al., 2009), which again represents a dynamic clearly matching with design thinking principles.

2.5.2 Relation of agile principles with action research

Considering agile from the perspective of the tradition of action research, there seems to be a clear connection with early studies on autonomous teamwork in small group dynamics (Trist & Bamforth, 1951). This is particularly evident from the perspective of sociotechnical systems (Emery & Trist, 1965), characterised by positive interdependence and co-operative developments, as they were already observed in some self-managed

[4] Apart from summarising these relationships here, the topic will be more widely discussed in the research discussion of the dissertation (specially in section 8.3).

teams immediately after the Second World War (Rothwell et al., 2009). Furthermore, these corpus of theories about self-management and organizational change were influenced by the systemic study of the workplace at that time by Kurt Lewin, whose ideas informed the socio-technical school of work design (Reason & Bradbury, 2001).

It seems more than a coincidence then (in terms of individual values, objectives and capacities, as key aspects of continuous improvement of people's conditions in social contexts), that Lewin's theories and practice at the foundations of action research, are also connected with the key agile principle of workers' collaborative participation in choosing options and evaluating results (Bargal, 2006). Quoting the author, when he defines the systems model on action research as an empirical and logical problem-solving process, involving cycles of action and reflection: "a spiral of steps, each of which is composed of a circle of planning, action and fact-finding about the result of the action" (Lewin, 1946), one can find here also the basics of feedback loops and shared workflow of agile methods like scrum. More resonances of agile can be identified in the work from one of the disciples of Lewin, Eric Trist, who influenced the discipline from his approach to organisational change when studying self-managing teams of miners (Trist & Bamforth, 1951). In that early context, workers informally created systems that allowed them to be multi-skilled and self-directing, rather dependent upon external leadership, adjusting to circumstances as they evolved for improving their daily work (Ashby, 1960).

If organisational development is viewed as a flexible spiral process that can implement change through organisational learning (Salehi & Yaghtin, 2015), and agile teams to some extent as the basic units of "socio-technical teams" defined in literature about action research (Reason & Bradbury, 2001), the other clear connection in this sense is once again the influential work of Schön. Within the established framework of basic principles of reflection in action (Schön, 1986), in order to surface complexity and unblock people's potential for "doing and thinking are complementary. Doing extends thinking in the tests, moves, and probes of experimental action, and reflection feeds on doing and its results. Each feeds the other, and each sets boundaries for the other" (Schön, 1983).

Those theoretical connections between action research and agile project management, based on the contrasting of different areas of knowledge, coincides with only a few studies with a relatively similar approach. Among them, how agile can be understood as organizational learning, based on the "double loop learning" process as defined by Schön and Argyris (McAvoy & Butler, 2009; McAvoy, 2015), and how lean thinking can be a vehicle for organizational learning as well, with similar feedback characteristics and self-adaptivity principles as those postulated by action research (Salehi & Yaghtin, 2015).

SECOND PART: COMPENDIUM OF PUBLICATIONS

3. Introduction to the publications

The six articles of this study, published in academic peer-reviewed scientific journals and conference proceedings between 2017 and 2019, are structured in three differentiated subsections. This division covers not only the rationale of structuring the different co-creation approaches according to separate and integrated analyses, but also reflect chronologically the order in which they were written and submitted for review. The relation of each publication with the case studies, research questions and methodology adopted can be found in Table 2 (page 29), in the first part of this compendium.

3.1 Main sections of the compendium

The first section of articles of this compendium, in Chapter 4, is related to the adoption of participatory design techniques and principles in collaborative research, and it comprises two papers. Drawing on the specific context and case study of co-created citizen science, the two articles establish the connection between principles and challenges in this type of transdisciplinary approach. This is possible thanks to several pieces of evidence and impressions collected over a one-year process of dialogue with a team of scientists in a European funded project which required new science and research projects to connect with wider audiences, social concerns and the collective construction of research questions.

The second section, about agile project management for research, focuses in Chapter 5 on the specific adoption of agile principles and methodological frameworks for the day-to-day coordination and communication of two different research initiatives. On the one hand, there is a project-oriented case in the context of the Dimmons research group, where such adoption was implemented for a short-term process of different authors contributing to a collective state of the art on the Sharing Economy. The fourth article, on the other hand, analyses a similar adoption experience in terms of agile principles and tools, but in this case for a wider, long-term initiative of collaborative research among CECAN members distributed in a wide research network in the UK.

Finally, the third section in Chapter 6 comprises two papers that reflect specific analyses about the integration of participatory design and agile project management in transdisciplinary projects. The first paper of this subsection establishes the connection between similar co-creation techniques in the field of digital culture, summarising observations from a wide palette of experiences through the different case studies. The second article of that section, and the last one of the compendium, focuses on the adoption of both co-design and agile project management for the strategic planning and day-to-day coordination of the Dimmons research group.

3.1 Summary of publications

The first publication of the compendium, "Developing A Research Co-design Toolkit", describes the elaboration and adoption of one of the main practical outputs of this project, which consists of a series of copyleft materials for facilitators of collaborative research processes. In this case, the early opportunity to apply some of the guiding principles of participatory design in a series of citizen science experiments with OpenSystems Barcelona (http://www.ub.edu/opensystems/), in the context of the STEM4youth project, allowed for the contrasting and discussing of how to engage in a transdisciplinary dialogue with groups of students in three different secondary schools. The main goal was to define together (scientists and students) the best approach for experiments about human behaviour, connected to areas of interest and research questions co-defined between all participants, as well as the details of the process in relation to methodologies, setting, communication, etc. Presented and published in 2017 in the proceedings of the prestigious *REDO Cumulus Conference* (http://cumuluskolding2017.org/), this publication represented an initial opportunity to recognise the value of my research under development in the context of the design community, at an international level. Eminently descriptive in its structure, with several visual references to the early materials developed and its use, the paper also sets the connection between the needs of collaborative work in the field of citizen science and the broad context of design thinking.

The second article, "Participatory Design of Citizen Science Experiments", elaborates further and systematizes the case study results from the approach described in the previous publication. In this case, published in the special number "Shared science and knowledge" of the *Comunicar* journal (https://www.revistacomunicar.com/), based on a wide survey and semi-structured interviews, the article reflects in detail how co-design can contribute to more collaborative science. From the adaptation of specific materials and co-creation methodologies to key facilitation mechanisms for promoting trust, creativity and transparency, the analysis represents an innovative approach, in this case, to literature in the area of communication and participation for new models of scientific activity.

The third paper, "Management of A Multidisciplinary Research Project: A Case Study on Adopting Agile Methods", focuses on the adoption of agile principles and tools for the coordination of teamwork of a cross-disciplinary initiative. In this case, a small team of researchers from different fields and with different levels of academic expertise, integrated in the Dimmons research group, jointly developed a state of the art about the Sharing Economy in the context of the EU funded DECODE project. Based on a survey and participant observation, as well as a wide literature review, this study published in the *Journal of Research Practise* (http://jrp.icaap.org/) contributes to the field of team science and meta-research with specific insights and recommendations about the topic. It also allowed for establishing a novel framework of key factors connecting agile methods and current challenges in collaborative research.

Following a similar process, but in a very different context from the previous case, the fourth publication of the compendium, "Adapting the Scrum Framework for Agile Project Management in Science: Case Study of a Distributed Research Initiative", articulates its analysis by a series of interviews and observations in the context of the CECAN research initiative, which comprises a network of more than 50 members composed of social scientists, policymakers, policy analysts and experts from different academic and government institutions in the UK. In this case, the study focuses on a specific agile framework (scrum) and the extent to which it is adopted and used in a context where researchers and other participants are not collocated, and different communication and coordination mechanisms take place in relation to research and evaluation of public policies related to complexity and environmental issues. This article, published in the social sciences section of the *Heliyon* open access journal (https://www.heliyon.com/), addresses important issues about this type of co-creation methods in research management. Issues range from the initial conditions of a given initiative for such adoption, to the specific features of the scrum framework in comparison to other agile principles, as well as challenges for this type of project management approaches in distributed research settings.

The fifth article, "Dotmocracy and Planning Poker for Uncertainty Management in Collaborative Research: Two Examples of Co-creation Techniques Derived from Digital Culture", addresses two specific co-creation techniques (one from the field of co-design, the other from agile project management) in order to analyse its commonalities when adopted in the context of transdisciplinary projects. Published in the proceedings of the 2018 *International Conference on Technological Ecosystems for Enhancing Multiculturality* (https://2018.teemconference.eu/) in the ACM Digital Library of the Association for Computing Machinery, this publication represents an opportunity to understand such similarities and shared values, from the perspective of digital culture studies and digital humanities. Based on the analysis of methods and results from several workshops, with the participation of communities of practice and research teams from diverse backgrounds, the study establishes a detailed list of specific uses of these co-creation techniques for the planning phase of research processes, and its importance for addressing uncertainty and complexity issues.

Finally, the sixth and last publication, "Co-created Strategic Planning in Academia: Case Study of Participatory Design in An Action Research Group", approaches the combined adoption of co-design and agile methods in the specific case study of the Dimmons research group. After a three-year period of experimenting with co-creation (not only as a methodological base for the team's research activity, but also for the day-to-day coordination of the group), the study analyses the development of a co-created strategic planning for research, its connection with participatory design techniques during its development, and how it embeds agile management routines and tools for its application and assessment. While the previous paper emphasizes specific techniques and applies participant observation, in this final case the scope is much wider. Using different sources and data, it seeks to reflect how co-creation not only represents an important opportunity for transdisciplinary research management, but also for the novel and complex issue of strategic planning in science.

4. Participatory design for research

4.1 Developing a research co-design toolkit[5]

This paper describes the adoption of design thinking for the co-creation of citizen science experiments. The project, which is currently gathering additional data from surveys and interviews after period of participant observation, is based on the collaboration of a scientific team and the researcher (as a co-creation facilitator) with different groups of secondary students, from three schools in different socio-demographic contexts around Barcelona. Based on the first version of a 'Collaborative Research Toolkit', participants developed through a series of sessions and iterations preliminary designs of experiments about human behaviour, moving from the initial identification of shared concerns to several prototype versions of research sequences and methods. Specific steps of the co-creation process involved discussions about social impact, feasibility and motivation around local issues, collaboratively defined research questions, and logistics needed for the management and production tasks behind each experiment realization.

1. Introduction

Citizen science involves the public or "amateurs" (Gura, 2013) in distributed and usually empiric scientific projects, to address real-world problems with the primary task, usually, of collecting scientific data (Cohn, 2008). A majority of citizen science projects consist of digital ICT infrastructures (Prestopnik & Crowston, 2012), where geographically dispersed participants can coordinate and centralise tasks of data harvesting (Wiggins, 2010). Although as a collaborative type of organizational and work design, based on volunteering rather than science as a profession, is not new to science (Silvertown, 2009), the concept of citizen science in recent times has grown in academic literature (Dobreva & Azzopardi, 2014). There is a growing number of cases where a more participative type of collaboration in research activities leads to common knowledge and community awareness (Cooper et al., 2007), or where non-expert participants develop new questions aided by data visualization and this way scientists identify non-expected challenges (Goodchild, 2007). However, still the most habitual forms of citizen science are considered only "contribution systems" (Wiggins & Crowston, 2014).

Different literature about this issue point to the need to generate citizen science projects according to deliberate and co-created research designs, that pay attention to diverse interests in order to achieve both social and scientific objectives (Bonney et al., 2014). For example when defining search questions, these can be formed in a top-down

[5] Senabre Hidalgo, E. (2017). Developing a research co-design toolkit. In *Proceedings of the REDO Cumulus conference*. http://cumuluskolding2017.org/proceedings/

approach (scientific-driven) but also in a more bottom-up way, as a community-driven process (Newman et al., 2012). In this respect, in order to advance to more collaborative modalities of citizen science, authors like Bonney et al (2009) suggest the importance of involving participants in the research design process in more deliverative and facilitated ways. Something that relates to the experience described in this paper and the relevance of determining collaboratively clear and project-specific goals, identifying through iterative periods of design different outcomes, tools and features of the research (Dickinson et al., 2012).

Evolved in its latter practices to different sub-fields, which denote design thinking as a "transitive paradigm" that differs depending on the context where it is applied (Di Russo, 2016), during the last decade there has been an increase of approaches and practices where co-design methods have been adopted by academia and industry (Sanders & Stappers, 2014). Authors like Manzini and Coad (2015) consider design thinking an open-ended culture and a practice or path of co-creation, with the main characteristic of involving all actors in the process, but with the key role of the design expert as facilitator. For Kimbell (2011) design in this context is seen as an exploratory cycle for new kinds of value creation between diverse participants, a process of "constructivist enquiry". The evolution of design thinking disciplines tends to be usually more prolific in researchers and designers producing facilitation materials and receipts, guiding participants through a collaborative creativity process of different scales (Sanders, 2006).

2. Description of the co-design process

Under the umbrella of a European project for engaging teenagers with science and technology (http://www.stem4youth.eu/the-project/), as one specific action program related to citizen science, the researcher and a scientific team at the University of Barcelona (http://www.ub.edu/opensystems/) organised a series of co-design sessions with three diverse groups of students from different Secondary Schools (totalling more than 100 participants). One of the basic premises of the process was to start in the same way in all cases: rather than only involving students in the data gathering process of an experiment about human behaviour (like in previous editions), to work with them in the earlier phase of defining together the goals, issues and methods related to the experiment, following the "co-created" approach (Bonney et al., 2009). In the early times of participatory design, the researcher served as a translator between the users and the designer (Sanders & Stappers, 2008). In co-design, as the most participative approach derived from design thinking, the designer (who may be a researcher, or a professional of design) takes on the role of a facilitator.

The project followed the same approach, structuring the process with a predefined sequence or logic, creating the first version of a Collaborative Research Toolkit (figure 1) and a series of steps for each session, where the researcher as a facilitator (with help from a representative from the scientific team, explaining concepts and theoretical aspects when needed) could guide participants through all the co-design process. This way, via four specific workshops with each of the groups, the dynamics moved from (1) shared issues of concern, then (2) derived research questions, followed by (3)

prototyping the experiment process in a visual way, and finally (4) eliciting and reflecting the type of tasks and logistics associated to it.

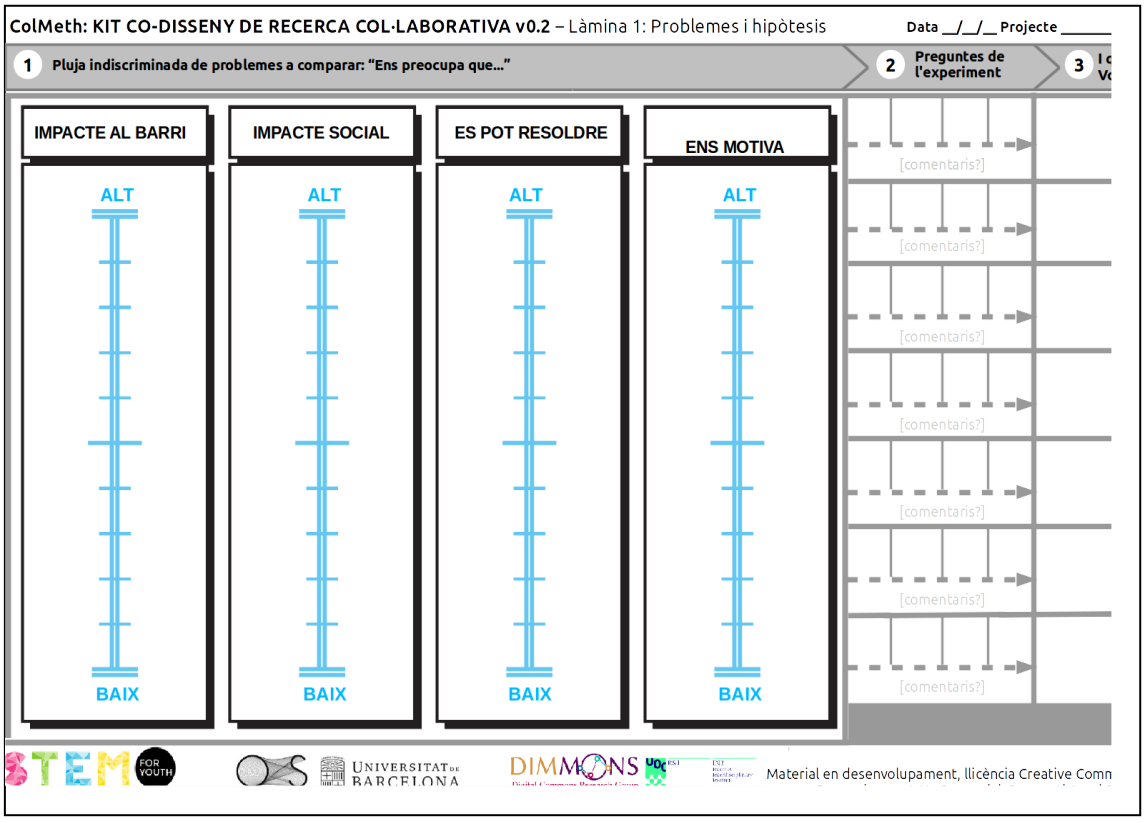


Figure 1: First page of the Collaborative Research Toolkit (in Catalan).

At each of the four stages of the co-design process for the experiments there was a divergence and convergence phase (Brown & Katz, 2011) for generating ideas collaboratively and then selecting together the best options. During all the process, facilitators served as connectors of concepts and active listeners, trying to operate "in the subtle link existing between action research and collaborative design" (Swann, 2002) and adopting informal ways of eliciting and presenting visual information (Kensing & Blomberg, 1998), in this case for starting with the students choosing whatever concern or problem they wanted to address with an experiment about human behaviour. This formed the first phase of the process, where there was a session when they could brainstorm about the types of issues at the local level where an experiment about human behaviour could help to generate evidence, taking into account indicators like "feasibility", "social impact" or "motivation", which were reflected on specific thermometers on a wall (figure 2).

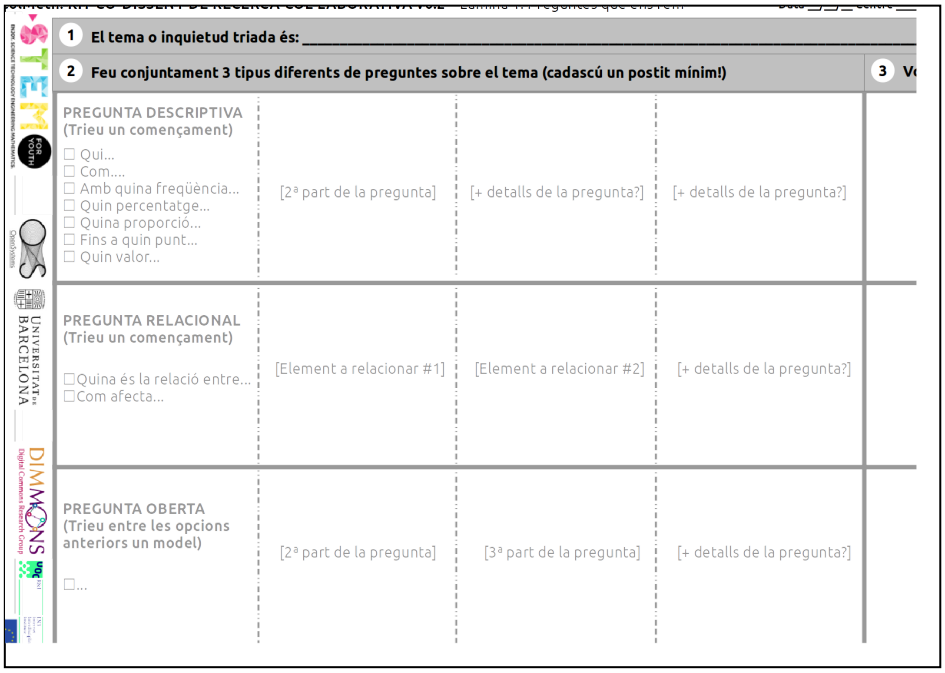
Figure 2: Discussion based on indicators for each research issue identified.

Although that first phase needed only as artifacts different figures of thermometers and proper post-its, for the next sequences we developed and tested a specific "Collaborative Research toolkit" as a structured and visual canvas (Nagle & Sammon, 2016), having also in mind the parallel component of learning as an important part of the co-design (Dubberly & Evenson, 2011), in this case in relation to the scientific method and notions about "doing an experiment". In front of the challenge of "leading, guiding, and providing scaffolds, as well as clean slates to encourage people at all levels of creativity" (Sanders & Stappers, 2008), the conceptual validation of a toolkit was also a specific co-creation experience and dialogue between the scientific team and the co-design facilitator.

That key material went under a series of preliminary versions and discussions, trying to find a balance between usability and rigour, in order to create a co-design toolkit useful for a research purpose. In those preliminary discussions, before the sessions with students (although refining the toolkit took place later on in other different key moments of the process, adapting to the evolution of each group and session goals), the main aim was to reach a real level of deep collaboration and mutual influence between research "experts" and research "amateurs", and not only some sort of excuse for light levels of participation. Quoting Swann (2002) about the practice of design in collaborative research: "authentic collaboration in research is more than just a multi-disciplinary design team approach. The users of design should be genuine 'collaborators', and not merely co-opted for token comments in an illusion of collaboration". For this, in all moments the facilitation team stressed the importance and relevance of each decision or discussion generated by students, on the toolkit or outside it, during debates.

For the second stage of co-creating specific research questions, each sub-group used a canvas where to place post-its, in order to cooperatively articulate at least three sentences following the same structure (as seen in the example of figure 3 and 4). Starting with predefined syntagms ("What if..."; "What is the relation between...";

"How..."), these empty structures contained in a modular way different options for a quantitative research question: descriptive, comparative and relationship (Onwuegbuzie & Leech, 2006). Again, a selection and assessment moment based on discussion and visually selecting the best options, allowed for filtering the more relevant research questions for the whole group (connected to the topic or issue already selected in the previous session).



1 El tema o inquietud triada és: _____

2 Feu conjuntament 3 tipus diferents de preguntes sobre el tema (cadascú un postit mínim!) | 3 V

PREGUNTA DESCRIPTIVA (Trieu un començament) ☐ Qui... ☐ Com.... ☐ Amb quina freqüència... ☐ Quin percentatge... ☐ Quina proporció... ☐ Fins a quin punt... ☐ Quin valor...	[2ª part de la pregunta]	[+ detalls de la pregunta?]	[+ detalls de la pregunta?]	
PREGUNTA RELACIONAL (Trieu un començament) ☐Quina és la relació entre... ☐Com afecta...	[Element a relacionar #1]	[Element a relacionar #2]	[+ detalls de la pregunta?]	
PREGUNTA OBERTA (Trieu entre les opcions anteriors un model) ☐...	[2ª part de la pregunta]	[3ª part de la pregunta]	[+ detalls de la pregunta?]	

Figure 3: Canvas for generating the research questions (in Catalan).

Figure 4: A sub-group of participants using the toolkit canvas for generating "modular" research questions.

The third phase of co-design of citizen science experiments allowed to connect the selected research questions from each group to a more explorative and creative moment, prototyping the sequence of the experiment itself. This was done considering the "big picture" of the research project as a flow of actions over a timeline, following the principle that research design usually should be detailed collectively early on in a project, in order to ensure the commitment and alignment of all partners (Barnes et al., 2006). For this, participants selected a series of icons from a large set of images that reflected key aspects around a possible experiment: research methods (surveys, observation, simulations, etc); experiment logistics (experiment protocols, dissemination, space needs, etc); previously mentioned key concepts or variables (trust, value, solidarity, among others); key people or participants (representing options of age, gender, profession, etc) and additional elements to visualize (depending on the theme and issues for the experiment, ranging from public space icons to other social or context related ones). These dense diagrams (see figure 5, 6, and 7) enabled once more to activate discussions and conversations about feasibility and motivation, in order to select one co-design for each of the three schools, among 4 or 5 "finalist" prototypes after the overall refinement.

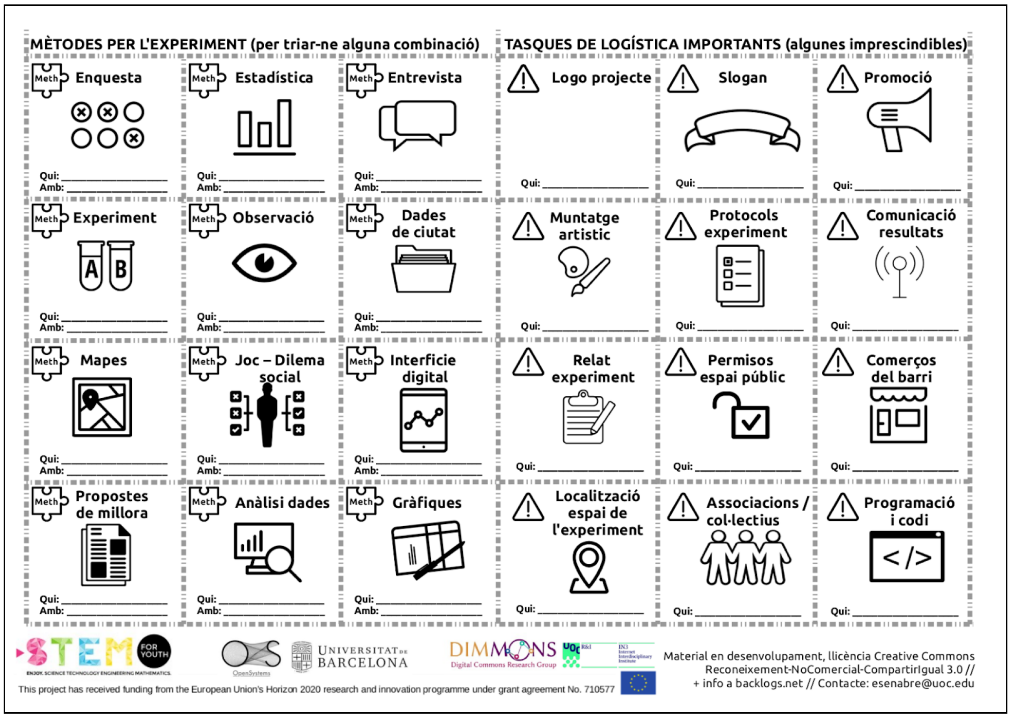


Figure 5: Some of the icons for creating the experiment prototype: research methods and research logistics (in Catalan).

Figure 6: Participants "collaging" the different icons for creating the prototype.

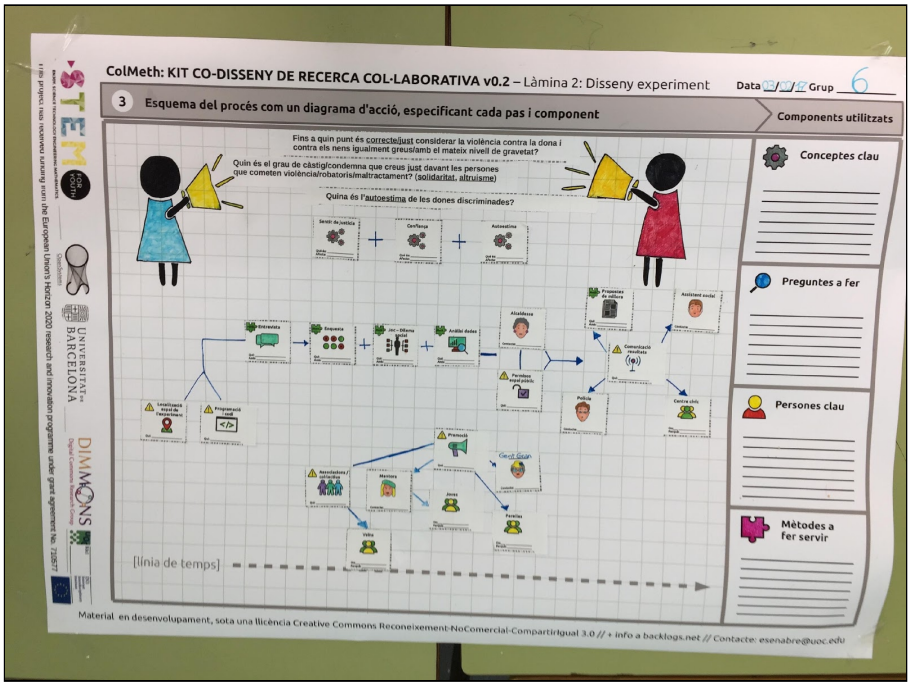


Figure 7: One of the resulting co-designs for an experiment.

For eliciting and discussing the main logistics and needed tasks to deploy each experiment, the fourth and final session of the co-design process involved again to create smaller sub-groups in each of the three classes, which at that stage had already very different approaches to the goals and sequence of the finally selected experiments (one related to perceptions about public space and infraestructures in the city, another one related to gender and violence in a specific neighbourhood and, finally, the third experiment concept focusing on equality and racial prejudices when enrolling kids at local schools). In each case, the session tried to move from the co-design paradigm to one of preliminary planning, based on the selected prototypes and the principles of agile management (Abbas et al., 2008). For this, the toolkit provided a surface divided in

different columns, as a sort of basic “kanban board”, making explicit tasks that otherwise would be ignored (Hines et al., 2004). Each column represented a category of tasks derived from the icons used in the selected prototype (figure 8 and 9): experiment logistics; communication and engagement; socio-demographic information; design of the experiment interface; data analysis; and dissemination of results. Participants, as a final stage of their research co-design, had to brainstorm and share with the rest of the group what they thought was needed at different levels in order to make the experiment possible.

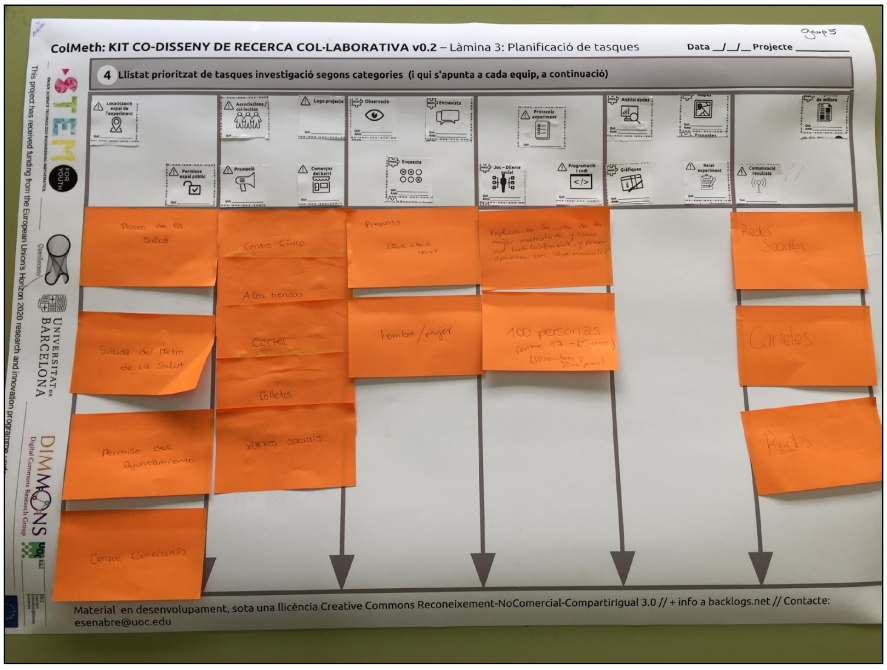


Figure 8: One of the toolkit canvas for brainstorming tasks and logistic needs behind the experiment production.

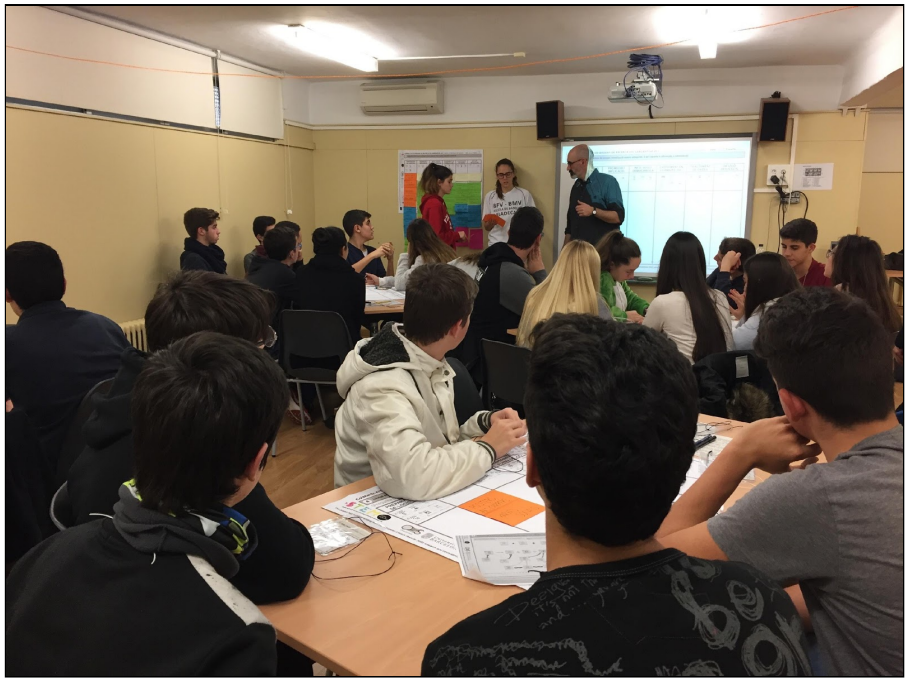


Figure 9: Discussing possible logistics of the selected experiment.

3. Preliminary conclusions

As a process that started with the "designerly" definition of problems, exploring with this citizen science experience how co-design and collaborative research can have a clear interconnection, it connects to further and broader considerations related to the co-design of research processes in other domains. Vom Brocke and Lippe (2015) point to an unconcluded paradox of managing collaborative research projects, in times when the vast majority of research is based on some degree and type of collaboration, which reflect clearly the opportunity and potential implementation of similar co-design approaches in other research contexts:

> "On the one hand, collaborative research fosters the integration of the research perceptions, ideas, and views that are needed in order to solve problems comprehensively. On the other hand, the resulting heterogeneity of partners leads to problems with respect to inter-cultural, inter-organisational, and inter-disciplinary management" (Vom Brocke & Lippe, 2015).

In relation to such paradox, the main question of this experience aligns with the hypotheses that design thinking (and more specifically co-design) can lead to fruitful combination of ideas and points of view from diverse participants in the design of a research (in this case a scientific experiment), setting the path for coordinated action afterwards.

In the moment of writing this, results are still partial and unconcluded, waiting for the different surveys and interviews to take place and being analysed, while the production phase and execution of the different experiments are just starting to take place. However, qualitative feedback and notes from participant observation so far, as well as evaluation meetings with the respective teams of teachers and scientific researchers in charge of the experiment, point to a high level of satisfaction with the predefined goals from different perspectives. Some of them can be summarised as:

- The scientific team engaged regularly in the elaboration and different versions of the toolkit, as well as in the co-facilitation, and based on their feedback all results from each session helped them to figure out the type of experiment and needs related to it.
- The scientific team also have an overall positive opinion about the level of engagement and insights from participants in defining progressively the issues, questions and methods to connect to each experiment.
- Teachers from each group observed a progressive implication and quality of results defined by their respective groups of students, and compared to the previous edition of the citizen science project (with other groups) more diverse types of learning implications (related to skills, cognitive tasks, self-assessment, meaningful participation, etc).
- Both teams have a high level of motivation to continue with the rest of the experiment phases, and also confidence in the practical and specific use of the outputs of this co-design phase.

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4.2 Participatory design of citizen science experiments[6]

This article describes and analyzes the collaborative design of a citizen science research project through co-creation. Three groups of secondary school students and a team of scientists conceived three experiments on human behavior and social capital in urban and public spaces. The study goal is to address how interdisciplinary work and attention to social concerns and needs, as well as the collective construction of research questions, can be integrated into scientific research. The 95 students participating in the project answered a survey to evaluate their perception about the dynamics and tools used in the co-creation process of each experiment, and the five scientists responded to a semi-structured interview. The results from the survey and interviews demonstrate how citizen science can achieve a "co-created" modality beyond the usual "contributory" paradigm, which usually only involves the public or amateurs in data collection stages. This type of more collaborative science was made possible by the adaptation of materials and facilitation mechanisms, as well as the promotion of key aspects in research such as trust, creativity and transparency. The results also point to the possibility of adopting similar co-design strategies in other contexts of scientific collaboration and collaborative knowledge generation.

1. The study goal and aim of the analysis

Citizen science represents a participatory research model that involves the public in scientific projects (Irwin, 1995; Hand, 2010; Gura, 2013), usually in data collection (Cohn, 2008) and, in some cases, in the collective interpretation of results (Delfanti, 2016). However in the last decade, citizen science has received greater attention and acknowledgement in the academic literature (Follet & Strezov, 2015) in its development mainly in the natural and experimental sciences (Ferran-Ferrer, 2015), and it has transformed investigative methods applied in these fields (Wylie & al., 2014).

The normal citizen science model considers collaboration between scientists and "amateur" participants as mere "contributory systems" (Wiggins & Crowston, 2015). Yet there are a growing number of cases involving greater collaboration on the part of the population at various stages of an investigation (Shirk & al., 2012; Delfanti, 2016), as also occurs in other collective knowledge-generation processes that adopt an open and innovative perspective (Yañez-Figueroa & al., 2016). Follet and Strezov (2015) define citizen science projects according to the type of voluntary participation:

[6] Senabre Hidalgo, E., Ferran-Ferrer, N. & Perelló, J. (2018) Participatory design of citizen science experiments. *Comunicar*, 54. https://doi.org/10.3916/C54-2018-03

- Contributory projects: participants take part in data gathering, analyze the data at certain points in the project and help disseminate the results.
- Collaborative projects: as well as the above, the participants analyze samples and, on occasions, help design the study, interpret data, draw conclusions or disseminate the results
- Co-created projects: the participants collaborate in all stages of the project, including the defining of the questions, development of hypotheses, discussion of results and responding to further questions that might arise.

Authors such as Bonney and others (2009a) point to the need to go beyond the contributory model of citizen science and involve the volunteer in the design process of the research in ways that are more deliberative and accessible. However, compared to the academic literature and resources generated around the contributory and collaborative modalities of citizen science, in the form of guides (Tweddle & al., 2012) or material for facilitation of this process (Bonney & al., 2009b), there is currently very little detailed information on the mechanisms used for the deliberate design of a co-created model of citizen science.

Apart from some pioneering experiences in techno-scientific participation, such as Public Lab (Wylie & al., 2014), or conceptual frameworks for public involvement in scientific research (Shirk & al., 2012) and methodologies based on logical models for citizen participation (W.K. Kellogg Foundation, 2004), as opposed to other co-created knowledge-generation settings (Manzini & Coad, 2015), there are few practical resources available for facilitating the co-designing of research processes, the exception being urban cartography experiences (Mindell & al., 2017).

This study analyzes how co-design can contribute to the idea that science can be made in collaboration with society. In our study, co-design is defined from an understanding of the co-created modality of citizen science as “participatory science” or “civic science” (Wylie & al., 2014), which encourages the appropriation of both the means that make it possible and the knowledge generated as a result of a collective investigation. This approach connects with methodological and pragmatic challenges to develop a “co-production framework” or “language of co-production” in research, following the formulations of Jasanoff (2004) and what she terms the “participatory turn” in scientific studies (2003).

With this in mind, this study analyzes the co-design process in three collective experiments of citizen science directed by a team of scientists with experience in co-facilitating and analysing similar experiments in the public space (Sagarra & al., 2016) using collaborative and contributory modalities (Perelló & al., 2017). The case study, whose sequence is described in detail in the third section of this article, is based on an important conceptual difference in design thinking between “co-creation” (the generic process of collective creativity) and “co-design” (a set of specific participatory design techniques), the latter being a specific feature within the broader co-creation setting (Sanders & Stappers, 2008).

Our analysis addresses the following research questions:

- Can co-creation contribute to a more collaborative form of citizen science?
- How can science integrate social needs and concerns in its design and communication dynamics?
- How can interdisciplinary work be coordinated to construct knowledge collaboratively?
- How has knowledge been developed in this citizen science co-creation experience?

2. Methodology of the study

The case under analysis forms part of the STEMForYouth (http://www.stem4youth.eu/) initiative, a European project of the Horizon 2020 programme that aims to encourage young people to study science and technology at university. Co-creation experiences were organized in order to design citizen science experiments with three groups of teenagers (95 in total) attending secondary schools in the Barcelona area (Spain) that covered a range of socio-demographic contexts.

To ensure that the research project was truly participatory and co-creative, the participants were involved at the start, from the design phase of the investigation. The co-design process of the experiments, based on a set of materials, or toolkit developed for the task, included collective agreement on the definition of the subject matter, the aims of the research and the research questions, and even the methods and logistics required to carry out the field work[7].

This article evaluates this co-created design phase of the investigation, for which a survey and interviews were used to address the research questions posed in the study. These two methods were chosen for the exploratory nature of our study in this relatively novel framework of citizen science, following the example of other advances in this field (Bela & al., 2016). The key aspects covered by the questionnaire and interviews derive from a review of the literature on citizen science (Shirk & al., 2012) and on co-design processes (Sanders & Stappers, 2008), as shown in Table 1.

Research questions	**Key related concepts**	**Citizen science (Shirk & al., 2012)**	**Co-design (Sanders & Stappers, 2008)**	**Survey question number**	**Discussed in interviews**
Can co-creation contribute to a more collaborative form of citizen science?	Motivation	X	X	Q11	X
	Generation of options (divergence)		X	Q8	X
	Quality of results	X		Q5	X
How can science integrate social needs and concerns in its design and communication dynamics?	Involvement	X		Q1	X
	Trust and credibility	X		Q6	X

[7] It is important to underline that the analysis centers on the initial phase of the co-creation of these citizen science experiments, before the following phases of organization and subsequent execution of each of the experiments, which also count on direct student involvement.

How can interdisciplinary work be coordinated to construct knowledge collaboratively?	Coherent sequencing	X	X	Q7	X
	Facilitation roles		X	Q4	X
How has knowledge been developed in this citizen science co-creation experience?	Quality of participation	X		Q10	X
	Decision taking (convergence)		X	Q9	X
	Power relations	X		Q3	X

Table 1: Research questions and key concepts in citizen science and co-design

2.1 Survey to participant students

Following the co-design sessions for each of the three citizen science projects, an anonymous online questionnaire was sent to all the students who took part (a universe of 97 individuals aged 13 to 17 with an equal gender mix, of whom 79 responded to all the questions (81.4%).

2.2 Interviews with the team of scientists

Five semi-structured interviews were carried out with all the members of the research team, to support the survey data with an analysis of their perceptions of the interaction that took place during the co-design process. A content analysis of the interviews was made based on the categories presented in Table 1.

The researchers interviewed were: MC, the main researcher, male, aged 42; RS, researcher and project manager, female, 41; AC, a teaching researcher, female, 27; AF, teaching researcher, male, 24; CP, researcher and project designer, female, 32

Codification was done by two other researchers, one who had conducted the interviews (in this case, also acting as facilitator of the co-design sessions), and another who had not participated in the interviews or in the co-design process. Later, each category was tested for reliability to check the level of agreement between the two codifiers. In this study, the overall reliability (0.86) was higher than the indices recommended by Krippendorff (1990), and greater than the 0.80 (alpha) that enables solid and fundamental conclusions to be drawn beyond mere speculation.

3. Description of the co-design process

A “design thinking” dynamic was used to achieve a co-created research design, in which interaction sequences between the different groups of participants were developed. The only premise for initiating the sessions was to describe a previous example of a citizen science experiment in a public space, as well as to focus the new experiment on an aspect of human behavior.

A series of sessions took place in the three secondary school settings, with some slight variations and adaptations between each, which dealt with the co-designing for each experiment in four stages: (a) the problem to be addressed, (b) research questions, (c) conceptual diagram and (d) planning the tasks for executing the experiment (see Table 2). There were 12 sessions in total, each lasting between one and two hours.

A toolkit was developed for use in the majority of the knowledge-generation dynamics. This key material[8] was tested in preliminary versions and in discussions during its use by the research team, in order to get a balance between usability and rigour, with the aim of producing a useful co-design toolkit for the collective generation of knowledge within a citizen science framework.

During the four stages, the use of the toolkit was guided by the research team acting as co-facilitators, to connect concepts and clarify doubts, while a main facilitator provided a framework for the work in order to achieve some informal yet specific ways to generate and present visual information, in accordance with participatory design practices (Kensing & Blomberg, 1998).

The aim in each session was to perform a divergence and convergence sequence (Brown & Katz, 2011). That is, to generate ideas and possibilities in a participatory way (a sequence of divergence: normally done by forming sub-groups) and a later coming-together to select options (convergence sequence): through idea-sharing and decision-taking mechanisms.

- Stage A: Identifying the collective problem to be addressed. Initially, to stimulate the use of a range of skills within each working subgroup (formed of 6-8 participants) it was proposed that the students select a badge to identify a role they wished to adopt from a set of investigator roles and profiles. Later, the students were invited to brainstorm types of problems for which an experiment on human behavior could generate evidence requiring actions to be taken for the improvement of a neighbourhood or city. The parameters used to reach a consensus within each group-class were concepts like the “viability” of the experiment, the “social impact” of the results or the “motivation” necessary to carry it out. Students’ opinions were posted on the walls and compared using thermometers.
- Stage B: Generation of research questions. For the co-creation of specific research questions, each subgroup used a template on which they could stick Post-its enabling them to complete at least three questions that started: What would happen if...? What is the relation between? How...?). In this cooperative way, they completed predefined syntagms which, in modular form, contained the different research question options: descriptive, comparative and relational (Onwuegbuzie & Leech, 2006). Later, a moment of convergence based on discussion and the visual selection of the best options helped to filter the most relevant research questions for the group as a whole.
- Stage C: Conceptual diagram of the experiment. The third co-design stage took the research questions selected by each group to a more exploratory and creative level, linking a sequence of concepts around the experiment like action flows through a chronogram. This dynamic followed the premise that the investigation should be designed collectively from its initial steps in order to ensure the commitment and alignment of all those involved (Barnes & al., 2006).

[8] The version of the toolkit used is available for consultation online or use by third parties, the intention being to promote the reproduction of the co-designing processes of experiments: https://goo.gl/xoU8vJ

The participants chose icons from a wide range of images that reflected the key aspects of a potential experiment: research methods; logistics; key concepts or variables; participants; and other elements to visualize. These "dense diagrams" reopened debate and conversation about viability and motivation, and helped in the selection of an experiment co-design from among the various "finalists".

- Stage D: Task planning and logistics. Based on the final selection of objectives and sequences (one related to perceptions of public space and infrastructure in the city, another to gender and discrimination, and a third experiment concept centered on inequality and immigration), each session aimed to move on from the co-design paradigm to preliminary planning. Here the participants dealt with the logistics and tasks required to execute each experiment, in this way ensuring scientific rigour by gathering data and obtaining relevant results for all the agents involved. In this instance, the toolkit provided a surface divided into columns like a basic "kanban" table, which made tasks that might have gone unnoticed both agile and explicit (Hines & al., 2004).

Each column focused on a category of tasks derived from the icons used in the prototype selected, in which the participants brainstormed ideas that they considered appropriate for an experiment (the performance of which, following the earlier participatory stages seen in Table 2, took place in various public spaces).

(Divergence sequence)	**>>**	**(Convergence sequence)**
Stage A: Definition of the problem to be addressed		
Presentation + Accreditation of the participants according to roles and aptitudes		
Brainstorming ideas on themes that concern participants on a local level	>>	Grouping, discussion and selection based on thermometers of concepts (social impact, viability, motivation)
Stage B: Generation of research questions		
Structured formulation of questions according to models: descriptive, comparative or relational	>>	Subgroups vote on questions to be selected, idea sharing and grouping of questions
Stage C: Conceptual diagram of the experiment		
Prototyped / chronogram of experiment steps: key concepts, timing and methods to be used	>>	Presentation by each group and discussion prior to individual voting
Stage D: Planning tasks and logistics		
Brainstorming ideas on tasks, logistics, dissemination and definition of the experiment	>>	Idea sharing and subsequent processing in order to perform the experiment
Later stages: Assigning tasks to each group > Production of digital tool and placing the experiment in its setting > Gathering the data > Results analysis > Dissemination and publication in academic outlets.		

Table 2: Co-design stages of the experiments

4. Results

We present the main results of the study based on the student survey and interviews with the team of scientists. These results link the research questions to the theoretical

fundamentals and key concepts of citizen science and co-design (Table 1) following the co-design sequence in the four stages previously described (Table 2).

4.1 Can co-creation contribute to a more collaborative form of citizen science?

The researchers were convinced that student participation in the design of the experiment was vital from the first moment. In the interviews, they criticized the role of the expert in citizen science (RS, MC) and expressed a desire "to make science truly participatory" (LD). They were initially concerned about whether the subject chosen by the participants would belong to a setting in which they, as researchers, were sufficiently experienced (RS).

Before beginning the co-design process, the researchers' intention to boost the participation of other actors in the design of the investigation had given rise to doubts: drawing up research questions in collaborative fashion (RS) could be a more complex process than letting the researchers do it themselves (RS, LD); the complexity of not knowing how a co-creation experience could evolve and end (LD); the casuistry of the schools and the populations, which could at times make managing the activity more complex (MC, LD). However, after various co-design stages had been completed, there was a consensus that the initial expectations had been more than satisfied (RS, CP, MC), and that motivation was considerably higher when the non-expert was involved from the beginning (AF, LD). The high level of motivation and commitment achieved through co-creation is also reflected in the responses of the 79 participants to the survey (Figure 1, question Q11), and clearly connects with the scientists' assessments, such as the "engagement of the citizens with citizen science projects is key for ensuring the success and sustainability of the projects" (RS).

The contribution to the research of the visual material in the co-design toolkit was also analyzed. The material was adapted to the needs of each phase of discussion (MC, CP), and fulfilled the main objective to provide a common language (LD) that reflected ideas that would later be selected (AF, RS). The material was considered essential by 49% of the student participants in conceiving the experiments, and 35% thought it relevant for enabling the acquisition of new knowledge; 15% found it quite useful and 0% thought it was of no use (Q8).

In terms of the quality of the results, the interviewees stated that the investigation had been democratized (AF, CP) and it yielded perspectives that had not been considered before (RS), including unforeseen circumstances: "the students took a critical stance on many occasions, more than I expected" (LD). The participants expressed satisfaction with the scope of the definition of the experiment design (Figure 1, question Q5), and declared that the experience had been enriching, while also emphasizing (compared to other forms of research design) the challenge to maintain this spirit of co-creation and transparency alive in the following collaborative phases of production, execution and analysis of results (RS, LD, MC).

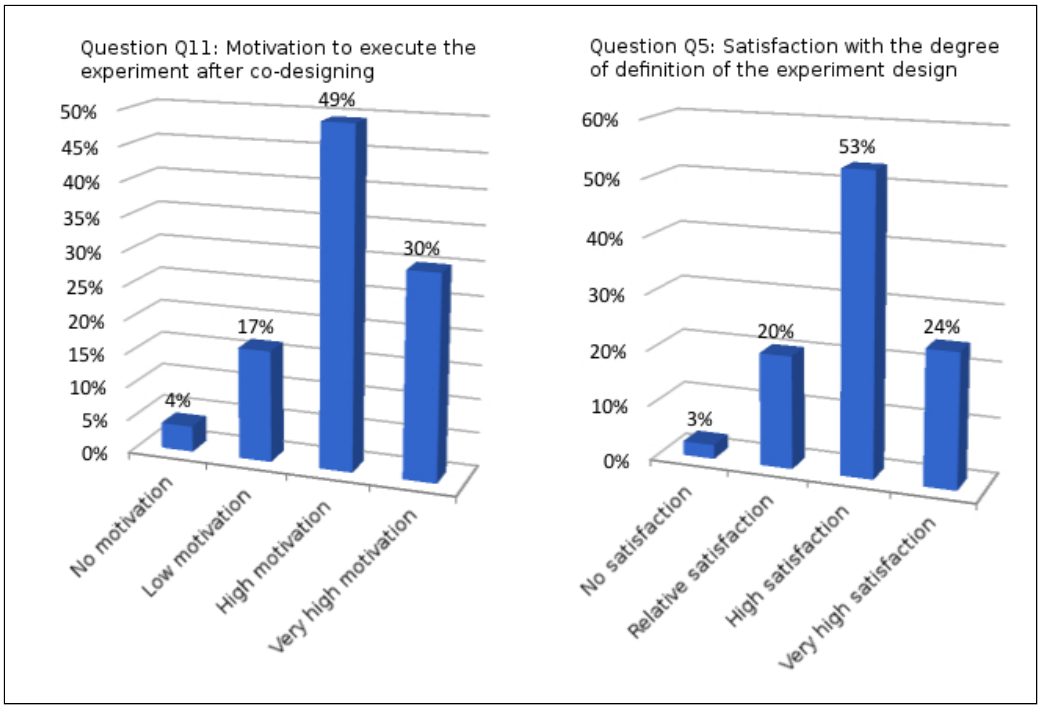

Figure 1. Motivation to execute the experiment and satisfaction with the experiment co-design.

Despite discrepancies regarding the extent of definition in some of the final conceptual maps (CP, AF), or on the level of detail in the tasks to be undertaken that were identified collectively (MC), the interviews reveal that the co-designing done with the students produced themes, research questions and experiment preparation that were useful (LD) and, in some cases, contained a level of detail that was unexpected (RS).

4.2. How can science integrate social needs and concerns in its design and communication dynamics?

The interviews with the research group show that the collaborative method described helped integrate the participants' local concerns into the investigation (RS, LD, CP). For example, RS stated that "the design process arose when the themes were decided and a genuine concern emerged; the connection with local problems has been very clear".

In the survey, most students agreed that they had been able to get involved by expressing their personal points of view (Figure 2, question Q1). The interviews also reveal that the level of involvement, when dealing with a subject close to their concerns and interests, increased student commitment to carrying out the experiment (RS, LD, AF). The students acknowledged the usefulness of the toolkit in discussing and contrasting their concerns (RS, CP), and how the result of the dynamics established to delimit the subjects of the experiments "was closely related to the way in which the participants perceive society and the problems of their surroundings" (CP).

The generation of an environment of credibility and mutual confidence was considered essential for the various stages of co-creation (CP, MC), since the dynamizing agent and the scientists could have been perceived as intruders in the classroom, which could have diminished motivation and contributions. The survey showed (Figure 2, question

Q6) that the majority of students had no problem in freely expressing their opinions and only a few felt insecure.

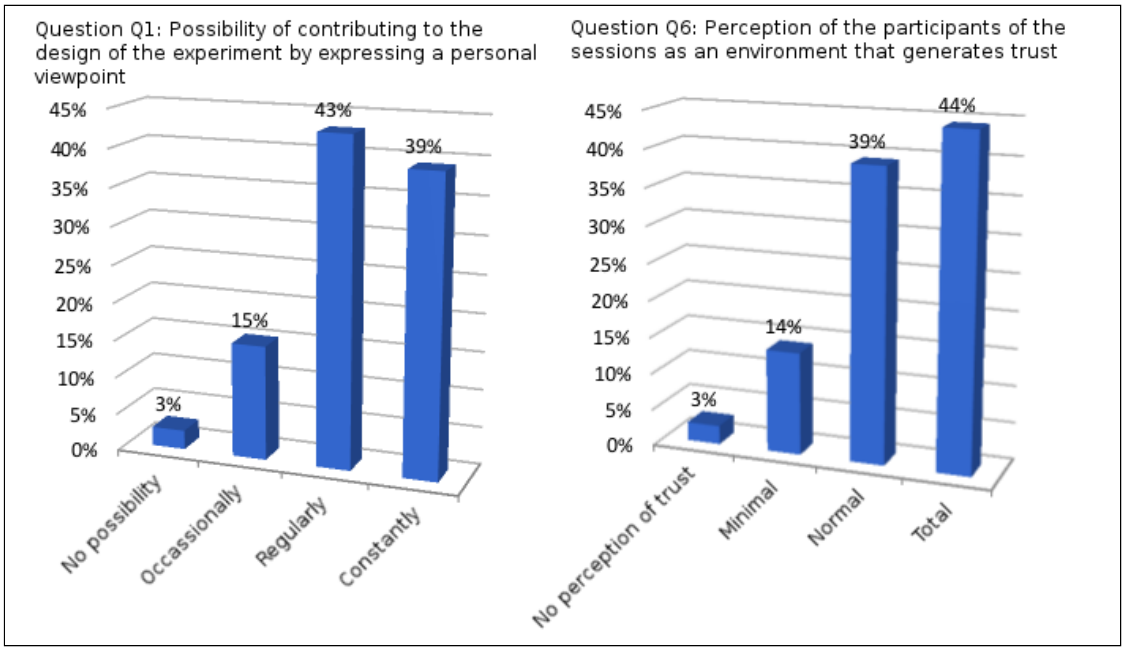

Figure 2. Students' perception of their integration in the co-design process.

4.3. How can interdisciplinary work be coordinated to construct knowledge collaboratively?

Various interviewees considered that interdisciplinary work and the collaborative production of knowledge can be facilitated thanks to this type of co-design: "each can take a step back from their individual discipline and establish peer-to-peer dialogues" (RS), "many people with different viewpoints have generated knowledge together, beyond one single disciplinary field" (LD). In addition, ideas sharing was highly rated by the researchers after each session (RS, LD, CP), in which preliminary results were put in order and they could try to predict the outcome of the next ones, thereby bringing coherence. The impression that the different phases of the co-design process were connected as an ordered sequence was confirmed by the majority of participants (Figure 3, question Q7).

It is also important to note that the team of scientists defined themselves as session co-facilitators exercising a support role to clear up doubts (LD, AF, CP), unblocking discussions that occurred in specific groups (RS) or making initial presentations to help students contextualize the investigation (MC). It is also relevant that the students did not appreciate any difference in the influence of the figure of the main dynamizing agent and that of the co-facilitators of the research group (Figure 3, question Q4). This understanding also underlines the interdisciplinary question and the importance of combining scientific knowledge and specific facilitation skills for co-creation.

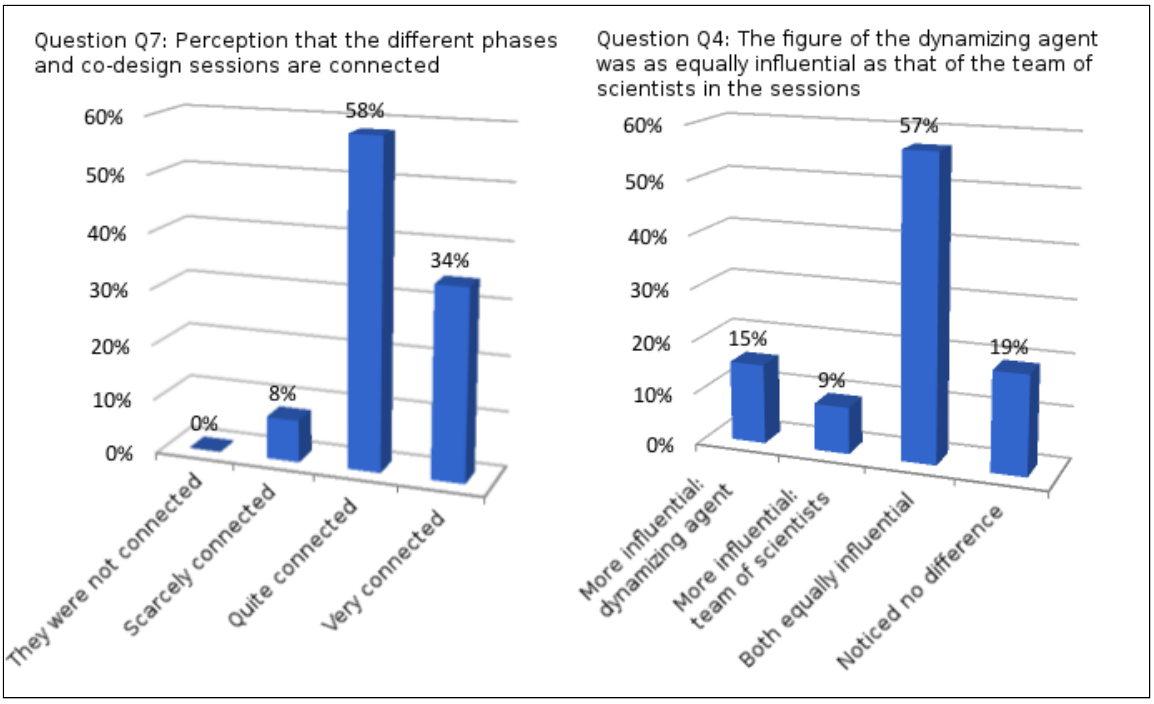

Figure 3. Valuation of the sequencing and facilitating in the sessions.

The research team mainly agreed that these co-creation techniques can be transferred to any scientific project design (RS, LD) and can help to channel scientific discussion (AF), however, most recognize the need for some experience and competence in conducting the co-creation dynamics in citizen science. “In the end, it is a question of finding a balance between democratizing science and the experience of the scientists” (AF), and that in terms of interdisciplinary work, “the researchers did not establish a knowledge hierarchy over the students” (LD).

4.4. How has knowledge been developed in this citizen science co-creation experience?

The collaborative development of knowledge was based on the crucial participation of the students. RS describes the process as a design “validated by the participants themselves”. In the relations between the team of scientists and students, the former describe this experience as an adaptive process (RS, CP) that is highly flexible (LD) and eminently cyclical: “when you begin the sessions, you realize that is not such a good idea to be so linear; and if you allow them a certain amount of freedom and open up options, then new things can be introduced at the last minute. Allowing for some room for maneuver is a good idea” (MC).

Regarding the materials, the scientific team considered that the combination of toolkit activities and their facilitation “generated debate and dialogue by integrating diversity through co-design, gathering different opinions and introducing them into the discussion and moments of reflection” (CP). This observation connects with the result in the survey for the question related to the quality of the participation: a clear majority of students agreed that the process allowed them moments for discussion and debate (Figure 4, question Q10).

Despite the fact that some interviewees referred to the complexity of carrying out collective decisions and of managing this requirement within the time limits of each session, which were perceived as very intense (RS, MC, AF), involvement with the co-facilitation dynamics and the associated toolkit materials meant that the entire process was more open (RS); another achievement was a "visualization of difficult concepts" (LD) and, in general terms, the necessary adaptation of the materials and mechanisms in order for decisions to be taken (AF, CP), which again was acknowledged in the survey by the students (Figure 4, question Q9).

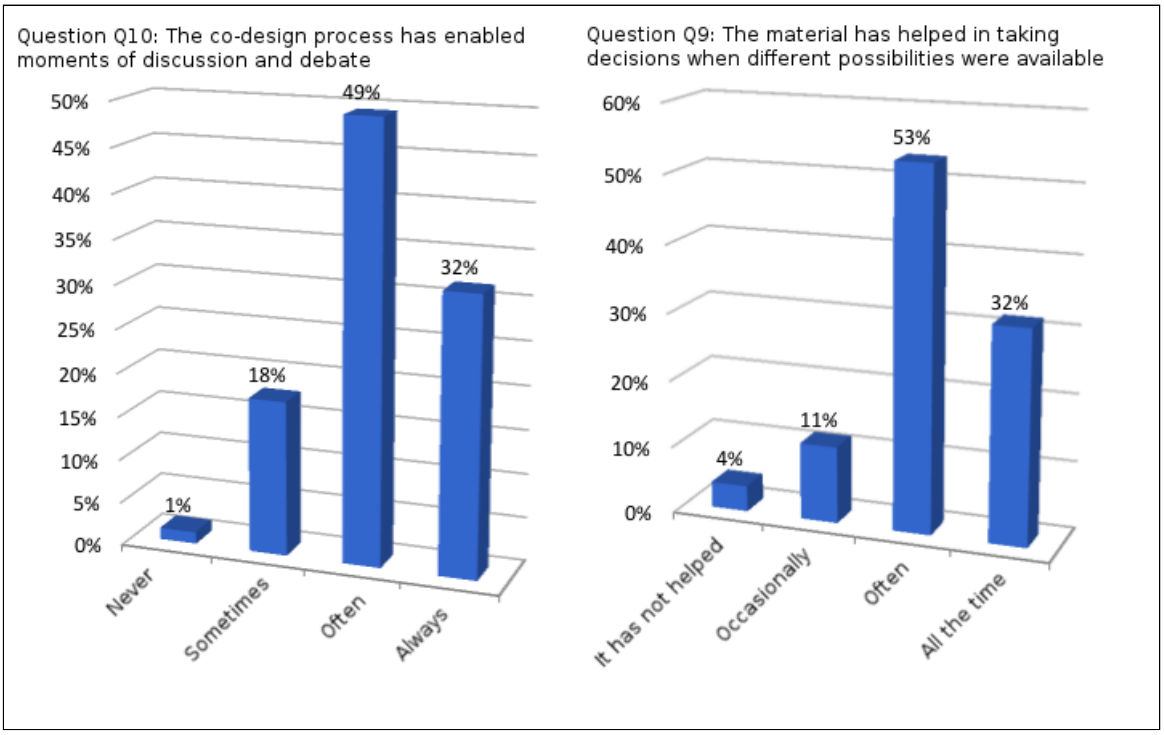

Figure 4: Keys for the development of knowledge during the co-design.

With the team of scientists agreeing that the following stages of the investigation required further processing of the co-design results (RS, MC, LD), another key aspect to emphasize is the recognition that the design of the experiment, as was intended, faithfully reflected the work performed by all the participants at all times, with no single influence prevailing at any time, with the team of scientists declining to adopt a position of power (LD, CP, AF). This perception was supported by the result in the survey (question Q3) in which 77% of those polled stated that the design of the experiment reflected the work carried by all the participants in the work sessions with the team of scientists, against 23% who declared that the design was very much influenced by the team (and 0% who said the results were only the work of the scientific team). This connects to the recurring question of the degree of influence exerted by the experts during the sessions, about which CP states: the themes discussed were not influenced by the scientific team, which is very positive as the students could feel part of the process".

Finally, another aspect that stands out was the team of scientists' generalized perception that the co-design techniques applied here could be transferred to other

forms of citizen science (RS, MC, LD) and even to other types of scientific research projects (RS, CP). In this sense, the co-design of the experiments can be understood as another experiment in itself, in this case one of participation and consensus generation (MC), and as a good initiation experience in the co-created model of citizen science (RS, LD) whose results enable an exploration of even greater levels of participation in the collaborative design of an investigation (CP).

5. Discussion and conclusions

By describing the process and analysing the results of this case study, we have tried to address the question of how collaboration in citizen science can be strengthened by co-created designs for investigation, attending to a wide range of interests and joining social and scientific objectives (Bonney & al., 2014). We describe the mechanisms that enable clear and specific objectives to be fixed for each experiment, identifying various possibilities by iterative design processes (Dickinson & al., 2012). For example, we describe how the research questions can be formulated as a process driven by the participants themselves, instead of the usual top-down schema dictated by the expert scientist (Newman & al., 2012).

The data obtained from the research questions enable us to draw the following conclusions:

- Co-creation, adopting visual material and participatory design techniques that allow the generation and selection of ideas provides quality results for a science that is more open to citizens, and which is more collaborative. In particular, co-creation is perceived as a fundamental factor in participants' motivation and commitment, a key aspect in citizen science projects.
- Citizen science can integrate social needs and concerns into its design and communication dynamics if, at the start of the co-creation process, it can generate the actors' trust in the process. Initiating the mechanisms for decision taking that are preliminary to any investigation is valued by the participants as an important aspect for successful integration.
- Good coordination of an interdisciplinary work is very important for achieving good collaborative generation of knowledge. In this context, coordination requires coherent sequencing of the various co-design phases in which scientific experts fully integrate their expertise with roles of facilitation of group dynamics.
- A key question is a good balance of power relations during the entire process, ceding the initiative to the amateur participants in a structured way while retaining the role of scientific expert, but as a guide and reference point at key moments, using as support mechanisms and material that generate reflection and debate.

The results suggest that the toolkit functioned well as a support of design techniques to integrate the diversity of viewpoints and opinions in visual form (Brown & Wyatt, 2015). As both the survey and interviews reveal, this material also encourages interdisciplinarity and can channel co-creation onto a structured visual canvas, something which, despite exceptions (Nagle & Sammon, 2016), constitutes an innovative contribution by this study to the design of research processes.

Among the limitations and the need for greater analysis of this type of co-creation developed in this citizen science experience, it is important to mention complications arising from time management in the development of co-design by phases. A recurring comment in the interviews was the complexity of managing each session compared to traditional research design processes, in particular satisfactorily combining the moments when ideas are generated with collective decision taking. In addition, certain deficiencies were detected in some co-design sequences during analysis such as in the initial identification of roles (not adequately applied when forming groups), or in the final phases in which the interface and protocol of the experiments were defined in greater detail. Future research that analyzes similar co-creation dynamics in the design of the investigation, whether in the citizen science environment or in other settings involving public participation in knowledge management, should consider these aspects when planning the development of co-design activities.

As well as the key questions posed at the start of this study, the responses of the team of scientists also suggest that this type of co-design can be extrapolated to scientific and academic interdisciplinary settings where the general public, the non-expert or so-called amateurs are absent from a terrain occupied by experts from various fields. In other words, the possibility of adopting similar co-creation dynamics for the design of research projects in professional teams with different scientific challenges.

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5. Agile management for research

5.1 Management of a multidisciplinary research project[9]

Agile methods, initially used by cross-functional teams in software development projects, can also facilitate teamwork in collaborative research processes. For this, project management-related issues need to be addressed, including the challenge of finding practical means for coordinating scientific collaboration, while garnering commitment from all participants. This article explores the utilisation of agile methods by a semi-distributed scientific team, for coordinating a multidisciplinary research project. It examines how these methods can contribute to task coordination in scientific research and highlights key factors for successful adoption of the agile framework in collaborative research projects. Data are collected from a research team, after a 10-week phase of implementing agile methods. Data analysis focuses on the effectiveness of team dynamics and the digital tools used for communication and coordination during the project. The findings indicate a perception that agile methods contribute to improved coordination and teamwork during project development, with less agreement on the utility of some of the tools used. Also, it suggests the importance of involvement of the Principal Investigator and the role and contribution of a facilitator.

1. Introduction

The agile methodology entails a set of principles and practices meant for application in software development settings. These principles and practices enable cross-functional teams to develop project requirements and solutions internally, through their collaborative work (Hoda et al., 2013). This article examines how agile principles and practices can contribute to task coordination in collaborative research. It highlights key factors for successful application of agile methods in this context and presents recommendations for research teams interested in using agile methods in multidisciplinary projects. Despite several limitations in the scale and depth of this case study, and the need for more research on the perceptions of early practitioners in this field, the results seem to concur with those reported in the literature on the adoption of agile methods in software development and other contexts.

2. Agile Principles and Practices for Collaborative Research Projects

Originally, the term *agile* was used in reference to software development (Hoda et al., 2013). The core principles of the agile framework were defined in 2001 by a group of software developers (Beck et al., 2001) in response to the weaknesses and rigidity of

[9] Senabre Hidalgo, E. (2018). Management of a multidisciplinary research project: A case study on adopting agile methods. *Journal of Research Practice*, 14(1), Article M2. http://jrp.icaap.org/index.php/jrp/article/view/588

plan-based methods of software development, criticised primarily for its lack of responsiveness to change (Cockburn, 2002, p. 74). The core principles and practices of the agile framework could be summarised as follows:

1. Emphasis on people and teamwork, and the social aspects of project development (Stephens & Rosenberg, 2003, chap. 3).
2. Use of shared visualisation systems, focused on doable and transparent tasks (West & Grant, 2010).
3. Iterative cycles of development, with a self-managed team following "light-but-sufficient" communication-oriented rules (Cockburn, 2002, p. xxii).
4. Key role of a Facilitator—helping with coordination and conflict resolution, and ensuring that team members contribute (Rigby et al., 2016).
5. Use of a "Kanban board" (i.e., a workflow visualisation tool) for reflecting progress, which is an artifact that enables documentation and transparency of project activities (Sharp et al., 2009).

Studies on the use of agile methods report predominantly positive results (Abrahamsson et al., 2015). Some of the acclaimed advantages include the positive influence on team performance (Fernandez & Fernandez, 2008), contribution to quality levels (Huo et al., 2004), and the improvement of outputs (Dybå & Dingsøyr, 2008), as well as the fostering of trust and cohesion in teams (McHugh et al., 2012).

The adoption of agile methods has expanded recently to contexts beyond software development (Rigby et al., 2016; West & Grant, 2010). In parallel with evidence that agile practices can lead to a more "agile organizational culture" beyond the software development world (Küpper, 2016), some studies focus on the adoption of agile principles and practices in research projects. These studies suggest that agile methods can bridge the gap between industry and academia (Barroca et al., 2015; Ota, 2010; Sandberg & Crnkovic, 2017), or describe how these methods can be used to coordinate distributed teams working on large-scale research projects (Marchesi et al., 2007). Other studies focus on the use of agile methods to develop prototypes in "action design" research projects (Keijzer-Broers & de Reuver, 2016), to manage a research and development laboratory (Lima et al., 2012), for experimental ethnography in the workplace (Mara et al., 2013), for evidence-based projects for behavioural interventions (Hekler et al., 2016), and for product development in the biopharmaceutical sector (DeWit, 2011).

On the other hand, in the field of collaborative research management, among the main challenges addressed in the *team science* literature are: (a) cooperation between disciplines and the requisite learning and adaptation to a shared language and the necessary tools (Jeffrey, 2003), (b) uncertainty about working methods and precise outcomes (Turner & Cochrane, 1993), (c) difficulty of coordinating a type of activity that is continually evolving (König et al., 2013), (d) importance of dynamism when adding new tasks to research plans (Lenfle, 2008), and (e) critical aspects of trust and shared vision in collaborative research (Bennett & Gadlin, 2012; Stokols et al., 2008).

Vom Brocke and Lippe point to three unresolved paradoxes pertaining to the management of collaborative research projects, which indicate the potential for the application of agile methods in this context:

> (1) On the one hand, research projects operate under considerable uncertainty and require freedom and flexibility if they are to generate innovative results. On the other hand, uncertainty needs tight management in order to avoid failure, and creativity needs firm structures in order to be transformed into widely usable project outcomes.
> (2) On the one hand, collaborative research fosters the integration of the research perceptions, ideas, and views that are needed in order to solve problems comprehensively. On the other hand, the resulting heterogeneity of partners leads to problems with respect to inter-cultural, inter-organisational, and inter-disciplinary management.
> (3) On the one hand, the manager is assigned only limited authority because of the autonomy of partners and governance structures. On the other hand, the findings show that certain tasks, such as management of the project vision and integration of results, require the commitment and involvement of all project parties. (Vom Brocke & Lippe, 2015, p. 1031)

These three paradoxes are directly related to the research questions addressed in this article. The first and second paradoxes are the bases of the following research questions:

1. To what extent could agile principles and practices offer engaging, transparent, and easy-to-adopt coordination mechanisms in collaborative research projects?
2. How can agile methods contribute to communication among participants in collaborative research projects?

The third paradox gives rise to the following research questions.

1. Can agile principles and practices help integrate different disciplinary perspectives for working towards quality research outputs?
2. Can agile principles and practices help facilitate commitment and involvement of the participants in collaborative research projects?

3. Case Study: Multidisciplinary Collaboration at the Dimmons Research Group

The case study focuses on the first phase of a multidisciplinary collaboration, spanning a 10-week period, during which agile principles and practices were adopted by a scientific team of 10 members. The scientific team is part of a network of collaborators of the research group Dimmons (http://dimmons.net/), from the Internet Interdisciplinary Institute (IN3) of the Open University of Catalonia, Spain. The team was created for (http://dimmons.net/collacy/), a specific research sub-project that is part of the European project DECODE (https://www.decodeproject.eu/), which required collaboration from experts in several disciplines for generating a theoretical framework for analysing the “collaborative economy” (Fuster-Morell et al., 2017). The objective of

the collaboration was to generate a research deliverable from multidisciplinary perspectives: legal, economic, technological, gender, sustainability, and policy-related. With the autonomous but coordinated effort of all members of this semi-distributed team, the goal was the production of a report integrating different states of the art, paradigmatic cases, theoretical debates, and results from interviews, following a research process that was engaging, transparent, and flexible.

The scientific team consisting of two senior researchers (one of them being the Principal Investigator [PI]), five PhD candidates from different disciplines, and three communication and design professionals, implemented a first phase of adoption of the agile framework. There were four women and six men in the team. The findings are based on a survey administered to the members of the team (to which 8 of the researchers responded) and notes from participant observation by the author (as one of the PhD-candidate members of the team).

The survey covered two main areas: first, perceptions about the digital tools used and the team dynamics during the process, and second, specific questions related to the agile methods and how these influenced several aspects of the project. This second part of the survey measured eight key factors relevant to the adoption of agile principles and practices in collaborative research. These factors are: (i) communication, (ii) visualisation, (iii) task distribution, (iv) transparency, (v) trust building, (vi) engagement, (vii) quality of results, and (viii) efficiency (for literature references, see Table 1).

Key Factor	Literature on Collaborative Research	Literature on Agile Methods
(i) Communication	Keraminiyage, Haigh, & Amaratunga, 2009; König, Diehl, Tscherning, & Helming, 2013	Abrahamsson, Salo, Ronkainen, & Warsta, 2017; Hoda, Noble, & Marshall, 2013; Ota, 2010
(ii) Visualisation	Bennett & Gadlin, 2012	Anderson, Concas, Lunesu, Marchesi, & Zhang, 2012; Sharp, Robinson, & Petre, 2009
(iii) Transparency	Jeffrey, 2003; Keraminiyage, Haigh, & Amaratunga, 2009	West & Grant, 2010
(iv) Task distribution	Bennett & Gadlin, 2012	Dybå & Dingsøyr, 2008; Fernandez & Fernandez, 2008; Hoda, Noble, & Marshall, 2013

(v) Trust building	Bennett & Gadlin, 2012; Stokols, Misra, Moser, Hall, & Taylor, 2008	Dybå & Dingsøyr, 2008; McHugh, Conboy, & Lang, 2012
(vi) Engagement	Stokols, Misra, Moser, Hall, & Taylor, 2008	Stephens & Rosenberg, 2003
(vii) Quality of results	Rigby & Edler, 2005	Huo, Verner, Zhu & Babar, 2004; Serrador & Pinto, 2015
(viii) Efficiency	Stokols, Hall, Taylor, & Moser, 2008	Fernandez & Fernandez, 2008; Serrador & Pinto, 2015

Table 1: Key Factors Relevant to the Use of Agile Methods in Collaborative Research.

Only 4 of the 8 participants from the team who answered the survey declared any significant previous experience in multidisciplinary research projects, while 6 had previous experience with the preparation of similar types of academic publications. Only 3 respondents declared any previous experience with agile methods.

From February to May 2017, the team adopted several practices derived from the most popular agile methods (Anderson, Concas, Lunesu, Marchesi, & Zhang, 2012), as well as specific digital tools for communication, with one of its members acting as a Facilitator. These practices are outlined below.

Regular Releases. This is an agile practice to ensure incremental development of results. In the present case, it took the form of regular planning meetings held every 2 weeks, in which all team members working on various aspects of the project participated to establish and discuss the objectives of the deliverables. There were periodic agreements on tasks and subtasks for each team member.

Agile Facilitation. In order to achieve a cross-functional team working iteratively towards the defined goals, the process was coordinated by one researcher who fulfilled the role of Facilitator or "Scrum Master," maintaining communication routines. The Principal Investigator (PI) as "product owner," assessed the overall quality and alignment with the broader European project.

Weekly Stand-Up. This practise refers to a regular but informal face-to-face meeting, where the participants update each other on the progress of their project activities. In the present case, a weekly virtual conversation took the place of face-to-face meetings. This was enabled by a web chat using the *Telegram* (https://telegram.org/) software. Each member made weekly reports to the team on accomplishments since the last weekly stand-up, planned tasks before the next one, and challenges likely to be faced in the interim.

Digital Kanban Board. This refers to the agile practice of using a workflow visualisation tool to reflect the status of project tasks. Task items, with their descriptions on virtual sticky notes, were reflected on a shared board using the *Odoo* (https://www.odoo.com/) software, so workflows could be visible to all team members (Figure 1).

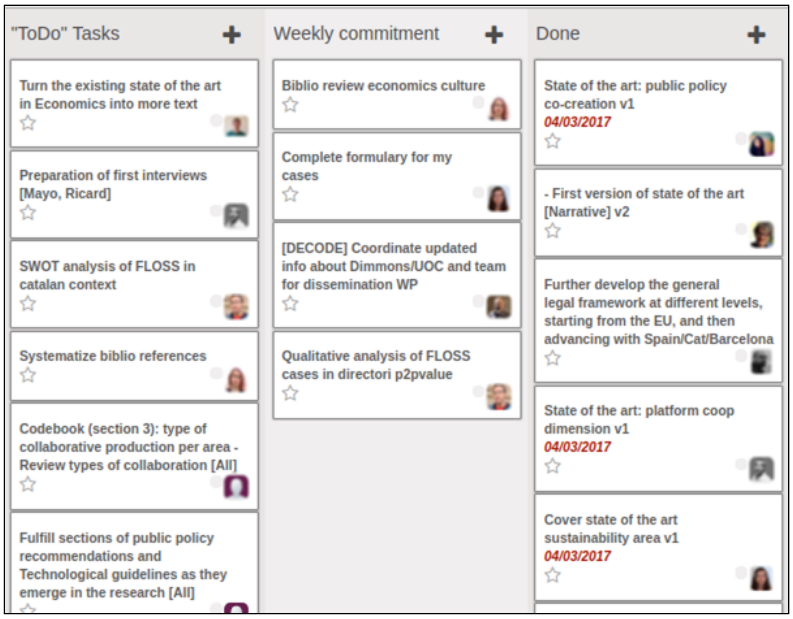

Figure 1. Sample Odoo interface with list of tasks.

3.1. Using Agile Methods to Balance Flexibility and Coordination

In this case study, the role of the Facilitator was instrumental in the research team's adoption of the selected agile principles and practices. It is noteworthy that, on a scale of *1 Very Negative* to *5 Very Positive*), survey participants evaluated the work environment positively.

The perception of survey participants was highly positive in relation to how the research process developed, from distribution of tasks and coordination of the group, to the possibility of individuals influencing the research design. The perception was also highly positive in relation to the adequacy of the digital tools used for the project.

With different levels of engagement, all members of the team adapted to the logic of the Kanban board interface when using it, focusing on a continuous flow of tasks, involving iterations where necessary (Al-Baik & Miller, 2015). The agile practice of "fixed development sprints" (i.e., a segment of time, usually between 2-4 weeks, during which teams work to achieve specified goals towards the eventual release of the final deliverable) was not utilised in this case. Instead, the team opted to use a chat convened via the *Telegram* software to communicate when needed in relation to the agreed tasks, as well as a dedicated mailing list created with the *Mailman* (http://www.list.org/) software for discussions beyond agile coordination. In parallel, the *Google Docs* (https://blog.google/products/docs/) software was used to share documents online for collaborative writing and modular development of texts prior to publication.

Initially, some participants were not actively engaged in tasks related to research design, but this changed progressively as the practices of agile management (regular releases, facilitation, stand-ups, etc.) evolved and weekly updates and bi-weekly meetings occurred with regularity. The survey results also indicate positive opinions in relation to gender and the various social dynamics (i.e., listening and respectful communication, emotional support in times of stress or difficulty, celebration of achievements, etc.). However, in relation to the project's roadmap (i.e., differentiation of stages, progress planning, intermediate objectives, work conclusion, etc.), the results indicate less agreement and, on average, more neutral opinions.

Overall there was a positive perception of the regular monitoring and coordination by the Facilitator (with responsibility for messages to the mailing list or *Telegram* chat, individualised messages, reminders, and assistance in specific matters). There were also positive perceptions of the individual attention given by the PI and her management of the team (from defining the general framework of research for the project, to supervision for development of the contents), consistent with the observations in the field notes as well. The PI outlined the indications and recommendations for elaborating the state of the art of the project during the first face-to-face coordination meeting, prior to a workshop on the basic agile principles to be adopted during the project and the establishment of the agile practices. The observations correlate with the survey results, as a majority of the participants expected the PI to provide the main vision about goals and work strategies.

In terms of the level of commitment of the team in performing the assigned tasks and in following the agreed "feedback loops" (in this case, the weekly stand-ups), a quick analysis of the communication generated around the volume of tasks assumed by each participant, which were all completed, shows that there was regularity in all cases. With the exception of the PI, the rest of researchers followed the agreed routine of sending updates about their progress and planned tasks for the week via the *Telegram* chat, which represented a total of 64 stand-up messages (6.4 on average per participant). An analysis of the volume of tasks and online communication activity per participant, as shown in Figure 2, indicates that in parallel to the research tasks performed by each participant, there was a relevant exchange of messages related not only to the stand-up practices, but also to other coordination needs and for different types of knowledge sharing.

3.2. Achieving Integration Within Heterogeneous Teams

The third paradox highlighted by Vom Brocke and Lippe (2015) reflects the need for integration of perceptions, ideas, and views required for comprehensive problem solving in collaborative teams. Challenges can arise in this regard from intercultural, inter-organisational, and interdisciplinary diversity among team members.

In this case, an analysis of the project activities indicates that, in parallel to performing specific tasks (i.e., development of a literature review, identification of pertinent cases for analysis within a specialised area, or planning and executing of interviews), the researchers also participated in the digital stand-up updates and exchanged other types of coordination messages (mainly reminders for meetings, links to various

documents in progress, or specific feedback on individual work). This additional volume of communication activity during the adoption of the agile methods, in relation to the assigned tasks, tend to correlate to the most active participants and those with most time dedicated to the project.

According to the survey, the perception of the utility of the mailing list and shared documents is positive, and also primarily so for the *Telegram* chat used during the weekly stand-ups. On the other hand, the perception of the digital Kanban board on the *Odoo* tool is less positive. This result coincides with several observations indicating that during the process (by the end of which 60 tasks in total were covered, as reflected in Figure 2) most team members did not interact as much on the digital Kanban board as initially agreed, and it was used mainly by the Facilitator to reflect the status of tasks.

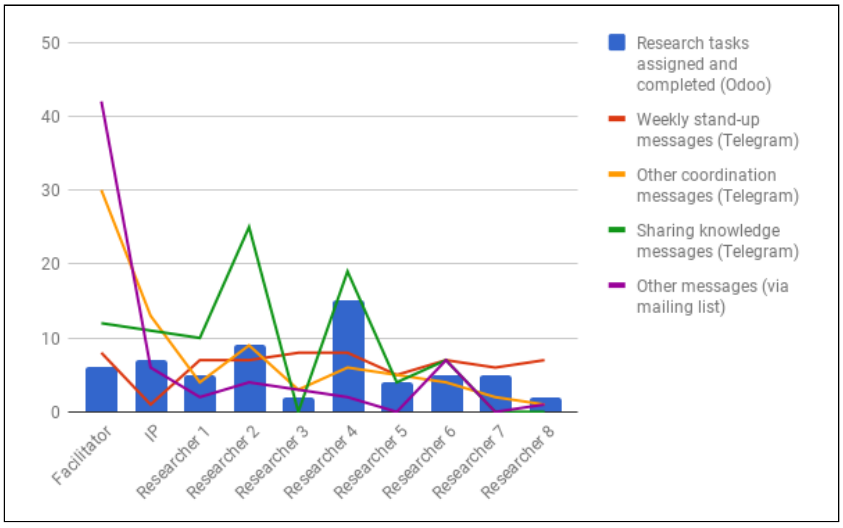

Figure 2: Volume of tasks per participant and online communication activity.

A total of 88 messages with links or comments related to academic papers, events, relevant journals, or information on digital media were shared among the team. Initially, only the Facilitator and the PI engaged in this activity, but progressively other researchers took the lead and were active in sharing knowledge. On the other hand, the mailing list was not used actively during the agile management phase, and except for some isolated cases, participants did not follow the activity that the Facilitator initiated via that channel. The results indicate that the two senior researchers and the participants with less experience in research activity had less engagement in using the agreed tools for the adoption of agile practices. It was participants with an intermediate degree of experience (e.g., those in the last stages of their PhD or with some experience in working on academic publications), who usually took the lead and were more dedicated to engaging via the agile tools.

There was broad agreement on the contribution of the agile methods to improved team interaction for better communication and visualisation of the work of others. However, there was less agreement on its contribution to the distribution of tasks (Figure 3a). Observations from the process reinforce this conclusion, since the face-to-face meetings every month (where the evaluation and distribution of tasks were reviewed, and new tasks were subsequently assigned) sometimes reflected the

strong influence of the PI and the most experienced researchers within the team. Also, it is probable that this lack of agreement on improved task distribution is connected to the underutilisation of the *Odoo* Kanban board mentioned earlier.

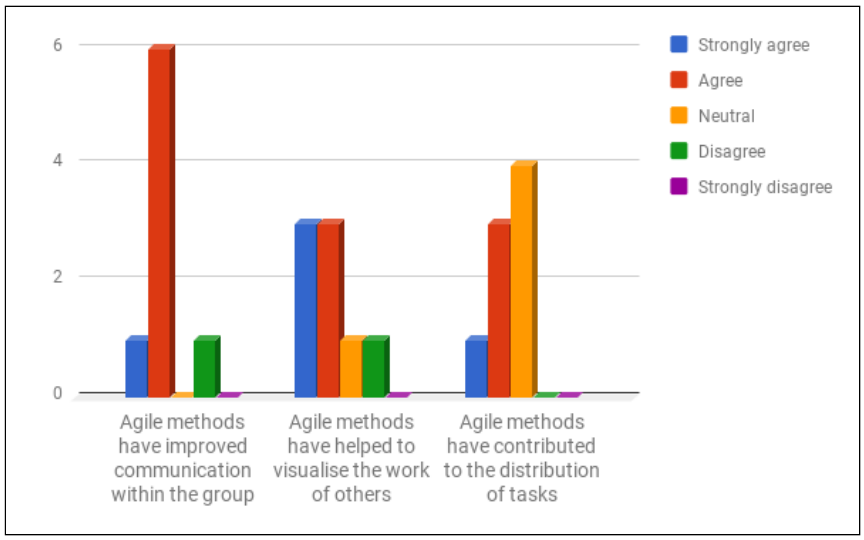

Figure 3a. Perceptions on the contribution of agile methods (towards communication, visualisation, and task distribution).

As Figure 3b illustrates, the adoption of agile methods seems to promote values related to transparency, trust building, and engagement. It was observed that certain factors, other than agile principles and practices, can also exert influence in that direction. For example, a mutually caring atmosphere among team members usually favours the transfer of knowledge (Zarraga & Bonache, 2005). Generally, participants portrayed positive perceptions of the contribution of agile methods. The participant observations reflect that engagements took place in regular cycles. On average, the pace of communication increased at the beginning of each week, in parallel with the stand-up messages, and was maintained at more irregular intervals until the end of each week, through diverse conversation topics (other than basic coordination).

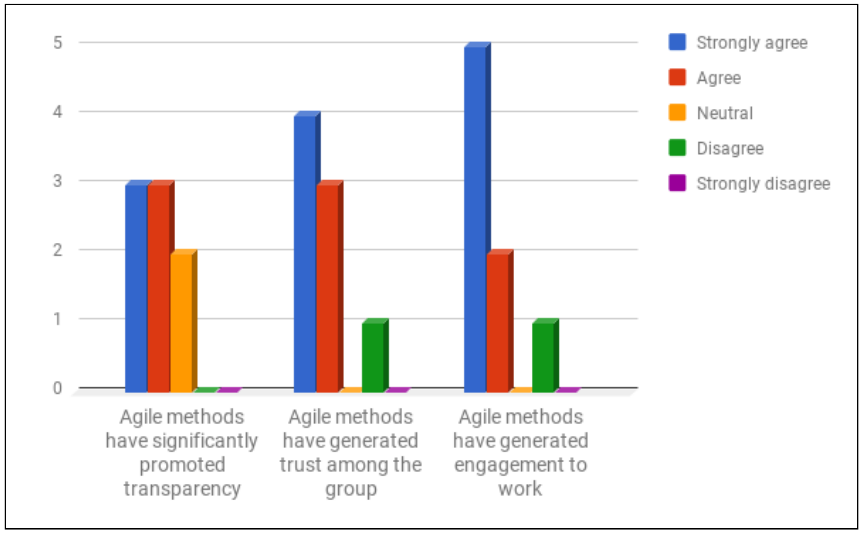

Figure 3b. Perceptions on the contribution of agile methods (towards transparency, trust building, and engagement).

Finally, more ambivalence is evident in the perceptions of the contribution of agile methods to improved efficiency and quality. While there is broad agreement with respect to improved team efficiency, there is less agreement on the contribution to improving the quality of the work (Figure 3c). Here, it is important to highlight that the focus on incremental, modular outputs consistent with the agile methodology was new to most team members, and it differed from their usual ways of conducting research. In this case, adoption of agile principles and practices led to intensive documentation (from lists of literature reviewed, to articles prepared). This difference may have influenced the perception of quality to the closing stage of the project, when the main deliverable was published. Other observations reflect the reluctance of senior researchers to share their work with the rest of the team unless an extensive draft or final version was underway.

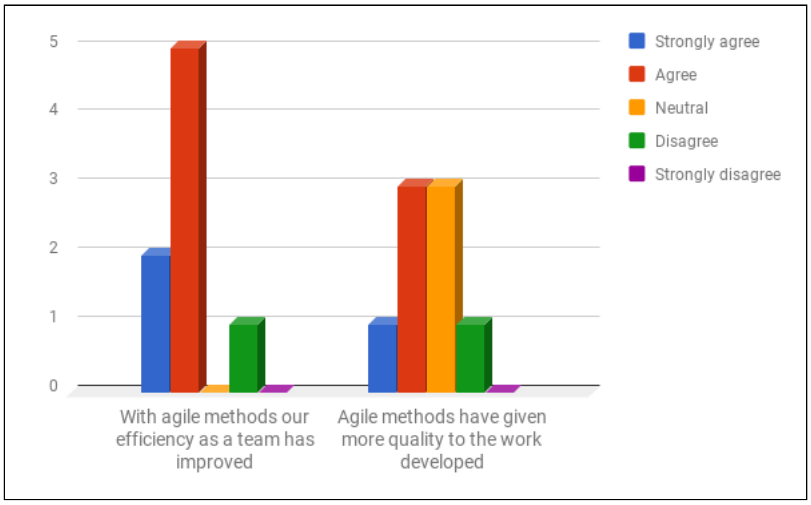

Figure 3c: Perceptions on the contribution of agile methods (towards efficiency and quality of results).

With respect to deadlines and deliverables, it is important to highlight the timely submission of the research product, namely a 145-page report from which other publications for academic journals and proceedings were subsequently derived. Accepting the report in its first version, partners of the European project and other stakeholders agreed that it served as a valuable source of knowledge from different perspectives, produced in accordance with project standards and internally defined levels of quality and rigour.

4. Conclusion

Some of the main challenges in managing collaborative research relate to commitment, leadership, trust, transparency, clarity, communication, and progress monitoring (Keraminiyage et al., 2009). When collaboration involves multiple disciplines, it requires learning and adaptation involving a shared language and accessible tools (Jeffrey, 2003). Moreover, there are the unresolved paradoxes of research collaboration, as described earlier (Vom Brocke & Lippe, 2015). The case of multidisciplinary collaboration at the Dimmons Research Group demonstrates the usefulness of a type of project management, with its specific methods and tools, known as agile management in the context of software development.

The case study reveals that agile management practices offered an engaging, transparent, and easy-to-adopt coordination framework in a multidisciplinary research project. The nature and extent of engagement seemed to depend on the level of academic expertise of the participants. An analysis of regular communication via digital channels suggests that agile methods could help to balance flexibility with structured coordination in heterogeneous research teams. On the other hand, there was less agreement among participants on the contribution of agile principles and practices to the integration of different perspectives for assuring the quality of the work produced. Likewise, there was less agreement on the utility of the digital Kanban board meant for visualisation of tasks. These observations may imply a need for more familiarisation and longer learning curves for the adoption of such agile tools and practices.

This study raises questions on the extent to which the use of agile methods in a scientific context requires coordination by a research Facilitator or manager (as recommended in the literature on the adoption of agile principles and practices in other domains). This case study suggests the need for this important role. The survey data and observations also indicate that an important aspect of this role is to enhance team participation and to assure that the Principal Investigator (PI) also participates in the regular agile coordination routines (as the other researchers do), in addition to participating in face-to-face meetings.

Ison observes, “a method, like any social technology, depends on many people working with it, developing and refining it, using it, taking it up, recommending it, and above all finding it useful” (Ison, 2008, p. 155), something that reflects the need to deepen the identification, description, and analysis of agile principles and practices in research projects requiring multidisciplinary collaboration. In this regard, this case study aims to contribute by contrasting the benefits of the adoption of selected agile practices with the challenges of collaborative research management. Results from this experience point to the need to adopt a degree of flexibility to allow the team members to become familiar with the agile framework after understanding its basic principles. Another important consideration would be to establish basic but clear rules for regular interaction with easy-to-adopt digital tools, especially in the case of distributed research teams. In relation to the use of tools, it could be required to dedicate training and technical support for those participants who are less familiar with the relevant computer software, essential in the case of distributed teams.

While there are limitations to this case study, and the need for additional research is evident, the findings appear to be in alignment with those of earlier studies on the adoption of the agile methods in fields other than software development. In relation to the formula adopted for the case, more extensive experimentation in new projects is required for advances to be made in this relatively new area of utilising agile methods and digital tools for the coordination of teamwork in the field of scientific research.

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5.2 Adapting the scrum framework for agile project management of science[10]

This article explores the adoption of agile methods for the management of projects in collaborative research initiatives. The use of the scrum framework, a specific set of agile principles and practices for self-organizing cross-functional teams in software development projects, is currently being expanded to other types of organizations and knowledge management processes. The study addresses the extent to which key principles and tools usually used in scrum, due to their potentially positive influence on team dynamics and efficiency, can contribute to the collaborative management and coordination of tasks in research processes. The responses from interviews with 17 researchers, as well as participant observation and analysis of online activity, are examined and presented as a case study on the adoption of scrum practices in a distributed research centre dedicated to the evaluation of public policies. Results indicate that integrating agile methods and principles for interdisciplinary collaboration requires a high degree of flexibility and a "learn by doing" approach.

1. Introduction

1.1 Team-based collaboration in research

Team-based collaboration is a critical factor in research organizations and scientific fields, as knowledge is increasingly being generated by research teams (Wuchty et al., 2007; Wagner et al., 2017). Literature on research practices indicates that teamwork and collaboration dominate knowledge production in academic organizations and is prevalent in large-scale international research networks (Cooke & Hilton, 2015). Academics and investigatory teams working on science, engineering and social science disciplines have shifted towards collective research (Wuchty et al., 2007). The benefits of research collaboration range from an increase in citations as a result of the co-authorship of papers to better use of existing resources (Ynalvez & Shrum, 2011). Other benefits include the capacity to generate wider social impact through large-scale research projects (Bammer, 2008), and more opportunities for knowledge transfer and learning (Lassi & Sonnenwald, 2010) or for managing complexity (Helbing et al., 2015).

[10] Senabre Hidalgo, E. (2019). Adapting the scrum framework for agile project management in science: case study of a distributed research initiative. *Heliyon*, 5(3), e01447. https://doi.org/10.1016/j.heliyon.2019.e01447

The study of collaborative research networks from diverse perspectives has gained momentum in recent years (Wang & Hicks, 2015) because funding agencies, which prioritise better use of existing resources, prestige and international reputation, are encouraging large-scale collaborative research programs, (Smykla & Zippel, 2010). In this respect, research collaboration may be viewed as a self-assembling entity, characterized by fuzzy boundaries and the tendency to function as networks (Spinuzzi, 2015; Wang & Hicks, 2015) that involve not only different research institutions, but also expand to include collaboration with industry, governments or civil society (Bridgeford & Amant, 2017). Collaboration may occur across sectors and types of organisations (Bozeman & Corley, 2004), such as government-based research programs, that usually emphasize multidisciplinary and applied research (Gray et al., 2001), or in industry, where the confines of conducting research are usually bypassed for the sake of academic publishing and the search for utility for the non-academic partners (Perkmann et al., 2013).

Several authors contend that this shift to research collaboration is occurring amidst a trend towards disruptive adoption of information and communication technologies (ICT) in knowledge-intensive organizations (Jirotka et al., 2013; Borgman, 2010; Powell & Snellman, 2004). At present, collective research is undertaken in more distributed, reflexive and less hierarchical work arrangements (Zuboff, 1988), thereby expanding the possibilities for complex multidisciplinary and interdisciplinary collaborations on varying scales (König et al., 2013). In parallel to the prevailing opinion that research collaboration correlates with high productivity (Daradoumis et al., 2012) and quality results (Rigby & Edler, 2005; Liao, 2010), some scholars describe it as a difficult and ever-changing process, particularly when involving collaboration between geographically dispersed remote teams (Eccles et al., 2009). Key challenges in team-based collaborative research management relate to issues of commitment, transparency or communication and monitoring (Keraminiyage et al., 2009). Collaboration across disciplines also requires progressive adaptation of a shared language and different types of tools (Jeffrey, 2003).

Kraut et al. (1987), describing the process of collaborative research in scientific teams, explain how plans become progressively more detailed and specific, but can often be revised and even abandoned without negatively impacting collaboration. Other challenges in collaborative research management relate to the need for supervision and coordination among peers (Delfanti, 2016), or to coordinating an activity that is continually evolving (König et al., 2013). Large-scale research projects usually imply more dedication to leading and coordinating each process, from research design to the collaborative authorship of papers and reports (Bozeman & Corley, 2004). In this sense, collaborative research projects often require new project management techniques (Vom Brocke & Lippe, 2015). Methodologically, these additional complexities when performing scientific activities represent an evolving interdisciplinary field requiring various types of analysis of how and when collaborative research is implemented (Sonnenwald, 2007; Katz & Martin, 1997).

1.2 Agile project management

Agile project management (APM) or "agile methods" represents a team management approach and a productivity framework that supports continuous and incremental progress on work priorities, even in the face of changes. APM has its origins in the agile processes of software development, such as scrum, XP, DSDM, Cristal, etc., which are programming methodologies based on adaptability to any change as a means to increase the chances of success of a project (Cohen et al., 2004). Most agile methods try to minimize risks during the execution of a project by developing software in iterations, which usually last from one to four weeks. Each iteration is like a miniature project of the final project, and includes all the tasks necessary to implement new functionalities: planning, requirements analysis, design, coding, testing, and documentation. An agile programming project aims to release new software at the end of each iteration, and between each iteration the team reevaluates its priorities.

APM has gained in popularity in recent years, primarily in the software industry (Scrum Alliance, 2016) but is progressively breaking into other domains (Ciric et al., 2018). In the late 1990s software development teams started to apply agile methods for the improvement of programming processes by making them more continuous and incremental on the basis of agile principles such as adaptability, personal and group autonomy, modularity and self-organized collaboration, as defined in the Agile manifesto (Beck et al., 2001). The manifesto was a reaction to the weaknesses and rigidity of popular plan-based software production methodologies, such as the previously highly acclaimed "waterfall" method, which has been criticised mainly for its lack of responsiveness to change (Cockburn, 2002). APM, more so than other management frameworks, emphasizes teamwork by focusing on the social aspects of software development (Rosenberg & Stephens, 2003), channelling co-creation between programmers and other participants in self-organized, cross-functional teams (Hoda et al., 2013), with collective ownership and collective responsibility as key attributes (Robinson & Sharp, 2003). According to Conforto et al. (2014) APM practices include: (1) the use of the "project vision" concept, (2) simple communication tools and processes, (3) iterative planning, (4) developing activities via self-managed and self-directed teams, and (5) frequently applying project plan monitoring and updating activities.

Despite the critique by some authors that the agile manifesto principles are insufficiently grounded in theory (Conboy & Fitzgerald, 2004) and claims that APM practices and principles lack focus on software architecture (Rosenberg & Stephens, 2003), that it is suitable for small teams but not larger projects (Cohen et al., 2004), and that it is not a panacea for effective project management (Veneziano et al., 2014), the majority of peer-reviewed papers and other empirical studies highlight the benefits of adopting agile methods (Dybå & Dingsøyr, 2008). The growing use of APM seems mainly due to the potential for optimizing the operative capacity of teamwork in short implementation cycles and the positive influence exerted on team dynamics (Fernandez & Fernandez, 2008). Some other documented benefits of the adoption of agile methods relate to the visualization and sharing of progress on tasks, thereby

maximizing possibilities for success in projects in complex and multidisciplinary environments (Cao et al., 2009).

As indicated earlier in this discussion, the use of APM has expanded beyond software development to other organizational contexts (Ciric et al., 2018; Rigby et al., 2016). Analyses have been conducted on the implementation of agile management in product development (Lehnen et al., 2016; Stare, 2014), educational projects (Grimheden, 2013; Salleh et al., 2010), construction projects (Demir & Theis, 2016; Georgy, 2016), venture capital groups (Sutherland & Altman, 2009), innovation processes (Hannola et al., 2013) and the management of projects in libraries (Niemi-Grundström, 2014) and banks (Niclasen & Stoklund, 2016). In parallel to evidence of the contribution of AMP to a more flexible and responsive organizational culture outside of the software development world (Küpper, 2016), there is increasingly more academic literature on the adoption of agile methods for different types of collaborative research processes and scientific projects. For example, studies highlight the successful utilisation of APM in academia-industry collaboration (Sandberg & Crnkovic, 2017; Ota, 2010); the application of agile methods to faculty work (Pope-Ruark, 2017) and bridging the gap between research and practice in the management of case studies (Barroca et al., 2016). There is evidence of success in enabling collaboration in working with and mentoring PhD students (Hicks & Foster, 2010); developing prototypes in “Action Design” research projects (Keijzer-Broers & de Reuver, 2016); coordinating a large-scale European research project with distributed teams (Marchesi et al., 2007) and for the production of multidisciplinary research reports (Senabre Hidalgo, 2018). APM can also be successfully used in managing a research and development laboratory (Lima et al., 2012); adopting experimental ethnography approaches in the workplace (Mara et al., 2013); using evidence-based projects for behavioural interventions (Hekler et al., 2016); or adapting lean software development in the biopharmaceutical sector (DeWit, 2011) or in human-centred research practices (Armstrong et al., 2015).

1.3 The scrum framework

The scrum framework is one of the most adapted APM principles and practices (Lei et al., 2009). The scrum methodology facilitates the coordinated activity of programmers who break their work into small tasks that can be completed within fixed duration cycles or "sprints", tracking progress and re-planning in regular meetings in order to develop products incrementally. The first reference to the term “scrum” appeared in Nonaka and Takeuchi’s (1986) “The New New Product Development Game”, where it was defined as a holistic approach to flexible, autonomous and dynamic teamwork with six main characteristics, namely “built-in instability, self-organizing project teams, overlapping development phases, ‘multilearning’, subtle control, and organisational transfer of learning.”

In their study on leading technological companies in Japan and in the United States, via interviews with CEOs and engineers about how they developed successful innovative products, the authors identified those key characteristics and defined them as follows. (1) Built-in instability: when top management offers a project team a wide measure of freedom and also establishes challenging goals. (2) Self-organizing project

teams: when groups take initiatives and develop an independent agenda for their work. (3) Overlapping development phases: instead of a sequential approach (where a project goes through several phases in a step-by-step fashion) the overlapping approach emphasizes speed and flexibility, and enhances shared responsibility and cooperation. (4) 'Multilearning': when team members engage in a continual process of trial and error, "learning by doing" along two dimensions: across multiple levels (individual, group, and institutional) and across diverse functions. (5) Subtle control: although teams can be largely on their own, management establishes checkpoints to prevent instability, ambiguity and tension, while in parallel there's also control through "peer pressure". (6) Organisational transfer of learning: participants transfer their learning to others outside the group, creating the conditions for new projects, and also by assigning key individuals to subsequent projects. Knowledge is also transmitted through the organization by converting project activities to standard practice.

Given the focus on a team's collective intelligence, the scrum framework usually requires facilitation to improve teamwork and motivation, to clarify who's doing what, to help with conflict resolution techniques, and to ensure that team members contribute (Rigby et al., 2016). Like the rest of the team, the facilitator or "Scrum Master", who can be an experienced colleague or a professional hired for such purpose, works on a Kanban board, which is used to document the elements, as well as enable the social aspects of tasks (Sharp et al., 2009). The Scrum Master, therefore, performs the role traditionally assumed by a project manager or team leader and, in this case, is responsible for implementing scrum values and practices, as well as removing impediments (Cervone, 2011).

Subjecting each task to "development sprints" (a period of work averaging 14-20 days) is another practice that is directly related to the scrum methodology (Abrahamsson et al., 2017). Sprints, which are iterative cycles where a given project is developed or enhanced to produce new increments, are usually initiated with a planning meeting at which participants agree on a list of tasks to be performed by the end of a specified period. During the sprint, the team meets daily in short meetings called "standups" to track work progress and communicate (Friess, 2018) and, if necessary, resolve issues (Marcal et al., 2007). At the end of the sprint, a review or "retrospective" meeting is held at which the team examines developments that occurred during the sprint (Marcal et al., 2007). Interested stakeholders may also attend this meeting. Another scrum practice that is directly related to the APM framework, in this case derived from Lean production models, involves the small, regular releases of "minimum viable products", as opposed to final, fully completed and evaluated outputs at the end of long periods (Münch et al., 2013).

Whether following the scrum methodology or more "light" and simple aspects of the APM framework, the adoption of a Kanban board is useful for its practicality and for tracking implementation on a daily basis (Anderson et al., 2012). The literal translation of Kanban, which is of Japanese origin, is "visual" (Kan) "board" (Ban). Using Kanban, work is broken down into tasks, with descriptions shown on cards or Post-It notes that are displayed on a shared board (usually with separate columns to reflect process). In this way, workflows are visible to all members of the team (Ahmad et al., 2013). Whether via

physical or digital tools, the Kanban board infuses the agile development process with high visibility –providing a means of displaying the work assignments of the team, communicating priorities, making it easier to highlight bottlenecks, and helping to optimize efforts (Cocco et al., 2011). This key aspect of shared visibility and dynamism in the coordination of teamwork —a paradigm focused on doable and transparent tasks— is a basic tenet of the adoption of scrum practices in collaborative processes and organizational structures outside of the software development context (West et al., 2010).

2. Background

As the previous section argues, agile methods constitute an increasingly popular management process based on principles of adaptive planning, continuous improvement, frequent consultation with participants and small and regular releases (Cao et al., 2009), as well as simplicity and dynamism (Abrahamsson et al., 2017). In this paper —an exploratory analysis— the focus is on the appropriation of scrum as a methodological framework and its experimental use in the management of distributed and interdisciplinary research initiatives, with the aim of identifying the experiences and perceptions of researchers in the adoption of APM principles and practices, as well as the potential benefits and limitations.

In this regard, the paper seeks to answer the following research questions:

- Which conditions favour the appropriation of APM for research collaboration?
- To what extent can specific scrum principles and tools be adopted in interdisciplinary contexts?
- What are the limitations and advantages of adapting agile methods in a distributed research organisation?

The UK-based Centre for the Evaluation of Complexity Across the Nexus (CECAN, cecan.ac.uk) is the focus of this case study. CECAN, a research centre hosted by the University of Surrey, was established in 2016 and comprises more than 50 members working in 14 different academic organisations such as the University of Warwick, the University of York, Cranfield University and Newcastle University. Conceived as a network of social scientists, policy makers, policy analysts and experts, CECAN explores, tests and promotes innovative policy evaluation approaches and methods pertaining to food, energy, water and the environment across nexus domains. The organisation carries out this mission through the implementation of a series of ‘real-life’ case study projects with UK partner institutions including the Economic and Social Research Council (ESRC), the Natural Environment Research Council (NERC), the Department for Environment Food and Rural Affairs (DEFRA), and the Department for Business, Energy and Industrial Strategy (BEIS), among others.

CECAN teams develop case studies and other interdisciplinary initiatives around research methodologies, complex systems, policy evaluation (in areas related to sustainability or economic promotion), as well as new evaluation and assessment methods. As a distributed initiative incorporating experts from diverse knowledge

areas with varying levels of dedication and time capacity for projects, and in the absence of a central physical office or shared space, it required a specific approach to coordination and management. For this purpose, from its early operations, CECAN adopted some APM principles and practices derived from the scrum framework, as well as a digital Kanban board for managing the information and knowledge generated by its teams.

3. Methods

This case study utilised three methodological approaches and data sources: participant observation, analysis of online activity and semi-structured interviews. This combination of approaches forms the basis for the analysis of the adoption of agile principles and practices and the scrum framework at CECAN. A six-month period of participant observation of various activities hosted by CECAN resulted in the generation of a database of observation notes. The notes covered team dynamics and references to APM principles and practices in four meetings and two workshops, as well as the direct experience of facilitating an agile process for a specific project with four participants from CECAN. The observation notes and direct experience, together with the parallel literature review on agile principles and the adoption of agile practices in a variety of contexts, served as the basis for the development of the structure and areas of analytical focus.

The statistical and content analysis involved group interactions on the digital Kanban tool Trello (trello.com). Trello, a web-based project management application, is used as the main channel for coordination and knowledge sharing at CECAN. Data gathered by exporting JSON files and manual scraping of web content from 43 Trello boards facilitated the understanding of patterns of interaction between levels of activity and types of interaction. More specifically, to observe the correlation between the number of active participants, topics covered on each board and relevant actions on cards (change of status, comments and attachments) were analysed. This provided an overview of relevant interactions as well as active projects related to the centre, and allowed for more detailed coverage of the use of digital Kanban boards, which was one of the topics addressed by the interview questions and the data analysis.

An interview protocol, designed as the third and main source of data for the study, was used for seventeen semi-structured interviews with researchers (nine men and eight women) from diverse disciplines and institutions who have experience with the adoption of agile practices in their projects (Table 1). The interview questions were developed with the goal of obtaining different perspectives on the experiences of researchers with the use of agile methods for collaboration in their projects. Using the semi-structured approach, the interviews took the form of conversations guided by questions on APM practices, the scrum framework, teamwork and research activity, which naturally evolved through relevant threads of conversation. The participants varied by field, academic background and experience; some were early-career while others were mid- to late-career. Ten researchers (RC), from several universities and backgrounds who collaborate with CECAN on a regular basis, were interviewed. Among them, six interviewees had the specific role of Scrum Master at CECAN, with

responsibility for the coordination of various case studies, on which other researchers and stakeholders from various institutions collaborate. The remaining seven interviewees (RE) were researchers and practitioners affiliated with institutions outside CECAN, who also had direct experience in the application of agile principles, to some extent, in research or academic-related projects. These seven additional interviews were conducted in the same period as the other ten, and served as a control group for contrasting diverse observations and for understanding widely important issues derived from interviews to CECAN members.

Role of interviewee	Institution	Gender	Involvement with CECAN	Scrum Master role
Associate Professor	University of Warwick	Female	Yes	Yes
Research Associate	Newcastle University	Female	Yes	Yes
Research Fellow	University of Westminster	Male	Yes	Yes
Research Associate	Newcastle University	Female	Yes	Yes
Research Director	University of Surrey	Male	Yes	No
Postdoctoral Researcher	University of York	Male	Yes	Yes
Research Fellow	University of Westminster	Female	Yes	Yes
Research Director	Newcastle University	Male	Yes	No
Research Director	University of Westminster	Male	Yes	No
Senior Consultant	Risk Solutions	Female	Yes	No
Senior Researcher	Technical University of Denmark	Female	No	No
Associated lecturer	Open University of Catalonia	Female	No	No
Research Professor	Open University of Catalonia	Male	No	No
Researcher	Open University of Catalonia	Male	No	No
Co-Founder	Collaborative Knowledge Foundation	Male	No	No
Chief Experience Officer	BeyondCurious	Female	No	No
Consultant	Risk Solutions	Male	No	No

Table 1: Researchers and agile practitioners interviewed

To capture interview data accurately, each interview (which lasted approximately one hour per participant) was audio-recorded and later transcribed for coding. Using a grounded theory approach, data was coded for emerging themes (Martin & Turner, 1986). Themes were discovered through a recursive coding process, then grouped into three areas of inquiry related to the research questions (Table 2): (1) conditions for

adopting agile methods in research, (2) adoption of scrum practices and tools, and (3) limitations and advantages of APM adoption in a distributed research organisation. Results were collated into a structured corpus of voices following that sequence, with the most representative and relevant answers selected from interviewees.

Areas related to research questions	**Themes**
Conditions for adopting agile methods in research	Complex and changing setting
	Capacity for self-organisation
	Flexibility
	Adaptivity
Adoption of scrum practices and tools	Facilitation roles (Scrum Masters)
	Kanban boards
	Development sprints
	Incremental development
Challenges for APM adoption in a distributed research organisation	Need for balance
	Offline vs online context
	Proliferation of kanban boards
	Trust in relationships
	Types of research
	Time and resources
	Ad hoc adoption
	Institutional culture

Table 2: Themes derived from interviews in relation to research questions

The results elaborate the relationship between key principles and practices derived from the literature review on agile methods and principles and reflect the findings based on activity and perceptions of participants, while at the same time integrating a description of the basic features of the scrum framework adapted during its experimental adoption.

4. Case analysis and findings

4.1 Conditions for adopting agile methods in research

From the observations and interviews conducted with CECAN researchers, from the outset, it appears that the underlying rationale for selection was premised on key features of the scrum framework and agile methodology such as flexibility, autonomy and self-organisation.

Complex and changing setting

Since the early operations of CECAN in 2016, its executive board promoted the idea of adopting scrum methods as a possible solution for the self-management of projects, from case studies or workshop organisation to other publication-oriented initiatives. The complexity of conducting research with groups of stakeholders who operate under existing policies, while also setting an evaluation framework for new ones, demonstrates, as one participant observed, that "unpredictable events can come along and change the system potentially" (RC1). This need to regularly adapt activity to a complex context, in a new research institution with more than 30 researchers involved (most of them part-time, and usually collaborating from a range of institutions), also presented a significant management challenge, where it seemed "quite hard for any individual to regularly keep up with all that's going on" (RC2).

Capacity for self-organisation

Another key agile principle relates to the focus on the interactions of self-organised teams. In this case, the scrum framework facilitated regular interaction and feedback among participants. The adoption of the scrum framework was based on the same logic of self-organisation of CECAN, with teams assembled according to the interest or potential contribution of each participant to specific topics, with a logic of combining diverse disciplines and points of view. In this way, as one participant noted, "the vision comes from everyone and it is not like that one person got the direction, it actually emerges from the collective expertise of the group" (RC3).

From the perspective of participants in CECAN case studies, self-motivation was a key factor in many of the parallel projects of the centre, which usually started with very open internal calls:

> The initial asking of people who wanted to be involved had to be very open, anyone who thinks they want to help is welcome to. So, I'd have that as a founding principle (RC4).

In this sense, challenges in self-organising, and especially self-assignment in adopting scrum methods for knowledge-based tasks, were cited by other researchers and professionals outside of CECAN.

> An ideal scrum team is that which can sit together for a long time and listen to each other. This can significantly augment your learning process. But my theory about research is that you usually don't have this kind of team (RE1).

Flexibility

From observations and interviews with CECAN researchers, the flexibility of the scrum framework seemed to be one of the main reasons why APM principles were considered useful and put into practice: "I felt that this was a way of rationalizing the process that we were already doing and getting it a little bit more structural, while still valuing the flexibility that we had" (RC7).

When interviewed, researchers from outside of CECAN, who have experienced the use of agile practices in academic and research settings, also considered the extent to which it is important to be flexible and start by adapting only some of the scrum principles (to avoid excessive rigidity in its application):

> If you take scrum very literal it might not work. For example, if you have divided the project into small areas and manage each one with scrum then it might be very difficult to have four daily meetings in four different groups is an hour of work every day. (RE1).

Adaptivity

Many participants viewed the agile framework as an interesting alternative, and a clear, easy concept to communicate and agree on. It is noteworthy that this occurred in the context of an organisation that deals regularly with the analysis and implementation of methodological approaches in areas of research and evaluation, adapting to different institutional environments and ways of working.

> When you use the word 'agile', I think people don't question it. I think in a natural language sense, in an English sense, the meaning of the word has relevance and it sounds fine. If you say 'we're going to work in an agile way', I think that communicates quickly the idea (RC4).

Researchers interviewed from outside of CECAN also highlighted the importance of "learn by doing" during the initial adaptation of the scrum methodology to their specific domains, realising that it meant a way of approaching management by progressively trying things out:

> We were already working with an agile approach but we had not called it 'agile'. Later on, we started formalizing things and picking up more and more scrum tools and techniques to improve the ways we manage our projects (RE2).

4.2 Adoption of scrum principles and tools

One of the fundamental principles of the self-organising, small operative teams at CECAN was to be innovative at the management level to gain efficiency in collaboration.

> We needed to adopt an approach where you can have a consensual decision making that's not necessarily a top down process, but more of a bottom up process of dialogue of mutual interaction (RC6).

It is also important to highlight that CECAN's approach to the adoption of the scrum framework was not based on specific, dedicated training or an expert coach hired for the task. It was instead based more on an evolving interpretation of the APM principles and on experimentation on the basis of an explorative, self-taught approach to the concept.

It was according to what was required and people's individual availability and restraints, and managing that set of interactions. Evidently, we were at each stage constantly thinking about agile. 'We might have to do this and this. That's what we should do' (RC6).

Facilitation roles (Scrum Masters)

Soon after that initial meeting at which the core principles of the scrum framework were introduced, several of the researchers collaborating with CECAN started to adopt some of its key elements. The role of Scrum Master was one of the principles adopted. At CECAN, the role was conceived as a coordinator for case studies, which had on average four, but up to eight participants (Figure 1). CECAN Scrum Masters viewed their role as the link between specific tasks and objectives and other collaborator researchers, as well as the liaison with policymakers and representatives from government agencies. This key role was performed by CECAN researchers instead of professional Scrum Masters, and was focused on coordination, facilitating connections and providing guidelines for specific case studies.

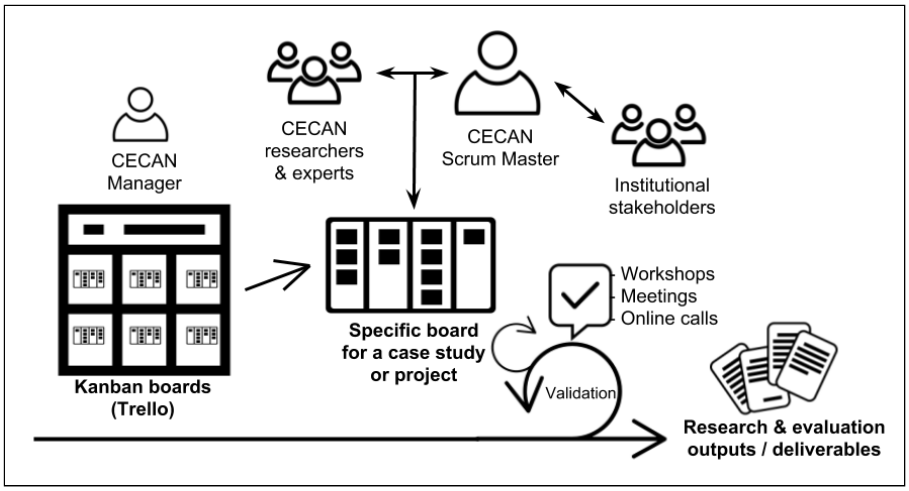

Figure 1: Diagram of the scrum adaptation for research and evaluation projects at CECAN.

At CECAN, Scrum Masters were seen as connectors of expertise and coordinators guided by shared goals, as one participant explained, "I see the role of Scrum Master as a kind of intermediary in an interdisciplinary project like this one. The expertise that a Scrum Master acquires is in linking an expert to an expert and that itself requires [a] particular set of expertise for CECAN, this is an ongoing challenge" (RC9).

In this sense, the role of Scrum Master could be considered an appropriation and reinterpretation. It was one of the key agile practices adopted at CECAN, and although perceived by some participants as not fully implemented, the Scrum Master seemed to play a critical facilitation role and contributed to expanding agile management practices to the various research initiatives and projects. As corroborated by the following comment from one participant, the facilitation role provided participants with transparency and guidance, as opposed to a command and control approach, as they engaged in joint activities.

> The role is very much one of a leading rather than controlling. That has to be the case because there's actually quite a lot of skill involved in managing a group of researchers for whom you have … to align management responsibility. We are a consortium of fourteen different academic organisations. If I wanted to tell you or anybody else in the team 'you have to do this, … because I'm telling you to' they will just go away (RC2).

Considering the high volume of case studies, publications and other tasks related to CECAN activity, for researchers acting as Scrum Masters there was also the opportunity to learn from colleagues doing the same, or even to share the role:

> [In a specific project] There's really two of us acting as Scrum Master because we're covering a broad complex area of policy, to which both of us bring complementary experience. So, he and me communicate, I would say, daily. With other colleagues in CECAN, usually it's once a week at least (RC1).

It is also significant the extent to which the responsibility of having a facilitation and coordination role required additional networking efforts and expertise from researchers new to the concept:

> [The Scrum Master role] It was slow to develop initially. I think it was partly about building trust and establishing relationships with the policy partners, and deciding what they wanted out of the process, and really getting a grip of what they wanted to do, how they wanted to work with CECAN (RC10).

Kanban boards

At CECAN—a "distributed virtual organization, with so many people doing so many things with different time involvement" (RC5)—the Kanban board was one of the agile management practices adopted. The CECAN boards were digital and created using Trello, a web-based project management application, in a format replicating Post-It notes (Figure 2). The Trello boards were one of the main channels of documentation for the centre. They were managed mainly by the Scrum Masters, and were accessed by the other CECAN researchers and occasionally by external collaborators or other stakeholders.

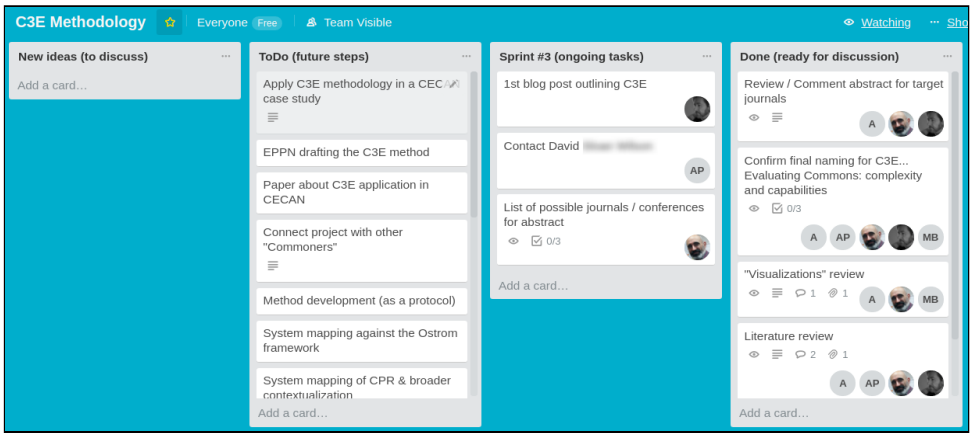

Figure 2: Screenshot of one of the CECAN Trello boards, with different tasks on cards

As explained in the excerpt below, each new initiative or discussion was eventually translated into modular pieces of information. This represents a novel way of accessing updated and valuable knowledge for the entire organisation about the progress of projects.

> One of the ways that CECAN is trying to adopt an agile approach was to set up the use of Trello boards and the use of Trello as a system for those who were engaging in case studies, but also those who were engaging in non-case study activities. To update not just their own group, but the rest of CECAN as well. The use of Trello was a way of leading the case studies, updating data for example with case study notes, and what was happening on the case studies, and any particular event that was going on (RC6).

The results from a basic statistical analysis of communication and interactions on the various Trello boards at CECAN (Figure 3) suggest that there is a relative correlation between more active users on each board, the number of cards assigned to participants and activity related to assigned cards (usually displacing them on the board according to workflows, or content edits). There appeared to be no correlation with publishing comments on cards and attaching documents to cards, as this occurred less regularly, apart from some exceptions. This would confirm that the Trello tool was used consistently through the different boards and related projects, following the typical APM process for visualizing workflows. On average, however, the analysis of the aggregated data shows that only a minority of researchers were active on the Trello platform (despite the entire organisation having full access to all the boards), which represents an unequal distribution of participation.

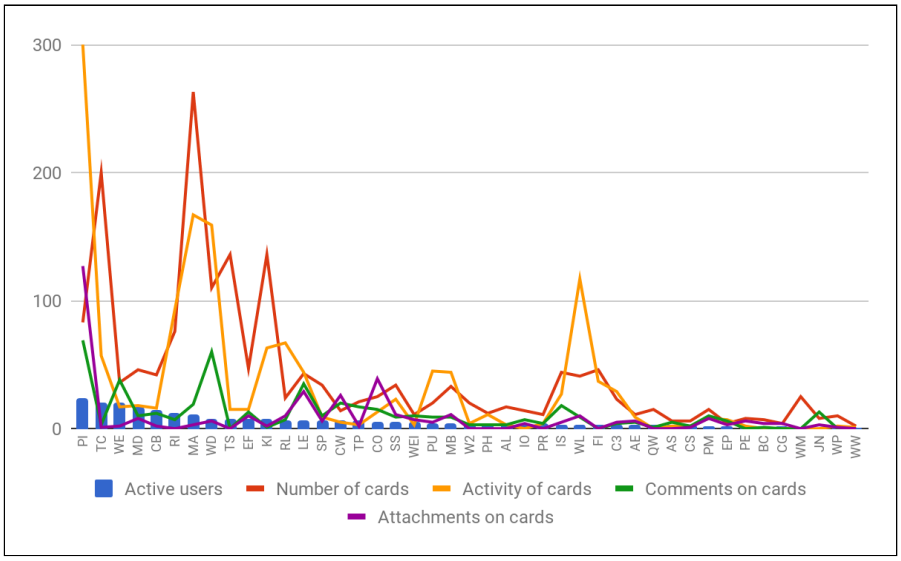

Figure 3: Statistic of cards on each Trello board, ordered by number of active users

A comparison of the most active Trello boards, an analysis of the different levels of engagement with the tool, as well as an observation of the progressive familiarization with its functionalities and connection to APM principles, revealed that participants generally viewed their experience in using the Trello boards as an evolving process parallel to the levels of intensity and activity in the organisation. This observation is supported by the following statement from a participant who was less active in interacting or generating cards, but benefited from accessing the Trello boards: "It has proved a useful kind of map of how the case studies have evolved, sort of a narrative, if you like, a narrative of kind of key points within each of the case studies and how they developed," (RC10).

Trello was generally perceived as practical and aligned with the need to specify, visualize and assign tasks for case studies or publications, and also "useful to have a quick overview of what is happening, and to understand what other people are doing in a quick way" (RC4). However, it represented a way of working and adapting to a specific type of interface with a significant learning curve, to which not all researchers found it easy to adapt:

> I have done a lot of different projects within different project management and communication tools and it becomes too complicated in my mind (RC9).

This coincides with experiences from other researchers, and the following excerpt highlights that some colleagues, perhaps on the basis of their digital literacy, perceive this type of tool as a barrier:

> There was a senior researcher struggling through it and ended up in chaos. She did not want to adapt to these things. If I said 'Put this on the Trello board, we do not need to implement the whole thing, we can manage with something' her response would be like, 'Oh! What is this? I do not want to install this. I do not want to join this, it's complicated' (RE1).

Development sprints

With respect to the adoption of scrum methods at CECAN, the concept of sprints was less explicit or used among participants. For example, the practice of establishing regular "standup" meetings, or retrospective meetings at the end of each sprint period was not routinely followed. Instead, researchers usually established collective agreements about the duration and responsibilities related to specific tasks, depending on the project.

Like other key aspects of agile management practices, this sprint principle —although not used with the same rigour as in software development contexts— was progressively incorporated into the logic of shared communication at CECAN:

> All of those things require structured communication baseline and tasks and milestone baseline. The point is not only moving forward but also ensuring that we are still understanding each other with constant feedback (RC3).

However, from some comments emanating from the interviews, the sprint also seems to be a problematic concept to appropriate from software development processes and to adopt for the peculiarity of research tasks:

> Usually two weeks long, I think everyone would agree that this is how long a sprint should be. I found it funny because probably in the tech world it works, but when you have a different type of tasks the two-week period is a bit arbitrary. In one of our case studies I had workshops which were organized about one month in advance, which made a very good sense of working in sprints (RC7).

When compared with other practitioners and researchers with longer experience using agile methods in non-software contexts, there seems to be a significant difference in the way sprints were adopted at CECAN and how they were experienced in other cases, where they constituted a central part of the process:

> You just don't do one sprint, it is more like doing sprints after sprints after sprints. By doing that and looking at things in many different ways, we get incredible depth (RE3).

> Sometimes we block entire evenings without any other task, or plan one-day trips to finish an article with another author. Then 10 hours working and although the article is not over, it is properly drafted (RE4).

Incremental development

It should also be noted that the concept of incremental development by small and regular releases (derived from the Lean principle of "minimum viable products"), when initially adopted from software development, was perceived as another complex approach to be tackled in the context of academic research.

> We do work considering minimum viable products in a way, by thinking about stages of our work. For example, from a case study to a paper, and all the steps in between. But we don't use these exact words, is more implicit than explicit (RC5).

However, this practice, once adopted, served as an inspiration or key principle for some participants. As with the principle of sprints, some researchers developed an understanding and progressive process of adaptation of the concept of incremental research results, particularly in relation to the other organisations and stakeholders with whom they collaborated. As two participants observed:

> What became quite useful I think in the use of the agile approach with [Stakeholder organisation A] was to say 'we're going to iterate. We know right from the beginning there's going to be a lot of iterations'. To be able to describe that to them at the beginning. They never expected a final product suddenly to appear out of nowhere (RC4).

> We start out with a set of objectives, but we have to adapt along the way. The set of objectives might change or how we meet those objectives might need to change, following the idea of continuous and feedback loops. That's how we're working in collaboration with [Stakeholder organisation B], but we're also having to touch base with them on a regular basis, because things are changing (RC1).

Outside of CECAN, other researchers also expressed familiarity with the principle, with some researchers even adopting and adapting the concept for use in their own research findings and academic writing.

> 'Minimal viable finding' is related to the way we are able to focus our research in every two weeks timeframes. 'Here are things which are more promising and we are going to focus in this process'. We usually find several things but this is about highlighting something which we are going to promise and are going to deliver (RE3).

4.3 Challenges of APM adoption in a distributed research organisation

Need for balance

Given the special nature of research activity, and the need for flexibility in terms of allowing experts to add value through their knowledge and expertise, there was a constant effort at CECAN to balance, adaptively, the need to produce results and to advance in the evaluation of policies without "having a hierarchical [structure of] control" (RC2). In this sense, some participants perceived the achievement of this balance as one of the most challenging aspects of assimilating new coordination approaches, and the need of leadership through the scrum framework as a key factor for providing results without sacrificing autonomy. For some participants, when compared with the expectations implied by APM self-organisation, these attempts appeared to be not always successful.

Offline vs online context

It is also important to highlight at this stage that there are few opportunities, in the context in which CECAN operates as a distributed research initiative, to meet offline in face-to-face meetings, with the result that facets such as self-organisation become more complicated (and usually require varying levels of online interaction), as described by this respondent:

> I feel the biggest challenges with me while trying to do agile and scrum with CECAN is that we are remote, so it is difficult to have the immediate emergency or urgency of something that I need to do, compared to if you are seeing someone in person (RC7).

Limitations in team size and difficulties in adapting online because of individual research styles were also viewed as key issues that need to be resolved for agile methods to function effectively in this context.

> [A specific publication project] started with probably 12 people who were interested but it was very difficult to get momentum of any kind. Everyone was interested in being involved but there was no momentum to start doing anything. So, in discussion with A., we decided to make the group much smaller to just three members. After this change, we have been working smoothly (RC7).

Proliferation of kanban boards

Due to the initial recommendations on the use of Trello at CECAN, the boards were used for the management of various types of projects, and not only case studies for publication but also for planning of workshops, the design of new methodologies or the evaluation of policies. As a result, there seemed to be a proliferation of boards, which were not always useful or used in accordance with agile principles. One participant expressed the following view:

> I think that Trello works best where people have defined responsibilities for a board and know who to contact, plus have predefined rules which are particular to a board. Probably, this concept has not been as clear to the users as it could have been, partially due to the fact that it is a new concept for everyone (RC7).

The experiences recounted by participants on the use of Trello boards as a discussion channel reflect their expectations about the tool in relation to their communication needs, given the complexity and limits of interchanging knowledge from their individual locations and institutions. Others highlighted the difficulty of adopting new digital tools instead of developing new strategies focused on the physical context.

Trust in relationships

The high volume of case studies, publications and other tasks reflected on the numerous Trello boards, afforded researchers acting as Scrum Masters the opportunity to learn from colleagues in similar positions, or for sharing the role, and thereby learn about the implications of managing case studies as Scrum Masters in a more networked and interactive way. However, as far as the responsibility of the facilitation and coordination role is concerned, as one participant explained, the extent to which it required additional effort and progressive 'learn-by-doing' expertise from researchers new to the concept is significant.

> It was slow to develop initially. I think it was partly about building trust and establishing relationships with the policy partners, and deciding what they wanted out of the process, and really getting a grip of what they wanted to do, how they wanted to work with CECAN (RC10)

This view is similar to that of other researchers who experienced the same challenges in similar roles in research-oriented or academic contexts other than CECAN.

Types of research

In some of the interviews, there was often a return to the question about the extent to which it is possible to adopt agile principles in all types of research or whether, as in the view of some CECAN participants, APM principles represent a methodological framework that is more suitable to applied research and contexts where time constraints and pressure from stakeholders make it more applicable and imperative.

> There are projects which are quite theoretical, with basic research, where this kind of agile is probably not likely to be very helpful. So, I wouldn't want to force agile on every piece of research (RC2).

In contrast, confirming interest in the scrum framework from a wider perspective, in front of the same question other interviewees commented how APM practices were incorporated into their own research organisations, outside of their collaboration with CECAN:

> I have seen it working nicely across a variety of domains. In my small department we started it from zero, we have been doing it and have witnessed it progress. Now, we are about ten people (RC3).

> I am working with two other people on projects who are not part of the original CECAN team, they have been subcontracted to come in and help work on it. I have been 'scrumming' with them offline, not using the traditional forums like Trello (RC7).

Ad hoc adoption

However, other perspectives also addressed the complexity of applying agile principles to CECAN research and evaluation outputs and the key limitations of time and resources, as well as its correlation with the need for more flexibility in coordination:

> I think adopting an agile approach in a prescriptive way it's not necessarily effective. It's easy to be quite agile in the sense of having a very weekly sense of meetings, at a particular time on a particular day, if the people that are involved are not overly constrained in terms of time or labour or any sort of resource constraints. When they are, then you have to be quite adaptable or flexible according to the regularity, according to the main principal parties involved. So, I think from that perspective, more open agile use approach is perhaps more effective than a prescript one that says 'we're going to be this regular in terms of when our meetings are going to happen, when we need to update the Trello board, so on and so forth' (RC6).

In this respect, other experts with experience in the utilisation of agile principles outside of CECAN also emphasized the importance of flexibility and openness when adopting these methodologies, instead of following blindly the rules and proceedings as they are established in software development processes.

> I have come up with methodologies, and I know that they're all made up, there are frictional of context specific tricks, and methods, and tools and thinking. Agile presupposes that the 'big box' methodologies can ignore context in a way. Like a call and response mechanism which is very rule based and explicit, and I don't think that this is how a method works (RE5).

Institutional culture

For other researchers, who are familiar with scrum and agile methods, another key issue is related to the complexity and the management challenges embedded at the institutional level in universities and scientific departments:

> The group can be agile but it faces a system like the academia and the university that is not agile. So, the motivation to do research and at the same time adapt to new ways of doing is complicated to manage (RE4).

> Managers of research projects and IPs are not trained in project management, nor these skills are covered in PhD courses or similar. You can only self-learn about it, or explore on your own your ability to do so by acquiring collaboration skills and techniques (RE7).

5. Discussion

The objective of this article was to explore the adoption of agile methods in a distributed research initiative, and especially the appropriation of the scrum framework as a coordination and communication solution for the management of collaborative interdisciplinary projects. Taking into account the specific characteristics applicable to research in academic and scientific areas (as a separate context from software development processes, where the APM framework was developed and is widely used), the adoption seemed successful overall in that it facilitated the generation of new dynamics of collaboration, benefiting from some APM principles and practices in various ways. However, the process was also challenging and had some limitations in terms of a shared understanding and coherent application of the scrum framework, when compared to similar experiences in the use of agile methods in research projects.

In this regard, according to the data obtained from interviews, the adoption of agile methods in research collaboration is suited to organisations embedded in complex and changing settings, with some capacity for self-organisation, flexibility and adaptivity to new management approaches, which connects with the description of organizational networks (Spinuzzi 2015, p. 58). On the other hand, relevant challenges identified for APM adoption in research point to issues related to: (1) the needed balance between efficiency and autonomy of participants, (2) the limitations of the online context for coordinating activity, (3) the tendency to proliferation of kanban boards; (4) the need to build trust in relationships when coordinating, (5) the type of research activity carried out, (6) time and resources constraints, (7) the importance of tailoring scrum principles to activities, and (8) the institutional culture of academic and research organisations.

Integrating agile methods and practices for interdisciplinary collaboration requires high degrees of flexibility and “learn by doing” approaches, similar to other project management methodologies and approaches (Lauren, 2018, p. 30). In this sense, the scrum framework constitutes a methodological framework that can be counterproductive if it is too ambitiously or rigidly implemented in this type of context, as indicated in the literature on the utilisation APM outside of the software development sector (Ciric, 2018). According to Nonaka & Takeuchi (1986), this type of participative management can be favourable for several types of agile development where conditions such as “built-in instability, self-organizing project teams, overlapping development phases, ‘multilearning’, subtle control, and organizational transfer of learning”, converge and are present to some extent in the philosophy of the collaboration initiative. When adopted by academic participants and experts familiar with research or evaluation methods, the scrum framework seems to be an easy concept to transfer and experiment with, even though specific tailoring to the idiosyncrasies of collaboration and personal motivations may be required when

adapting APM (Gandomani et al., 2014). Also, as attested by the literature on agile software development, characteristics such as team size and specificities such as the online tools required for operating in distributed contexts seem critical, as well as its suitability for small groups but not for large projects (Cohen et al., 2004), or the significant complexity that may be experienced when adopted by remote as opposed to collocated project teams (Paasivaara et al., 2009; Teasley et al., 2000).

Scrum principles adopted by various research teams, as analysed in this study, were seen as a valuable addition to the coordination of projects, with diverse levels of agreement about their successful implementation and perceived challenges. For CECAN self-organised teams, in a networked context requiring new participation strategies, working on case studies following APM principles provided a structured approach to a different style of management of evaluation and research-related tasks. Teams perceived positive attributes that are also referenced in previous studies about agile methods, including easy adoption and relation to project success (Serrador & Pinto, 2015), as well as improved teamwork through the focus on human and social factors (Dybå & Dingsøyr, 2008). Several interviewees highlighted the key role of the Scrum Master as facilitator but showed less agreement in relation to new concepts when applied to scientific activity such as “sprint development”, or the importance of small and regular releases of research outputs, when applied to scientific activity.

Studies on agile management have demonstrated the benefits to be gained with respect to fostering trust and cohesion in teams (McHugh et al., 2012). Empirical evidence points to a correlation with differing levels of shared leadership, team orientation, cross-functionality, internal learning processes and team autonomy (Moe et al., 2009; Stettina & Heijstek, 2011). This seems to be the case as well in the specific research context studied at CECAN, and also when contrasted with perspectives from other researchers who are familiar with agile methods. Some of the limitations of agile methods addressed by academic literature are also present in this case, such as the difficulties experienced by certain individuals or personality types in properly integrating into agile teams (Whitworth & Biddle, 2007). As well as the constraints perceived as inherent to the tradition of academic institutions and the lack of new management practices in scientific activity (Pope-Ruark, 2017), or difficulties in adapting to digital tools by senior researchers, some other complexities of adopting agile methods for research were evident. For instance, the timeframes for developing intellectual activity, and the motivation for doing so, can vary significantly depending on the type of project. Also, some researchers held the view that there should be a balance between prescriptive and adaptable formulas for this type of dynamic management.

In relation to specific tools, only a relative minority of researchers were active on the Trello platform, despite the entire organisation having full access to all the boards. This unequal distribution of participation via the digital Kanban board seems to represent a typical “90/9/1 principle” or “power law” (Nielsen, 2006), usually present in online communities of peer production, where the fact that a large percentage of people do not contribute does not necessarily constitute a problem or put at risk the achievement of common goals (Fuster Morell, 2010). In this sense, for a number of researchers, the

proliferation of Trello boards represented an organisational challenge in terms of managing the tasks in progress and staying on top of all the boards, once several boards were in active use, which coincides with the findings of other studies about the adoption of digital Kanban boards for knowledge management in distributed organisations (McLean & Canham, 2018).

Lessons learned from this case study point to the need to reconsider the suitability of the scrum framework as the best agile approach for distributed research management. Future studies should explore if more open interpretations of APM practices (which for example focus on the regular but less structured updating of tasks via Kanban boards) could be more successfully adopted in this context, or if on the contrary, additional scrum practices (such as regular "standups" in short periods, or retrospective meetings) could improve the adaptation of APM principles and practices adapted to research activity. Another relevant issue emanating from this exploratory study relates to whether the adoption of professional agile facilitation (by experts in scrum or other agile practices and not researchers) is important and should be addressed with a comparative focus in future cases. As one of its main limitations, this study did not gather data that could compare adoption in such terms. Finally, in relation to the critical factor of remote, distributed research teamwork, another line of inquiry should address how agile practices could be used effectively in fully allocated science teams, where sharing the same physical space could benefit from the use of offline Kanban boards, as opposed to digital ones.

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6. Combined co-creation for research

6.1 Dotmocracy and planning poker for uncertainty management in collaborative research[11]

This study is an exploratory approach to two co-creation methods derived from digital culture, applied to collaborative research ideation and management. Specifically, it describes and analyses the use of dotmocracy (from participatory design) and planning poker (from Agile frameworks) for decision-taking and uncertainty management in the early definition of collaborative research processes. The analysis, based on participant observation and facilitation in nine collaborative research settings, identifies commonalities on how some issues of uncertainty in collaborative knowledge generation contexts can be addressed by both techniques. Results point to the possibility of using dotmocracy and planning poker for articulating decision-making processes among different available options, in order to find consensus in a visual way, and at the same time to make more explicit the degree of agreement and risk perceptions in relation to scientific activities.

1. Introduction

1.1 Uncertainty and open collaboration in research

Uncertainty lies at the heart of research and scientific activity and its type of complex, collaborative workflows. Uncertainty about working methods and precise outcomes is the main characteristic of any research environment, specially around the key issues of defining methodologies and goals (Turner & Cochrane, 1993). When planning research outputs and results, these are normally characterised with a high level of uncertainty about the degree of goal achievement and the best way or methods to succeed (Lassi & Sonnenwald, 2010). On the other hand, contrary to a traditional context where much research was conducted by lone researchers or by co-located teams, and where most team members had the same or similar disciplinary backgrounds, in recent times there has been a clear shift to more explicit and regular collaboration in science and research (Katz & Martin, 1997). However, different scholars describe how research collaboration is still a complex and ever-changing process (Stokols et al., 2008).

Managing uncertainty in collaborative research has to do, among other things, with the ability to estimate tasks or add new ones to a research project plan with fast

[11] Senabre Hidalgo, E. (2018, October). Dotmocracy and Planning Poker for Uncertainty Management in Collaborative Research: Two Examples of Co-creation Techniques Derived from Digital Culture. In *Proceedings of the Sixth International Conference on Technological Ecosystems for Enhancing Multiculturality* (pp. 833-839). ACM. https://dl.acm.org/citation.cfm?id=3284325

decision-making mechanisms (Lenfle, 2008). In this sense, Vom Brocke and Lippe (2015) point to a unconcluded paradox when managing collaborative research projects:

> On the one hand, research projects operate under considerable uncertainty and require freedom and flexibility if they are to generate innovative results. On the other hand, uncertainty needs tight management in order to avoid failure, and creativity needs firm structures in order to be transformed into widely usable project outcomes.

Effective co-design and management techniques, from that perspective, emerge as basic practices for collaborative work in scientific production, where according to the 'Mode 2' framework described by Gibbons (1994), scientific knowledge (and innovation emerging from it) is problem-focused, context-driven and it crosses disciplinary boundaries in order to create holistic approaches. As opposed to a 'Mode 1' of research (motivated by scientific knowledge alone, not necessarily concerned with the applicability of its results), such Mode 2 is embedded in social contexts, where even citizens and non-scientists can be under that approach more active in the processes of scientific knowledge production and evaluation (Nowotny et al., 2013).

In this sense, an important area related to collaborative research has to do with the tradition of action research and community based research (Santos & Hissa, 2011), where participants who are not professional or academic researchers can be involved in several aspects of an investigation process (Corburn, 2005). In that field, participants usually collaborate with researchers in relation to practical or pressing issues at the local level, representing the needs of different organizations and communities (Reason & Bradbury, 2001). Another example of a collaborative research domain is the new paradigm of citizen science, in terms of volunteer citizens working with researchers for digitally gathering or analysing scientific data (Bonney et al., 2009), and even engaging in other critical parts of the research design and planning (Wylie et al., 2017).

In such contexts, in times when collaborative project design, planning and decision-making in research processes are critical for making possible 'hybrid forums' of transdisciplinary problem solving (Callon et al., 2009), the question of methods becomes crucial. Not only in relation to research methodologies *per se*, already surpassed by the digital domain (Rogers, 2013) or frontier experimentation beyond qualitative and quantitative approaches (Law, 2004), but also in terms of how knowledge and tasks can be managed. Because in different research domains there's a lack of conceptual and practical approaches to how effectively co-design and plan the day-to-day operations of scientific processes in more participative ways (Wilbon, 2012) as well as a need of successful research management practices (Derrick & Nickson, 2014).

1.2 Two digital cultures of co-creation: participatory design and Agile frameworks

From a Digital Humanities perspective, digital culture has evolved with the expansion of the Internet and diverse examples of collective intelligence processes, generating and appropriating tools and visual languages for collaboration, resulting in different phenomena of artifact-mediated communication (Dwyer & Suthers, 2005).

Furthermore, the digital domain has also influenced in turn offline cultural practices (Manovich, 2013), and nowadays citizens are also 'prosumers' (Manovich, 2009) that share interfaces from mobile applications, web pages, video games, etc. as global patrons of communication, via homogeneous icons, functions, expressions. Behind the rise of co-creation processes made easier by new interfaces, and in parallel to the digital domain and the offline one influencing each other, we can find the key role of two types of very influential actors: interaction designers and software developers.

On the one hand, the field of participatory design emerged in Scandinavia in the 70s and 80s, aiming to empower the users of computer systems to play an active and creative role in designing them (Bødker, 1994). In parallel to other advances in the design disciplines, this represented a shift from social methods to technological ones, and during the following decades resulted in the emerging field of interaction design (Di Russo, 2016), which started to generate different methods like prototyping, 'mock-ups' or scenarios (Kensing & Blomberg, 1998). In this sense design thinking, and co-design as it's more participative dimension (Manzini & Coad, 2015), represents a set of practical approaches for the creative definition and solving of problems (Cross, 2011), as well as for generating different types and forms of 'design knowledge' (Thoring & Müller, 2011). It offers a great variety of visual methods, procedures and techniques for designing new projects in complex and uncertain circumstances, as well as the simultaneous exploration of scenarios, user-centered and participatory approaches and the integration of many possible points of view (Blizzard & Klotz, 2012). In this sense, according to Schön (1983) from a perspective of action research, design can be considered:

> [...] an epistemology of practice implicit in the artistic, intuitive processes which some practitioners do bring to situations of uncertainty, instability, uniqueness, and value conflict.

On the other hand, in close relation to these advances between technology and communication in the field of participatory design and interaction design, the other relevant phenomena in recent times has been the practice of programming and software development, constituting a fast-growing and influential industry where uncertainty represents one of its main challenges (Sillitti et al., 2005). In this sense, the world of software developers represents itself a full cultural system of norms, procedures and appropriations (Himanen, 2010). In parallel to different engineering schools and approaches to openness in software development, in recent times there has been a shift from rigid and 'waterfall' planning to more effective collaboration processes, resulting in what has been called 'Agile' (Hoda et al., 2013). Agile principles and frameworks started to be widely applied by software development teams at the beginning of 2001, as defined in the Agile manifesto (Beck et al., 2001), with the aim of making workflows more continuous and incremental based on principles of adaptability, personal and group autonomy, modularity and self-organised collaboration. Also representing a set of emerging co-creation practises, Agile has recently expanded to other organisational contexts (Rigby et al., 2016), as well as for the management of research projects (Senabre Hidalgo, 2018). This is mainly due to its potential for optimising the operative capacity of teamwork in short cycles of

implementation, for visualising and sharing tasks progress and for maximizing the success possibilities of projects in uncertain, complex and multidisciplinary environments (Cao et al., 2009).

Going back to collaborative practices and uncertainty in research domains (as reflected in Figure 1), although there's a wide corpus of academic literature and references about specific methods for data gathering and analysis, there's still a general lack of methodologies and clarity on practical details about how to co-design and co-develop collaborative inquiry processes (Frideres, 1992), where participatory research projects in many occasions require better approaches to apply project management techniques (Vom Brocke & Lippe, 2015).

In this sense, the ideation and crafting processes behind different types of scientific production seems currently in need to improve mechanisms for sharing certainty and more sources of creativity (Wang & Hicks, 2015), and this is where some of the techniques derived from co-design and Agile practices could offer solutions in different ways.

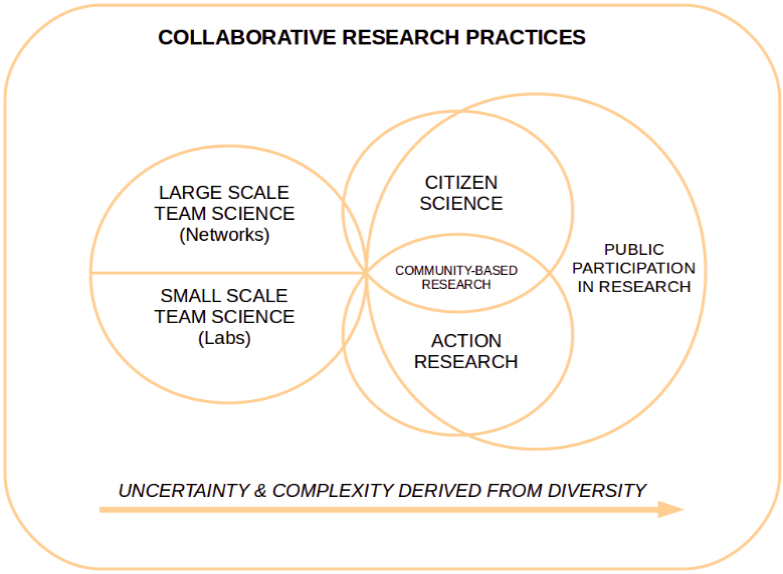

Figure 1: Collaborative research practices in relation to uncertainty and complexity.

2. Methodology

This study constitutes an exploratory approach to specific methods from participatory design and Agile frameworks, as two areas of practice derived from digital culture, in this case applied to collaborative research ideation and management. Specifically, it reflects on the observations and visual analysis of two concrete techniques used for agreement and 'convergence phases' (Sanders & Stappers, 2008) during decision-taking and uncertainty management in the early definition of collaborative research processes, applied in contexts from case studies of diverse characteristics.

2.1 Selection of co-creation methods

The selection of the two co-creation methods described below ('dotmocracy', derived from participatory design, and 'planning poker', derived from Agile practices of software development) have been chosen for representing an adequate example of a type of appropriation evolved from a humanistic interpretation of digital culture. That is, in both cases looking for a parallelism that illustrates how there are specific methods that can be adopted in different settings than the original ones, due to a shared understanding of the basic mechanisms that operate behind them and makes them useful under a Digital Humanities perspective[12].

Dotmocracy (or 'dot-voting') can be understood as a collaborative selection technique that generates a shared visualization in which the team's wisdom about its priorities emerges through the individual perceptions of each member, where each vote is represented by a dot sticker. Every participant is allowed a certain number of votes (dots) to apply across the total number of items, contributing to generate rankings of the items from highest to lowest, based on the greatest to least number of votes per item. Derived from Internet-based rankings, and applied originally in the domain of participatory design for software development (Takaba, 2006), dotmocracy methods have also started to be documented in action research (Bowles et al., 2016) and citizen science contexts (Senabre Hidalgo et al., 2018).

Planning poker (or 'Scrum poker'), on the other hand, constitutes a specific example of Agile techniques adopted by software developers for planning and coordinating workflows (Grenning, 2002), as a consensus-based, gamified technique for estimating the effort behind specific tasks (Mahnič & Hovelja, 2012). In planning poker participants of a group make estimates iteratively by playing numbered cards face-down to the table (instead of speaking them aloud), and when cards are revealed the different estimation of tasks are discussed.

2.2 Data sources and procedure

The number of cases and contexts where both methods have been tested and observed in research settings cover 9 sessions, with a total of 94 participants, between 2017 and 2018, in different locations and communities of practice, from scientific teams collaborating in the same discipline to transdisciplinary settings involving also citizens and non-experts:

- 27th June 2017, at BCN Activa (Barcelona): Procomuns forum - Action research intervention for suggesting new public policies. Participants: 45 attendees in a conference event (researchers, policy-makers and practitioners).
- 17th May 2017, at The Centre for the Evaluation of Complexity Across the Nexus (London): CECAN Team 'open space' - Session about Agile for policy evaluation methods. Participants: 4 researchers (social sciences, policy innovation).

[12] Although in both cases there is also a clear connection to the Delphi method, as an interactive forecasting technique which relies on panels of experts (Wang et al., 2012), our focus here is the way both techniques are adapted and adopted from digital culture as collaborative methods, by different practitioners than its original users, in order to have clear mechanisms to deal with collective inquiry processes under conditions of uncertainty.

- 17th November 2017, at Open University of Catalonia - UOC (Barcelona): Dimmons strategic planning 2018-2023 - Discovery and co-design session for long-term strategic plan of a research group. Participants: 10 researchers (communication, social sciences, law, design) and 6 collaborators.
- 28th November 2017, at Eugenides Foundation for Science Education (Athens): STEM4youthworkshop - Citizen science experiment co-design. Participants: 20 Secondary School students and 4 researchers (physics).
- 20th November 2017, at BAU - School of Design (Barcelona): City Station / Environmental Health Clinic x Barcelona - Session about new approaches for citizen science. Participants: 10 researchers (environmental sciences, policy making and social sciences).
- 19th January 2018, at Coventry University (Coventry): Agile for research - Workshop at 'Disrupting Research Practices Unconference'. Participants: 8 researchers and PhD candidates (social sciences, education and computer science).
- 9th May 2018, at Institute of Agrifood Research and Technology (Barcelona): Agile for research management - Team training session. Participants: 6 researchers (environmental sciences).
- 25th May 2018, at Austrian Centre for Digital Humanities (Vienna): Co-design and Agile management for transdisciplinary research - Internal workshop about co-creation. Participants: 6 researchers (digital humanities and social sciences).
- 12th June 2018, at Internet Interdisciplinary Institute - IN3 (Barcelona): Dimmons coordination meeting - Long term planning for research strategy. Participants. 5 researchers (social sciences) and 1 external collaborator.

In all cases the analysis was based on participant observation (from the perspective of main facilitation of the dynamics), as well as on analysis of visual results and feedback discussions with some participants from each session.

3. Results

Data obtained from participant observation and facilitation during the above mentioned research design workshops and sessions, using dotmocracy techniques and planning poker cards, allows to identify commonalities on how some issues of uncertainty in collaborative knowledge-generation contexts can be addressed by both techniques.

During all the sessions, one of the shared characteristics was the possibility of articulating decision-making processes among different available options, in order to find consensus in a visual way. And at the same time, to make more explicit the degree of During all the sessions, one of the shared characteristics was the possibility of articulating decision-making processes among different available options, in order to find consensus in a visual way. And at the same time, to make more explicit the degree of agreement or perceptions from individuals in front of new collaborative projects. In the majority of cases, feedback from participants referred to the opportunity of having these easy, visual and engaging way for articulating decision-making in a short period of time, avoiding unstructured and time-demanding discussions for identifying opportunities or issues in new research projects.

3.1 Dotmocracy applied to collaborative research ideation

In the case of dotmocracy techniques, they were applied for several levels of research activity, depending on the context and needs, both in citizen science and in action research projects. The voting dots were used in those cases to find consensus from the micro-level of selecting research questions, to broader approaches of scientific goals. Among the observations and discussions generated during each session, results from the different experiences converge in validating this technique as useful for:

1. Research topics: To address which problems, concerns or research topics can be prioritised at the very beginning of the exploration phase of a collaborative research initiative.
2. Research questions: To visualize and discuss among different clusters of research questions which ones are more interesting of promising for a heterogeneous group of researchers or participants (Figure 2).
3. Research methods: To reflect the expertise of a research team or group in relation to qualitative and quantitative scientific methods (Figure 3).
4. Community interests: To identify priorities related to specific topics or measures to apply in a participative way, from different perspectives.

Figure 2: Group of researchers from different universities selecting research questions about sustainability at the beginning of the citizen science project 'City Station - Environmental Health Clinic x Barcelona'.

Figure 3: First session of Dimmons research group strategic planning for 2018-2025, mapping familiarity with qualitative and quantitative methods from members and collaborators.

Apart from activating mechanisms for early and more explicit discussion around research design than in traditional contexts (where the scientific activity tends to be relatively isolated, and projects usually defined by non collaborative processes), this technique also implies an easy way of documenting outputs, by taking pictures of the whiteboards or walls used for placing the information, and afterwards if needed creating tables summarising results.

In all cases, the rule was to assign freely green dots to any item, except in those occasions when the options displayed where generated by different groups of individuals (in such cases, with the condition of not voting on one's output, but choosing among the rest of options).

An important evolution of the method has been to introduce the concept of the 'red dot', which instead of being anonymous (like the green ones for showing support or interest) represents an opportunity for participants to highlight potential risks, obstacles, problems or difficulties about specific options. This way, apart from the opportunity to prevent or stimulate action towards a specific direction, there's an additional layer of discussion around uncertainty and potential complex conditions. In all cases where this additional use of red dots was implemented, results derived from observation and feedback point to its utility for detecting risks, avoiding uncertainty about research approaches and methods.

3.2 Planning poker applied to collaborative research management

When testing planning poker for collaborative research activity, the level of understanding and expertise around scientific practise and research tasks was also significantly different among participants. That's why it's important first to clarify, in relation to this technique, that although all the group dynamics where the planning poker method was applied were within research teams, they also represented a wide diversity in terms of backgrounds (predominantly, researchers from social science disciplines) and in terms of experience (from PhD candidates to senior researchers or

principal investigators, as well as professional collaborators with no specific scientific training).

The numbered cards and mechanism of the planning poker exercise (as summarised in section 2.1) were in this case translated to the domain of collectively estimating individual effort in research related tasks. Six types of tasks were the most used and discussed through the different sessions, and during the activity results annotated on a whiteboard (see example on Figure 4):

1. Effort for writing a short text for a call for abstracts of a conference.
2. Effort for writing a 5-8 pages theoretical manuscript about a known topic.
3. Effort for preparing a one-morning workshop with research subjects.
4. Effort for preparing questions and conducting a structured interview.
5. Effort for leading the proposal of a European funded project with partners.
6. Effort for preparing slides for a presentation in a conference.

In all cases, before selecting the cards each type of task should be briefly discussed and bounded, in terms of a minimum understanding by all participants about its implications. Also, another recurrent discussion during the exercise was the difference between the concept of 'effort' (more abstract) and the one of 'time' (more familiar to participants), where some researchers found complicated to make the distinction when making their estimations this way.

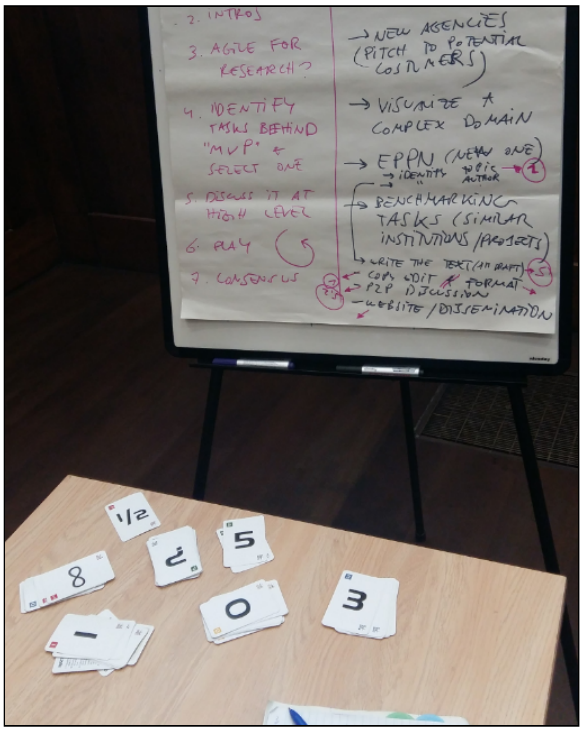

Figure 4: Results after a planning poker session about research and policy evaluation at a CECAN workshop.

Another relevant dynamic observed was the tendency of senior researchers and group directors to choose on average the lower numbers (thus estimating less effort behind different tasks) as opposed to less experienced researchers and collaborators (who on

average selected higher card numbers for their estimations). This reflects, as indicated above, one of the main virtues of the method, which is to allow making more explicit the perception of risks or ambiguity when discussing differences in estimation, at the early stage of planning a research project.

Reflecting also in some occasions the tendency to over-simplify or over-complicate tasks when organising collaboratively a research process, the planning poker technique when applied during the different cases resulted in discussions about shared worries or levels of unpredictability behind potential projects. Like in the case of the dotmocracy technique (when applying red dots as explicit signs of alert for the group), this represented one of the contributions of this type of co-creation method derived from the culture of software development.

In general, even between colleagues from the same research group or project, the usual situation during the planning poker sessions was that it was the first time that detailed discussions took place about specific research tasks and its characteristics. This was observed as a clear indicator of the potential utility of adopting this technique not only for addressing uncertainties about specific research project, but also as a type of team-building and 'gamified' way of getting to know more about the perceptions of close collaborators on day-to-day activities.

4. Discussion and future research

Results from the adoption of dotmocracy and planning poker techniques in collaborative research planning and management, as described in this study, point to the benefits of using such methods for managing uncertainty and improving collaborative decision-making mechanisms. From the visualization of shared concerns or issues at the beginning of a participative inquiry process, to generating discussions and making more explicit the level of complexity or predictability of specific research tasks in different transdisciplinary settings.

However, there should be broader explorative and interpretative incursions analysing the degree of usefulness of the described methods in more research contexts. For example, comparing dotmocracy with other visual decision-taking mechanisms (where due to group size and time restrictions, other techniques can be equally useful), or making more accurate analysis of the type of dynamics when assigning dots (since in some cases the first interactions adding votes could influence and generate bias by influencing the latest contributions). The latter tendency (also known as 'bandwagon effect'), has been an observed phenomenon in some occasions, whereby the rate of uptake of trends increases the probability of being selected by others.

Planning poker sessions for research planning and estimation of tasks, on the other hand, solve this potential tendency of the bandwagon effect by making sure that each estimation is selected individually but only revealed afterwards, at the same time that the rest of participants. In this sense, in case of relevant discrepancies second or even third rounds of recalculating the effort after a group discussion usually generate more aligned results and close estimations among participants. Something that, on the other hand, represents a plausible indicator of team cohesion and shared perceptions about uncertainty, limitations or work capacity.

Both methods should be studied broadly from the perspective of discourse analysis and team science interactions, experimenting and exploring how they generate new insights and channel discussions about planning or research design among academic peers, as well as with external collaborators or the public. Quoting Cross (2011) about similar approaches to design in action:

> There is the need to tolerate and work with uncertainty, to have the confidence to conjecture and to explore, and to interact constructively.

Something that, in the absence of more specific techniques and facilitation like the ones described here, seems still relatively rare in the scientific world, as opposed to other knowledge-intensive domains where co-creation and visual mechanisms are proving its usefulness for dealing collaboratively with uncertainty.

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6.2 Co-designed strategic planning and agile project management in academia: case study of an action research group[13]

Strategic planning, a standard activity for project management in different areas and types of organisations, can contribute to improving the dynamics of collaboration in academia, and specifically in research processes. This paper joins the still scarce studies on strategic planning within research groups, contributing to the field of both team science and organisational management from a social sciences perspective and "strategy-as-practice" paradigm. Through the case study of an action research group, after the experimental co-creation of its long-term strategy involving different participatory design methodologies, we quantitatively analyze how this process influenced communication and group relations, both internally and in relation to its participation in the ecosystem with other stakeholders. Thus, as a result of a detailed content analysis in the different communication channels and tools of the group, we address its impact on the team's agile project management (APM), adopted in a novel way by its members. Data compared between periods, once the strategic plan was co-created, suggest that this type of approach to co-created strategic thinking can improve coordination, cohesion and joint vision among participants. In agreement with emerging academic literature in this field, pertaining to the need to understand strategic planning as a process of socialization and dialogue, other relevant results of the study point to the particular suitability of this type of planning in research environments interested not only in its academic, but also social and ecosystemic impact. The results obtained and discussed also provide elements of assessment when considering the applicability of this type of strategic co-creation process in other areas of knowledge and disciplines.

1. Introduction

Despite the current competition among academic institutions for resources and prestige in the adoption of evaluation systems, ranking mechanisms and performance indicators (Ordorika and Lloyd, 2015), regarding current challenges in the organisational dynamics of academic systems there's little evidence of successful strategies and practices for research project management (Derrick and Nickson, 2014). This is especially the case when it comes to the additional need to adapt the production of

[13] Senabre Hidalgo, E., & Fuster Morell, M. (2019). Co-designed strategic planning and agile project management in academia: case study of an action research group. *Palgrave Communications*, 5(1), 1-13. https://doi.org/10.1057/s41599-019-0364-0

scientific knowledge to collaborative and interdisciplinary teamwork (Wuchty et al., 2007), connecting networked academic organisations and researchers (Wang and Hicks, 2015), in a new context that Jasanoff (2003) defined as the "participatory turn of science". From the fields of social studies of science and science of team science, authors like Jeffrey (2003) or Bozeman & Boardman (2014), describe how collaboration across teams and disciplines also requires progressive adaptation of a shared language and different types of tools. For these reasons, strategic planning seems to be one of the elements that could possibly contribute to better management practices in academia (Wilbon, 2012), which is usually a complex and ever-changing process (Eccles et al., 2009). On the other hand, when considering alternative modes of knowledge production in academia, as well as the paradigmatic transition of universities in the global context (Santos, 2012), strategic thinking usually emerges in research groups oriented to achieve impact beyond the academic domain, like in the cases of action research (Fuster Morell, 2009) or mission-driven research (Holm et al., 2013). This article provides an analysis of how far co-creation could have a role in the application of strategic planning in academic contexts, in this case through an action research group, and its impact at the levels of management and interrelationships.

1.1 Strategic planning in the field of project management

With its foundations in the principles of action research and organisational development (Argyris and Schön, 1997), project management is generally considered as the practice of planning and executing the work of a team, based on specific control models and theories, to achieve specific goals and success criteria (Kerzner and Kerzner, 2017). From a social science perspective, however, project management has also been studied and applied in understanding projects as social processes, focusing on human behavior and actions within groups and organisations (Blomquist et al., 2010). Strategic planning, on the other hand, as applied in project management, can be defined as "deliberative, disciplined effort to produce fundamental decisions and actions that shape and guide what an organisation (or other entity) is, what it does, and why" (Bryson, 2011, pp. 4-5). Strategic planning, in this sense, is one of the most widely used strategy tools in business, but is also used in public and non-profit organisations (Ferlie and Ongaro, 2015).

Besides the fact that empirical evidence of a positive relationship between strategic planning and organisational performance remains inconclusive (Wolf and Floyd, 2017), after Mintzberg's (1994) critique of the fallacies of rational and centralized strategic planning as a top-down process, from the field of organisational studies it has also been analysed as a key mechanism for team integration and coordination, and as a basis for both centralizing and decentralizing organisational decision making (Spee and Jarzabkowski, 2011). In this regard, influenced by the mentioned social science perspectives, in recent years there has been a shift in the field of project management research on strategic planning (Wolf and Floyd, 2013), pointing to its benefits from the perspective of participative and socialized process models (Andersen, 2004). From this second perspective, strategic planning can be studied more as a "process" than a "product", and strategy development, therefore, as an evolutionary and integrative activity (Jarzabkowski and Spee, 2009), within a strategy-as-practice paradigm (Whittington, 1996). However, even considering how strategic planning has evolved

towards these more integrated and process-oriented approaches, there has been little focus in management literature on addressing to what extent and, specifically, how it could be co-created using participatory methodologies.

1.2 State of the art on strategic planning applied to research

Again, with regard to the current challenges of academic systems and research activity from an organisational perspective, although there is scarce academic literature about strategic planning for research organisations, studies in this area show how it has gained some popularity in the general operation of universities (Srinivasa et al., 2015; Dooris et al., 2004), and also with open and participative approaches (Amrollahi and Rowlands, 2017). More specific studies about the application of strategic thinking in research examine its implementation in R&D processes in firms (Bemelmans, 1979), in industry-academic collaboration (Burke et al., 1985), in research teams in the health sector (Leischow et al., 2008), in global initiatives of medical research (Berkley, 2010), in strategic collaboration within scientific centers (Boardman and Gray, 2010), or for the administrative management of research (Drummond, 2003).

In this respect, focusing on scholarly activity and academic organisations, relevant case studies on achieving collaborative and participative consensus for strategically planned research agendas address how to combine online tools and offline sessions during the process (Wilbon, 2012), or how to engage iteratively different academic communities of practice around research strategic planning (Best et al., 2015). Sá and Tamtik (2012), on the other hand, highlight the diversity of the approaches and perceptions of academics about the research mission, usually constrained by broader social and organisational structures of universities, and by the complex nature of the research enterprise itself. In all cases, however, there is still scarce literature on how to collaboratively develop strategic plans in academic research organisations, and its effect on group dynamics.

1.3 The co-creation approach: participatory design and agile project management

Co-creation (or co-production), which refers to processes of collective creativity, is a very broad term, with its applications ranging from the added value of customer participation in the definition of a product or service (Ranjan and Read, 2016), to public participation, collaborative governance or community involvement in civic-oriented projects (Voorberg et al., 2015). Within this broad concept, participatory design (or co-design) refers to a specific instance of co-creation that occurs when designers and people not trained in design work together in a design development process, with participants as “domain experts” of their own needs and experience (Visser et al., 2005). Some key principles of co-design, in this sense, connect with the perspective of iterative and participative strategic planning, as defined above, especially when it comes to the involvement of diverse stakeholders (Flood and Jackson, 1991). This points to the opportunity for adopting visualization techniques derived from co-design (Sanders and Stappers, 2008) in order to integrate different perspectives, mutual understanding, inspiration and engagement between participants in the research strategic thinking process (Eppler and Platts, 2009), thereby enhancing visual and textual representations of contexts and strategies (Giraudeau, 2008).

On the other hand, some approaches analyse strategic planning from the perspective of how it can be improved by adapting agile project management (APM) (Cervone, 2014; Rand and Eckfeldt, 2004). APM, which can also be considered as a co-creation practice (Spinuzzi, 2015), consists of a set of methods and principles originally conceived for flexible and participative software development, but currently adopted in many other different domains (Ciric et al., 2018). This wider adoption of APM is due to its attributes of adaptive teamwork, transparency, continuous improvement and small and frequent releases for early delivery (Cao et al., 2009). APM, more so than other project management frameworks, emphasizes teamwork by focusing on the social aspects of project development, channelling co-creation between participants in self-organized, cross-functional teams (Hoda et al., 2013), with collective ownership and collective responsibility as key attributes (Robinson and Sharp, 2003). Among the different practices within APM, some typical ones are the regularity of short feedback meetings ("standups") and the use of kanban boards for visualizing the workflow and team tasks from conception to completion (Polk, 2011).

1.4. Research questions

The arguments exposed above justify the interest in an analysis connecting such diverse bodies of literature, in order to fill the gap and contribute to the questions about how strategic planning could be based on co-creation methodologies. And also, from a meta-research perspective (Ioannidis et al., 2015), how such an approach could be applied to research processes. More concretely, to what extent participatory design could be used for articulating the research planning phase, and afterwards integrated with the APM for the research development phase. This leads to the following two research questions, which form the basis of this study:

1. How can co-creation methods be used to lead the strategic planning process of a research group?
2. What would be the impact of co-created strategic planning on the agile project management of research?

Answering these two questions requires, in the first case, to describe in some detail how participatory design can be combined with strategic planning principles, explaining the integration of both approaches. In relation to the second question, a quantitative approach is needed considering the general lack of empirical evidence, especially in the fields of social studies of science and team science, on how strategic planning can impact research management. In this regard, our analysis of the co-creation approach to research strategic planning is applied to the participants, sequence and methods used in the entire process.

2. Methodology

In order to address the two research questions, a distinctive methodological design has been applied to each one of them. Articulated around a specific case study on the Dimmons research group, this methodological approach is twofold. The first part is based on participatory design, utilised to conceptualize and prototype the Dimmons strategic planning according to co-creation principles. The second part analyses the

impact of co-created strategic planning on the group's day-to-day APM, through content analysis of the online tools used for coordinating teamwork. On this basis, the results allow us to discuss which insights of the study could be generalized to current challenges in research project management.

2.1 Background of the Dimmons case study

Created in 2016, Dimmons (http://dimmons.net/) is one of the eleven research groups of the Internet Interdisciplinary Institute (IN3), the research center of the Universitat Oberta de Catalunya (UOC) based in Barcelona. Following the development of strategic planning of the IN3[14], which took place after the main strategic planning exercise of the UOC[15] in 2016, the Dimmons group developed its own strategic planning with the aim of establishing its strategic objectives for the period 2018 to 2023. On the one hand, the selection of the Dimmons research group as a case study is due to how it is immersed in a strategic planning context that crosses several levels of the academic institution to which it belongs, reflecting an increasingly recurring but still little studied trend. On the other hand, Dimmons also represents a paradigmatic example due to its diversity, since it is composed of members with a consolidated scientific career, but also of PhD students, external collaborators and management-oriented profiles. Since the beginning of its activity, in that sense, Dimmons operates in a framework of competitive evolution between universities and research centers, and at the same time in new collaboration dynamics to achieve not only academic impact but also social impact, as we will see. In that sense, therefore, the case study reflects a way of addressing a series of current challenges and complexities that research groups experience between long-term strategic vision and day-to-day project management.

The Dimmons research group is focused on transdisciplinarity and action research for the study of socioeconomic innovation and the collaborative economy, from the perspectives of economic and public policy analysis. The group's composition since its beginning has evolved into a networked structure (Spinuzzi, 2015) which consists of different "layers" of participation (all of them involved with its strategic planning, as we will see in the results section). The action-oriented character of the research group, and its specialization in collaboration dynamics, makes it a case study particularly adapted to develop a novel approach, concretely in terms of opening up its strategic planning process by applying co-creation methods. This was seen early on as an opportunity to engage with its core team members and network of close collaborators, as well as with other representative stakeholders from the Dimmons community and ecosystem. In sum, the coincidence that the research group had to develop its own strategic planning, has an experimental and action-oriented approach, which added to its expertise on collaborative dynamics, made the Dimmons group a good case for the study. Regarding the first research question on how co-creation methods could be adapted for strategic planning, Dimmons was a good choice due to the group's regular adoption of participatory design techniques. On the other hand, Dimmons' novel adoption of APM (Senabre Hidalgo, 2018a) also favours addressing the second question,

[14] IN3 strategic plan: https://www.uoc.edu/portal/en/in3/coneix/pla-estrategic/index.html
[15] UOC strategic plan: https://www.uoc.edu/portal/en/universitat/pla-estrategic/index.html

regarding the impact of the co-created strategic planning on the group's day-to-day management.

As a general result of the co-creation of the strategic plan, in which more than 40 people participated, there were a total of 38 actions defined in accordance with 6 strategic goals for the period 2018-2023, each one with an average of three key performance indicators (KPI) associated (97 in total). Its final version was published online on the Dimmons research group webpage[16]. After one year of implementation, by the end of 2018, 24 of the 97 KPIs were accomplished satisfactorily. This result represents an accomplishment of 24%, and considering that a 5-year period is envisaged for full implementation of the plan, suggests satisfactory performance in terms of achieving the co-defined goals during the first year.

2.2 Participatory design for how to apply co-creation in strategic planning

Regarding the first research question ("How can co-creation methods to be used in leading strategic planning process of a research group?") the methodological approach was qualitative, based on participatory design. Departing from the key consideration that participatory design is indeed a methodology of action research (Spinuzzi, 2005), and benefiting from co-creation derived from design thinking methodologies (Kimbell, 2012), which have proven to improve participant engagement in research (Senabre Hidalgo et al., 2018), we established different visual and discussion techniques at each stage of the process for the effective participation in a transdisciplinary context. The participatory design was developed and data collected from the fall of 2016 through 2018. The methodology applied is consistent with the participatory design notions of user-centered co-creation, in detailed stages and techniques such as those described by Naranjo-Bock (2012) for (1) self-reflection of research methods (focusing on research goals and questions, who the participants are and what tools they can use, the stage of the project, etc.); (2) running co-design activities onsite, with techniques and "placements" like context mapping, storyboards, inspiration cards, diagrams or paper prototyping; (3) pilot testing and results, where the data obtained is generally visual and tangible, accompanied by the important debrief of the results of each participatory design session or process.

Following that approach, and adopting the framework of Spinuzzi (2005), through different qualitative techniques the co-creation process was structured around the three key phases of: (1) Initial exploration of work, where participants meet each other and commonalities are identified, as well as for preliminary discussions; (2) Discovery processes, when design facilitators employ various techniques to understand and prioritize work organisation, clarifying the participant's goals and values; and (3) Prototyping, a final stage for iteratively shaping outputs and assessing results. The data came from a range of sources, including offline co-creation sessions and team meetings, meetings and interviews with some researchers and collaborators, as well as documentation resulting from the different phases and sessions of the strategic planning. Outputs of each participatory design stage were recorded in detail as they took place, through documents shared online.

[16] Dimmons strategic plan: http://dimmons.net/strategic-plan-2018-2023/

2.3 Content analysis for the impact of a co-created strategic planning on APM of research

Regarding the second question ("What would be the impact of co-created strategic planning on the agile project management of research?"), the approach was based on quantitative data collection and text analysis, in order to address how far the co-creation methodologies had an impact on the group's project management, focusing on the researchers' discussions and behavior through digital channels. The analysis was based on extensive content analysis of two of the main online coordination tools for the AMP of the group: a chat group for daily communication and an online kanban board platform for task management.

2.3.1 Telegram chat content analysis

The "Dimmons al dia" Telegram chat group was adopted from February 2016 until the end of 2018 as a first approach to daily standup meetings, inspired by the Scrum method derived from APM for software development (Cervone, 2011). Scrum, which is one of the most adopted agile frameworks for managing knowledge work, facilitates the coordinated activity of participants who break their work into small tasks that can be completed within fixed duration cycles or "sprints", tracking progress and re-planning in regular meetings in order to develop projects incrementally (Senabre Hidalgo, 2019). Via Telegram, on a daily basis from Monday to Friday each Dimmons team member (a total of 15 users, through different periods over time), via a short message during the morning period, informed others about the planned tasks for the day (Figure 1), among other coordination discussions that took place regularly on that chat tool between team members.

Figure 1: Screenshot of the Telegram chat group for daily updates about tasks.

A combination of computer-assisted massive text analysis and comparative visualizations[17] for these chat discussions on the Dimmons Telegram group was used, after dumping and extracting to plain text the full history of the "Dimmons al dia" chat

[17] Via https://voyant-tools.org/ (web-based text reading and analysis open source environment) and https://rawgraphs.io/ (open source data visualization framework).

group since its creation (a text corpus mainly in Catalan, which is the normal language of team members). The data gathered consisted of the complete history of messages from 2 September 2016 to 27 December 2018 (28 months of activity). This represented a corpus of 6,520 messages, with a size of 794,464 characters in 6,941 lines of text.

Afterwards, in order to compare the different flows of communication in relation to the co-designed strategic plan of the research group, it was decided that the date on which the first strategic planning team workshop took place (20 December 2017) would be used as the key date for dividing the chat history in two plain text documents: "Xat Telegram Dimmons al dia 2017" (pre-strategic plan period, until 20 December 2017, with 78,644 total words) and "Xat Telegram Dimmons al dia 2018" (post-strategic plan period, after 20 December 2017, with 83,200 total words).

As a first step in the analysis, prior to coding, the plain text obtained from each document was processed as a tabular view of terms frequently used in the entire corpus. That is, a list of the most used terms for the period 2017 and a list of the most used terms for the period 2018. This facilitated an initial overview of recurrent terms, which could then be filtered and coded, identifying multiple stop words to exclude (non-relevant meaning, numbers, ambiguous terms, etc.) and on the other hand selecting specific words related to categories to include in the analysis. The coding of data obtained in this way consisted of the clustering of words relevant to the following two categories:

1. Coordination-related terms: data about terms related to time periods or days (today, tomorrow, now, etc.), general work-related keywords (meeting, call, document, task, pending, etc.) as well as specific verbs (preparing, sending, finishing, etc.).
2. Strategy-related terms: data about terms related to the six main goals of the Dimmons strategic plan (as described in the results section), for (1) academic impact (paper, data, review, survey, specific projects, etc.); (2) open tools (platform or toolkit-related); (3) ecosystem (specific partners mentioned, dissemination or projects); (4) team care and empowerment (words related to good climate among members, greetings, gender topics, etc.); (5) sustainability (new proposals, specific projects for new funding); and (6) university shift (references to the university or research center).

2.3.2 Kanban board content analysis

In January 2017 (when the strategic planning was co-designed) the Dimmons team adopted an open source project management software (https://kanboard.org/) for additional APM practice, such as the use of an online kanban board for visualizing the flow of tasks accomplished by core team members (Figure 2).

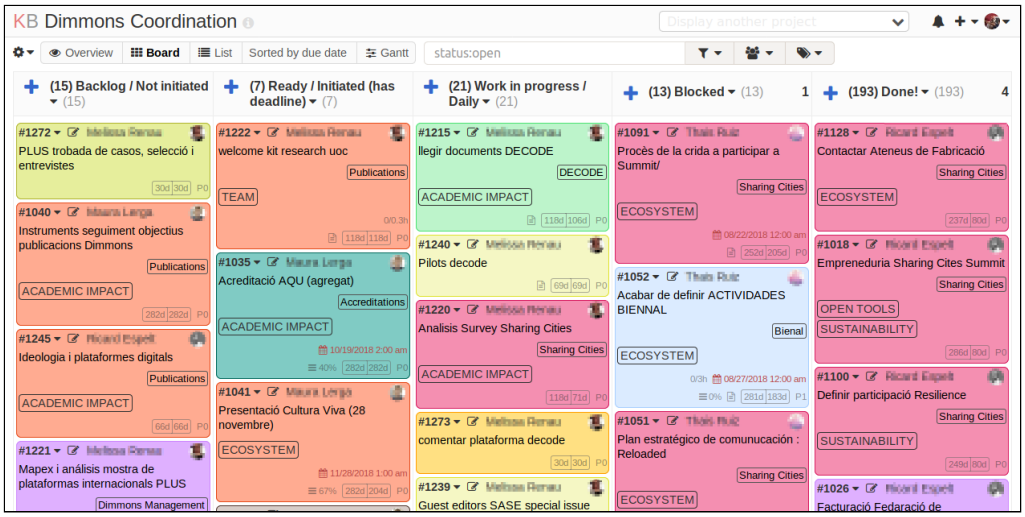

Figure 2: Kanban board reflecting the workflow of tasks of team members, related to strategic goals and specific projects.

For this, in connection with the six strategic goals defined in the co-design phase, each planned task could be properly tagged (selecting “academic impact”, “open tools”, etc.) according to the researchers criteria. Additionally, tasks could be classified by selecting from a dropdown menu the corresponding project or category (specific projects, management tasks, dissemination, publications, events or initiatives related to networking, etc.). An analysis of this workflow-related data on the Dimmons online kanban board during the mentioned period (with different levels of participation among the nine core team members, depending on their familiarity with digital tools and perception of utility) allows for an understanding of the evolution of planned and achieved tasks in relation to the Dimmons strategic plan, as well as among team members.

Data obtained from the Kanboard log comprised details about a total of 166 user-defined tasks, in relation to tags selected (for the six strategic goals), category of project selected (among the 11 existing projects and initiatives during 2018), user activity, level of accomplishment, due dates and task description, among others. In this case, the coding related to the strategic goals was self-generated by each user at the moment of naming and defining the task, by selecting the most appropriate tag in relation to the strategic goals.

3. Results

This results section is divided into two parts, which address the research questions with the methodologies described above. First, we outline how the co-design process of the Dimmons research group planning unfolded, describing the methods used as well as its internal and management implications, based on the participatory design process itself. Secondly, we summarise the main results of the impact of the process on the group’s project management and regular communication in relation to its experimental co-creation approach, derived from the content analysis of the main coordination channels used during the regular activity of Dimmons.

3.1 How can co-creation techniques and principles be used in leading the strategic planning process of a research group? Insights from the participatory design of the Dimmons strategic planning

In relation to the first research question, about how the strategic planning process of a research group can adopt co-creation methods, the participatory design practices and principles adopted resulted in an iterative, dialogic and eminently visual approach to strategic planning. Questions related to participants ("who"), sequence ("when") and methods ("how") were of critical importance since the beginning of the process (Table 1).

Participants (*who*)	**Sequence (*when*)**	**Methods (*how*)**
● Participation as ecosystem ● Power law dynamic (1/9/90) ● Decentralised	● Iterative ● Convergence and divergence stages ● Organic	● Initial exploration of work ● Discovery processes ● Prototyping ● APM

Table 1: Key questions for co-created strategic planning in the Dimmons case study

"Who": Participation as ecosystem

In contrast to the traditional strategic planning process, developed by the group's core team only (i.e., those with strong ties to it), Dimmons adopted a broader perspective in which the basic principle for co-creation that emerged was the concept of "participation as ecosystem" (Fuster Morell, 2010a). That is, the Dimmons research group could be considered a research ecosystem with diverse forms and degrees of involvement, following the structure of a "power law dynamic" (or "1/9/90") in online collaborative production (Fuster Morell, 2010b). This reflects the composition of the participation that took place when articulating the strategic planning process, according to the three layers of the Dimmons research ecosystem:

1. Core Team: Director, postdocs and PhDs with grants, and research assistants (9 people).
2. Dimmons "Community": University professors, former visitors, external researchers, experts and practitioners on Dimmons areas (12 people).
3. Dimmons "Ecosystem": Representatives of a network of institutions with further collaborative relations, target impact or audience (10 participants from a total of 32 private and public organisations).

In relation to this, a first observation regarding how to apply co-creation in strategic planning has to do with the suitability of adopting a broad, open and participative approach, as well as decentralised approaches for higher engagement and performance in dynamic environments (Andersen, 2004). For this reason, who to involve in the process became a critical aspect, considering that ecosystemic participation is also meant to engage the research group community and stakeholders in the process (not only highly involved team members). In this case, the open

invitation to all members of each layer of the ecosystem, as defined above, resulted in the "power law" distribution, of which only a small representation were engaged in the process but with a high level of involvement through the different co-creation sessions. Defined as a modular sequence, with the possibility of joining the process at different times, also allowed for a wider participation than if following a rigid and traditional strategic planning approach.

"When": Iterative sequences of convergence and divergence

The iterative unfolding of the co-creation process was another main characteristic. That is, rather than a predefined sequence of steps, the guiding principles were based on the participatory design notions of "convergence" and "divergence" (Sanders et al., 2010). This allowed for several divergence instances (during which a considerable number of possibilities regarding goals, ideas, SWOT factors , etc. were generated by participants), followed by intense convergence stages of synthesis (where the main options were presented, discussed and finally selected via different mechanisms).

Departing from that key consideration in co-creation, and its adaptation of a sequence guided by participatory design methods (Spinuzzi, 2005; Sanders and Stappers, 2008), the overall approach of the participatory design integrated key notions in literature for effective strategic planning (Wilson, 1994). In this respect, the organic and iterative development of the process as a co-creation sequence was consistent with the four stages of a strategic plan, as defined by Eppler and Platts (2009): analysis, development, planning and implementation (Figure 3).

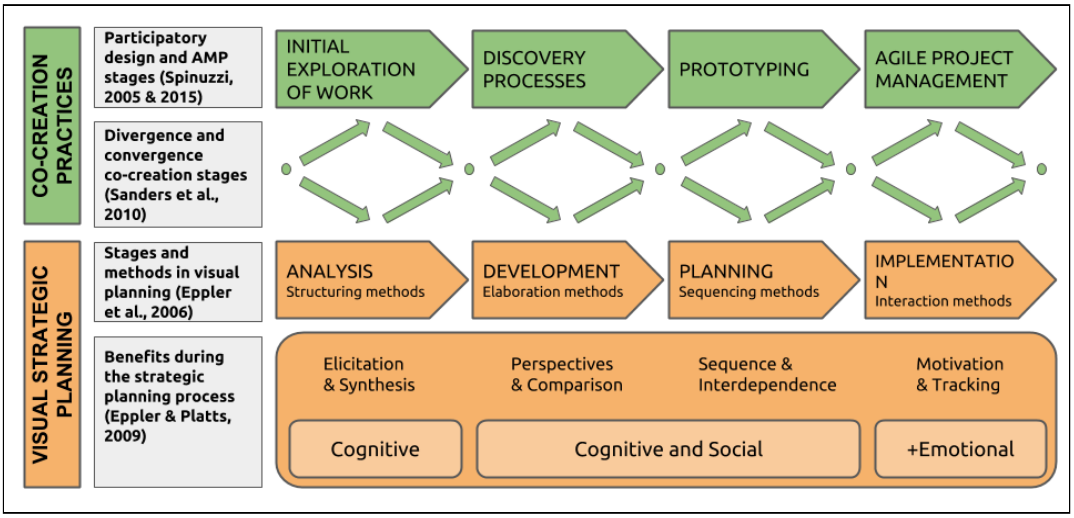

Figure 3: Stages followed in the co-creation of the strategic plan of the research group, connecting co-creation approaches (Spinuzzi, 2005; Sanders et al., 2010; Spinuzzi, 2015) with visual strategic planning (Eppler et al., 2006; Eppler and Platts, 2009).

As reflected above, a key consideration derived from the case study in relation to its temporal sequence is that it was possible to establish a clear coherence between the literature of co-creation and participatory design (Spinuzzi, 2005; Sanders et al., 2010; Spinuzzi, 2015) and of visualization techniques for strategic planning (Eppler and Platts, 2009; Eppler et al., 2006).

"How": Integrating co-creation methods in strategic planning

The co-creation process unfolded by connecting the different participatory design stages to specific phases of strategic planning, via a combination of five sessions in total and the adoption of nine co-creation methods (in offline but also online formats), and with the regular participation of diverse participants from the Dimmons research ecosystem (Table 2).

Participatory design stage (Spinuzzi, 2005)	**Phase of strategic planning**	**Co-creation method**	**Meeting format**	**Participants**
Initial exploration of work	Individual research approaches	DIY accreditations	Offline session	First co-creation workshop: Core team + Community members (16 participants)
	Areas of interest in research	Lightning talks + Concept clustering	Offline session and Online	
	Methodological orientations	Dotmocracy	Offline session	
Discovery processes	Mission and guiding principles	Survey #1 + Shared document	Offline session and Online	Second co-creation workshop: Core team + Community members (10 participants)
	Map of the ecosystem	Survey #1 + Diagram	Offline session and Online	
	Competitive analysis and SWOT analysis	Survey #1 + Card clustering	Offline session and Online	
	TOWS matrix[18]	Shared document	Internal meeting and online	Core team (4 participants)
Prototyping	Strategic objectives	Brainstorming + Shared document	Online	
	Actions and key performance indicators (KPI)	Shared document + Survey #2 (for priorisation and validation)	Offline session and Online	Core team + Community members (10 participants)
	Roadmap and actions	Shared document	Offline session	Core team (4 participants)

Table 2: Dimmons strategic planning according to participatory design stages, methods, format and number of participants.

In this way, the first co-creation workshop (Figure 4) focused on mapping personal attitudes and strengths, experience in methods and research approaches, which contributed to visualizing methodological affinities within the group.

[18] While the SWOT analysis focuses on opportunities and threats at external and internal levels, the TOWS matrix is a technique for strategy generation and selection, opted at the later part of the planning process to decide the way forward.

Figure 4: Different moments and materials used for the workshop sessions with the research team.

Following the mentioned co-creation principles of "convergence" and "divergence" (Sanders et al., 2010), the second co-creation workshop departed from the first survey results to engage in a broader discussion about the mission and guiding principles of the group, which were discussed and re-edited offline during the debate. That second session also adopted a card-sorting technique for clustering the survey results of the SWOT. During the second co-creation workshop, a first version of the map of the Dimmons ecosystem was also drafted and discussed. An important part of this participative analysis stage of the planning was the collective identification of the "ecosystem" or external environment in which the group operates. For this, a key activity was the collective mapping of the different institutions and agents with which Dimmons collaborates or has a relevant relationship, bringing the concept of ecosystemic research closer to the perspective of the Quadruple Helix for innovation systems (Carayannis and Campbell, 2012). In contributing to the generation of an internal environment of transparency and openness, it is important to consider that all the dynamics took place in a context of action research where the majority of participants were familiar beforehand with similar methodologies and processes to integrate diversity and explicit points of view. Also noteworthy is the general absence of conflict situations during the whole process, and that initial discussions about methodologies and specific theoretical perspectives were activated early on. This was probably due to the fact that it was based on a small core of participants who were already cohesive around the Dimmons team, joined by other actors with diverse theoretical backgrounds and experience, and for that reason each session was oriented towards the search for synergies and learnings, making explicit the knowledge, expectations and opinions of the majority of the group. However, it should also be pointed out that sometimes during the discussion, the opinion of those with a consolidated academic profile tended to weigh more and took more preeminence, in contrast to predoctoral researchers or participants with a profile not linked to academic research.

As another important element of the group's strategic thinking in this case, the final stages of the process not only had as benchmark reference the IN3 research center's strategic goals, but also the potential connection with the Sustainable Development Goals (SDG) and Responsible Research and Innovation (RRI) principles. The SDGs are a collection of 17 global goals set by the United Nations for addressing urgent issues like poverty, education, gender equality, energy, environment or social justice, among others (Griggs et al., 2013). RRI is a multidisciplinary approach promoting the involvement of stakeholders and civil society in scientific activities for developing more inclusive innovation processes (Owen et al., 2012). This element of strategic planning around external indicators represented for all participants a first approach to new principles and a series of values, leveraging perspectives and discussions around the key aspect of social impact of research beyond the academic context.

As a final result, among the different key elements that are usually integrated into a strategic plan (Eppler and Platts, 2009), the definition of six strategic goals were incorporated into the first draft of the document (considered as a "prototype") of six strategic goals: (1) Academic impact ("generate a high-quality research corpus of theoretical framework on socio-economic innovation"); (2) Open tools ("contribute to processes in action for the resolution of social challenges by developing research-based resources"); (3) Ecosystem building ("consolidate a 'glocal' network of partner organisations for quadruple helix collaboration to favour social impact and resilience"); (4) Empowered team ("consolidate the team with complementary backgrounds, healthy environment and gender-balanced talent"); (5) Catalytic sustainability ("obtain funding for action research from competitive calls with high impact and visibility"); and (6) University shift ("engage with open access, "commonification" processes, transdisciplinarity, agile principles and other changing paradigms in the academic culture").

3.2 What would be the influence of co-created strategic planning on the agile project management of research? Insights from the analysis of impact in Dimmons coordination

Once the strategic plan was finished and shared online as a definitive version, it was incorporated into the day-to-day activities of the research group, both explicitly (by incorporating the strategic goals as categories in the group's agile kanban board for task management) and implicitly (by guiding topics of conversation, and being in the background when regularly communicating online and offline). In order to analyse it and answer the second research question of this study, on what would be the influence of a co-created strategic planning on the APM of research, a series of content analysis on the main coordination digital channels provides different elements for discussion, especially from an action research perspective.

3.2.1 Dimmons Telegram chat content analysis

The evolution of user's daily participation on the Telegram chat during 2017 and 2018 suggests that once the strategic planning was co-designed and adopted (at the end of 2017), the communication dynamics evolved from being relatively asymmetric (with

just a few very active users) to a much more balanced distribution where all members contributed, following the "standup" meetings and derived conversations (Figure 5).

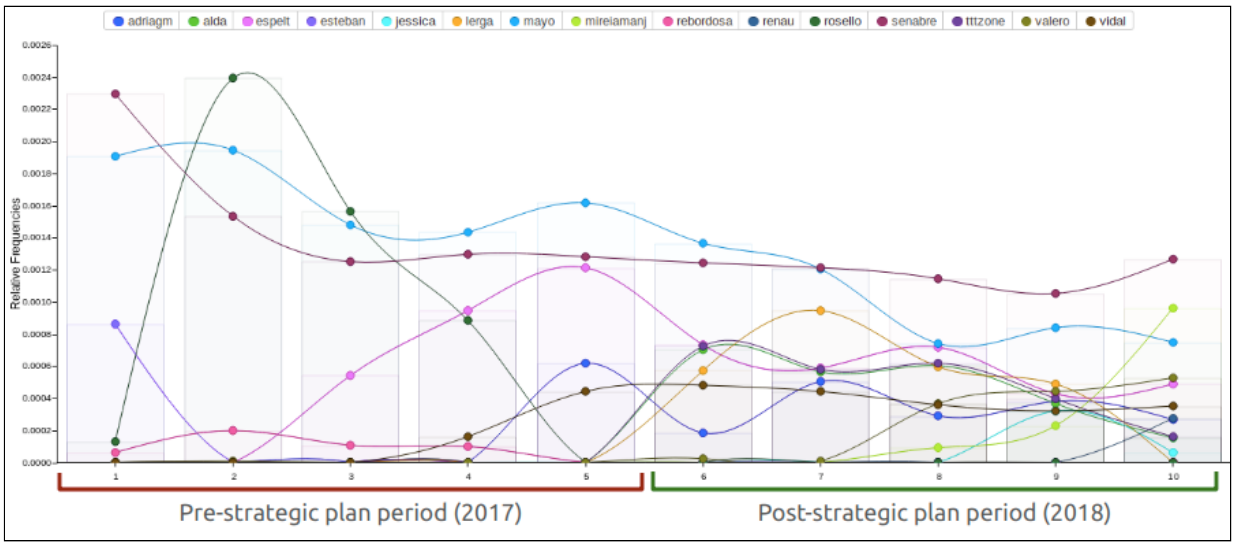

Figure 5: Evolution of user participation in "Dimmons al dia" Telegram group chat during 2017 and 2018

More specifically, from a medium used by nine participants over a timeframe of approximately two years, the co-design and implementation of the Dimmons strategic plan between December 2017 and January 2018 seems to set a landmark between a relatively unequal distribution of messages among team members (where only a few of them contributed, at very different levels) to a regular pace and volume of interventions by the majority of participants. This probably derived from applying the strategic planning as a co-creation sequence, thereby as an integrative and socialization process. In this sense, it should be noted that among the observations about the daily communication of the group through the Telegram channel, most messages and discussions focused on the planning and execution of tasks, both academic (writing articles, organisation of workshops, data collection, etc.) as administrative (agenda management, budgeting, event logistics, etc.). In contrast, during the day-to-day of the group and outside of the co-creation process itself, theoretical or conceptual discussions normally took place in other spaces and moments, normally during the development of face-to-face meetings between two or more members of the group (before and after the strategic planning process).

On the other hand, if we look at data from the content analysis of the daily update "standup" messages in 2017 (again, prior to the strategic plan) compared to the corpus of terms used in 2018 (once the strategic planning was in place) patterns also demonstrate a coincidence with a significative increase of terms related to the different strategic goals, and therefore a probable influence of the strategic planning on the daily communication of the group (Figure 6).

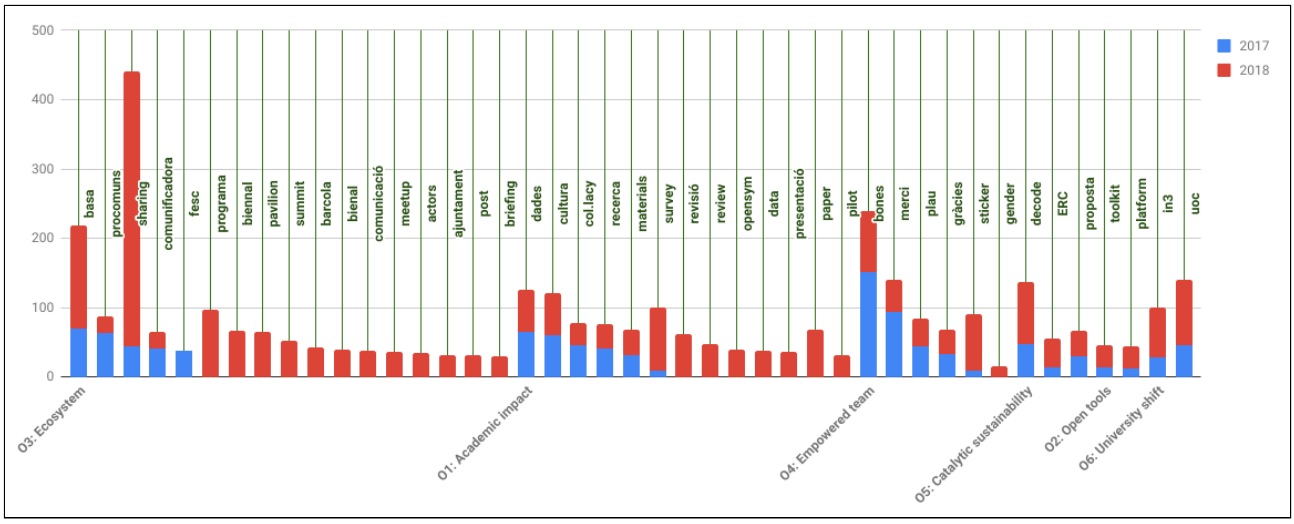

Figure 6: Comparison of mentions to Dimmons strategic plan related terms in Telegram between 2017-2018

This reflects a relative imbalance in how the different goals were addressed during both periods. While, according to these results, the attention to the group's ecosystem and to academic impact where at the center of activity, there was much less activity, in terms of percentage, related to others such as the generation of open tools or team care. This imbalance simply demonstrates that after year one, of the five goals covered by the strategic plan, the group gave priority to tasks and processes related to its ecosystem (specific partners, collaborators or events) as well as pertaining to academic impact (publications, data, surveys, specific projects under development). What seems significant from this data, apart from how it can serve as a parallel indicator to the group's agreed KPIs, is the increment and diversity of terms related to the strategic plan in the regular conversations and update messages on the Telegram chat for the 2018 period (and to what extent they were more relevant than in the previous year, before the co-design of the strategic plan took place).

In relation to the adoption of APM methods (in this case, establishing additional regular weekly meetings and the use of a digital kanban board, beyond the daily updates via Telegram), the increment there between 2017 and 2018 in vocabulary related to coordination tasks, timing and other key terms is also significative. Specially the preeminence of messages containing words like "today", "pending", "version", "tasks" or "meeting", which doubled in general compared to 2017.

Again, patterns show a wider use of vocabulary in coordination-related communications, with reference to tasks informed on a daily basis, once the co-creation process around the strategic planning of the research group took place. This suggests not only that team communication incorporated more perspectives related to the Dimmons strategic goals, as observed above, but also more references to general coordination and therefore the operative awareness of the group.

Finally, if we focus on 2018 (the period of the co-designed strategic plan), another relevant analysis of the content data gathered via the daily updates and conversations on the Telegram group chat, is the extent to which it reflects a very similar proportion

of conversations about specific areas of the strategic goals (Figure 7) for the tasks defined on the kanban board. In both cases, the majority of references during 2018, coincidentally, focus on academic impact and ecosystem building, followed by a corpus of team-related and university shift terms.

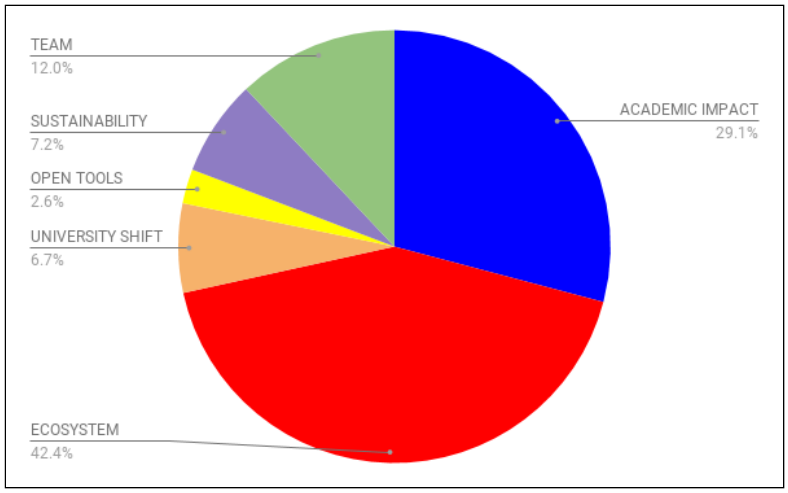

Figure 7: Percentage of terms related to Dimmons strategic goals on Telegram chat during 2018

3.2.2 Dimmons kanban board content analysis

As mentioned above, the results of the tags used most on the kanban board related to the strategic goals, when informing the regular tasks of team members (Figure 9), point to a very similar distribution as in the previous analysis of the Dimmons main Telegram chat (Figure 8), where academic impact and ecosystem creation are the most selected ones, followed by a smaller proportion of the other four categories:

This suggests that both patterns coincide as an indicator of the most influencing priorities for the team derived from the strategic plan, but more importantly points to a coherence on a shared vision as an action research group derived from the co-design process. Also, this result when comparing content on the coordination channels, suggests a consistent integration of the strategic goals with the APM methods, ensuring an interconnection between the strategic plan goals and the daily activities.

Another result from the task-related data gathered via the kanban board is to what extent there's a good balance of members contributions to the projects and initiatives connected to the strategic goals. Instead of a specialization pattern or "monolithic" distribution of projects to researchers, despite the different levels of participation informing planned tasks between users, results show a relevant quality of teamwork in terms of shared projects and cross-functionality.

Additionally, the extent to which specific projects not only comprehended tasks related to different researchers but also to the various strategic goals, suggests a coherent and transversal categorization when researchers classified their regular activity in relation to the strategic plan. Data obtained from activity on the kanban board, when compared with activity on the Telegram chat informing about planned tasks for each day, also

shows a clear correlation between the content generated in both channels and terms related to the different strategic goals. As already indicated, however, not all the core team members used the kanban board with the same level of regularity (as opposed to the Telegram daily updates, where participation followed the same volume and pace for all team members), with the main reason probably related to the difference in the levels of familiarity with digital tools for management.

4. Discussion

With this study a prototype and analysis of a co-creation methodology for the strategic planning process of an action research group was developed. Regarding participation, guided by a 'strategy-as-practice' approach in project management and the concept of ecosystemic research, the case study integrated the diversity of perspectives and voices of more than 20 participants in total. This way of proceeding generated a key mechanism for team integration and coordination within the group, and also with its external layers of collaborators and stakeholders, which were also represented through the process. As data indicate, this required a combined approach of co-creation methods and iterations, which followed principles of participatory design and online participation. As a consequence, besides a fully defined document for the strategic roadmap of the group activity, the different actions co-defined by the core team and its ecosystem of collaborators achieved a satisfactory level of accomplishment after the first year of implementation.

In relation to the first research question, on how co-creation methods can lead the strategic planning of a research group, our study points to the possibility of developing strategic planning processes with such methods. In this respect, our contribution reflects the key methodological aspect of integrating participatory design techniques for structuring the process. This aligns with theories connecting principles of action research in social sciences, and especially co-design in the context of organisational learning, in terms of tacit and explicit knowledge transfer processes as well as constructivist approaches to addressing complexity and uncertainty in teamwork (Argyris and Schön, 1989). The analysed case study of Dimmons, in this sense, seems coherent with a wider consideration of design thinking as a practical approach for enabling transdisciplinary collaboration and as a process for "shaping processes" (Lindberg et al., 2010). In our opinion, as addressed in this case, this connects to the need to adapt strategic planning to co-creation practices as a decentralized, integrative and iterative dialogue (Wolf and Floyd, 2013). Our analysis also suggests the opportunity for the utilization of academic strategic planning as a means of integrating the values of the social impact of research, such as those derived ones from SGD and RRI, which can be adopted as a landmark when addressing academic and scientific activity from a collaborative and ecosystemic perspective. Observations and outputs from this process reflect that it allowed for deeper insight into discussions and comparisons about research methods, in many cases for the first time among team members. By "voting" for preferences and visualizing expertise in such explicit ways, and selecting a wide range of possible methods, the iteration and parallel discussion allowed for the identification (later on the strategic planning process) of several areas of improvement and implications for the group composition in the mid and long term. All the data generated and shared as open documentation during this first initial exploration stage

of the strategic planning, concerning the group's composition, allowed on the one hand, the identification and mapping of opinions, basic assumptions and implicit understandings around research that needed to be surfaced, and on the other one the initiation of the co-creation of the strategic planning with the needed openness and implication of all participants.

Regarding the applicability of the model to managing research projects in other scientific research contexts, the type of participatory co-design described and the degree of involvement of the different layers of stakeholders probably require departing from reduced, cohesive teams and familiarity with principles of action research or community-based research, frequent in the social sciences. In this sense, it is important to highlight that, as detailed in the first part of the study, the concept of impact of research was regularly taken into account beyond the academic context, as a requisite to integrating in the strategic planning other perspectives that do not come from the scholarly context. As another relevant element derived from the results of the study, when prototyping the co-design process in connection with previous research on visual strategic planning (Eppler et al., 2006; Eppler and Platts, 2009), it should be noted that the iterative sequences of convergence and divergence of each phase allowed the described levels of participation and integration of perspectives. Again, considering it a strategic thinking process that is likely to be generalizable in research contexts in which, beyond academic and administrative tasks, there are conditions for the consideration of different types of research impact for initiatives in the medium and long term.

Regarding the second research question, the results pertaining to the impact of the co-created strategic planning on the group's APM coordination and communication routines (and specifically data about terms related to the strategic plan) suggest that it contributed significantly to a shared vision and helped to deal with the inherent complexity of research activity (Fuster Morell, 2012). In this sense, with respect to the positive influence of a co-created strategic planning on the APM of research, our method provided results complementing previous studies (Rand and Eckfeldt, 2004). Specifically, we described how the integration of strategic goals with the agile management of daily tasks can serve as a parallel indicator to KPI used in strategic planning, and how such integration can provide immediate user-generated information for assessing the implementation of the plan (as compared to the usual retrospective checking of KPI over longer periods of time). Taking into account the need to connect strategic plans with managerial practices during the implementation phase (Poister, 2010), this combination of co-design techniques and AMP practices for the strategic planning of the Dimmons research group reflected the importance of design features and social mechanisms for successful strategic planning (Barzelay and Jacobsen, 2009). The data compared between the period prior to the strategic plan and its co-creation process suggest, on the one hand, an increase in the group's cohesion through its daily communication and coordination channels, and on the other, an alignment in terms of discourse and follow-up of the objectives set. Again, in relation to being able to extrapolate the results of this process to other contexts, it is probably key to start with some previous experience with basic principles and practices of project management, and especially those based on AMP. However, as we reflect in the first

part of the study, on the state of the art in social studies of science and team science with respect to the management of research projects, as well as the progressive need for mechanisms of efficiency and collaboration in academia, it is likely that this type of approach could be useful and produce similar results in other types of scientific and research initiatives.

Despite the above, the results also show a relevant imbalance between the accomplishment of some of the strategic goals after the first year of implementation of the strategic planning, with a significant dedication of efforts to "ecosystemic activity". This suggests that, from an action research perspective, after the participative design process there was a greater priority given to the perceived need for addressing tasks related to community events, meetings with stakeholders, institutional agreements or online dissemination. In contrast, according to the data derived from the combination of KPI compared with the volume of specific tasks defined in the APM coordination channels, critical aspects of research management related to team building or open tools did not receive as much attention and effort in comparison. In our view, besides the experimental character of the case study (and the novelty of its research group focus), this result also relates to the current context of pressure and complexity within "accelerated" academic organisations (Vostal, 2016), which represents a challenge in front of competition for excellence (Sørensen et al., 2015) and the "projectification" of university research (Fowler et al., 2015). In this sense, in relation to the day-to-day activity of the group connecting strategic planning with co-creation principles of APM in research, it was observed that the experience also increased the need for the project management role or main facilitator of the entire co-creation process. In this regard, it was usually complicated to separate that function, as the guide of the participatory design of the strategic plan, from the wider role of APM coordinator.

This study's limitations and potential mainly have to do with two areas. On the one hand, the content analysis of the kanban board covered an early stage of its adoption, but in comparison to the Telegram chat activity not all participants used the system with the same level of intensity and engagement. As explained in the results section, however, the relative coincidence with percentages of strategic-related terms between both channels suggests it worked as a relevant source of data for assessing the implementation of the strategic plan. In relation to the co-creation process, this limitation (related to an unequal adoption of APM coordination by the majority of the group), represented a challenge for some participants, and probably affected its impact during the implementation stage of some of the strategic goals. As mentioned, the degree of familiarity with digital tools for project coordination, as well as with internal discussion processes and personal positioning in research projects, seems a key factor that also requires future analysis in other academic contexts, to determine to what extent similar processes of co-creation and strategic thinking can be applied in the field of social sciences and in other disciplines. On the other hand, following this type of exploratory analysis, the need to observe and compare data generated by other research groups that apply similar (or different) methods for project management and strategic planning creates in our opinion a potential for future research, and would allow for further understanding of such an important area of meta-research. In this line, another analysis based on the case study of the Dimmons research group for a

different period in the near future, in order to compare the evolution of KPI in parallel to communication and coordination related to tasks until 2023, would be needed to confirm some of our initial results.

Through this study we have described how strategic planning could be applied to research in order to confront current challenges in academic collaboration, and how to do so through the opportunities offered by co-creation methodologies applied to project management. Our analysis has identified potential benefits and challenges in this respect, suggesting further development of this field in the social sciences and action research, and proposing it as a possible area of research and development in parallel to other documented and studied efforts to deal with innovative and agile management of scholarly work. Besides an analysis of its impact at the communication and relational levels, our study also offers a detailed description about how co-creation for strategic planning in research could be applied, which could be of practical interest for scientific institutions in relation to their project management practices.

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THIRD PART: GENERAL CONCLUSIONS AND DISCUSSION

7. Summary of research results

This chapter presents the most relevant results and observations from the publications in connection with the point of departure of this dissertation: how from scientific teams integrating experts in different disciplines, to action research or citizen science projects involving laypeople, the current increase of diversity when planning and the additional complexity for research management in transdisciplinarity could benefit from co-creation. In relation to it, results through the different case studies and publications specifically address the following research questions:

1. How can co-design help to integrate diversity for the collaborative ideation of research processes in transdisciplinary contexts?
2. To what extent is it possible to co-develop complex transdisciplinary projects following agile project management principles?
3. At the intersection between the ideation and the management of projects, how can both co-design and agile co-creation techniques be combined for the strategic planning of transdisciplinary research?

The following summary of results is also based on the key factors reflected in the introduction, which have been considered transversal to the fields of co-creation and collaboration in research (Table 1, page 16). These factors are visualisation; engagement; communication; transparency; task distribution; trust building; efficiency; quality of results. Additionally, the summary takes into account the classification of scientific collaboration stages as defined by Sonnenwald (2007): that is, the foundation, formulation, sustainment and conclusion phases of such collaboration (Figure 2, page 13). The combination of the main focus, specific research questions, key transversal factors and stages of collaboration in research configure the analytic framework of this dissertation, which guide as indicated in figure 9 the summary of results through the following sections.

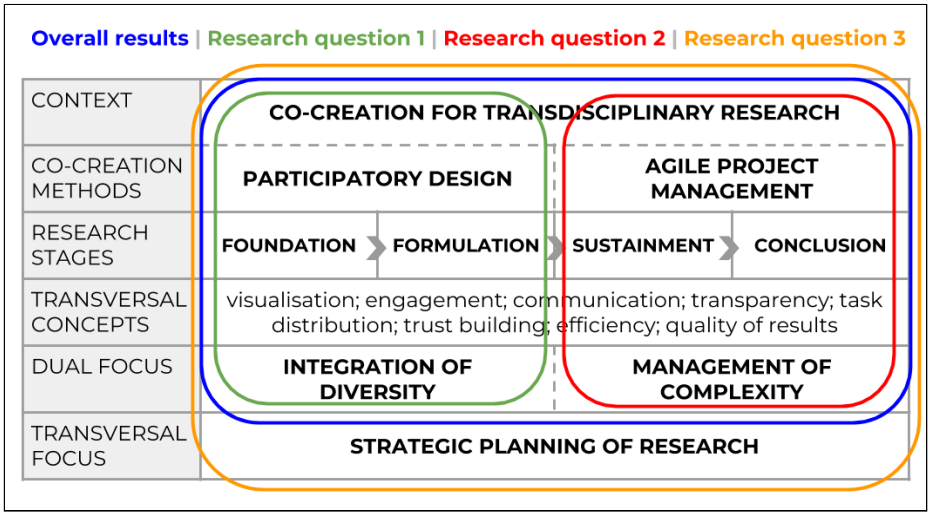

Figure 9: Analytical framework of the study in relation to results summarised in the different sections of this chapter.

The first section provides the overall results in an integrated overview of co-design and agile project management as co-creation practices applied in transdisciplinary research, both from a shared perspective. This departing point for presenting results is not explicitly reflected in any of the three research questions but it is transversal to all of them, following the rationale of first addressing common concepts about co-creation as a whole. The second section of this chapter focuses on results around participatory design applied to transdisciplinary research foundation and formulation stages (research question 1). The third one provides a summary of specific results derived from the case studies that inform the adoption of agile project management, in this case for the sustainment stage of research processes (research question 2). The third section establishes the connection of co-creation with the strategic planning of research, based on results from the two final publications of the compendium (related to the research question 3). Finally, previous to the research discussion, the last section about results briefly addresses some limitations of the analysis and approach of the various case studies.

7.1 Co-creation approaches for transdisciplinary research: overall findings

As reflected in the introduction and state of the art of this dissertation, one of the challenges in today's scientific practices is the level of uncertainty and complexity that can emerge when managing transdisciplinary research, especially when it comes to dealing with the integration of different expertise and perspectives of participants from inside and outside academia. Whereas for the foundation, formulation or sustainment stages of collaborative projects, the context of networked teamwork, combination of disciplines and accelerated pace of academic activity require new approaches to collective ideation and management of research.

In view of this, the main goal of the thesis, from a meta-research perspective, has been to explore the application of co-creation methods and principles in different types of transdisciplinary contexts. For this, a fundamental question was to establish a connection between participatory design and agile project management under a shared perspective of co-creation. In this respect, results from this research are closest to that of authors understanding co-creation as a wide field of practices for collaborative work and creativity. This approach is based on the broad literature review in the first part of this dissertation, as well as on the results of the case studies and participant observation when facilitating co-creation workshops (with different research groups and stakeholders). On this basis, my study contends that agile project management and participatory design derive from a shared tradition of user-centered co-creation practices influenced by digital culture.

Generated and formalised in the core of communities of practice in the context of design thinking and software development, respectively, both co-design and agile have also been observed as coherent co-creation frameworks under an action research perspective. Furthermore, both represent a type of co-creation that can be adopted in different ways for managing complexity and uncertainty in transdisciplinary research,

as it has been analysed throughout this study. More specifically, these co-creation practices can contribute to several stages of research collaboration, thanks to visualization techniques, dynamic ways of communicating and generating discussion. They can also contribute by improving decision-making mechanisms, transparency in teamwork (by making more explicit the level of complexity of specific research tasks) and contributing to engagement and trust building when facilitated in flexible, adaptive and scalable ways. In terms of the efficiency and quality of results, data from the case studies are less evident and the scope of the study has less clear indicators to affirm such extent. However, according to some results derived from the interviews and surveys, it seems that adopting co-creation practices of agile frameworks and participatory design is not detrimental to the level and pace of research outputs in the settings studied.

Considering co-creation from this perspective, in the context of transdisciplinary research, the results of this project reveal that there is clearly a potential benefit in adopting participatory design for strategic planning in research, during its foundation and formulation stages. This also applies to integrating it with tailored agile project management for the sustainment phase of collaboratively developing research processes (ensuring the interconnection between outputs of participatory design and daily activities). However, results also point to the importance of adopting adequate digital tools and facilitation roles when applying co-creation techniques in this context.

From a perspective of networked organisations and “ecosystemic” research, both co-design and agile practices and tools can be integrated for balanced and goal-oriented performance of scientific teamwork. Moreover, the adoption of co-creation seems to contribute significantly to integrate diversity, by articulating a shared vision among team members and collaborators. As a dynamic and adaptable way to generate communication and participation spaces, the co-creation cases of transdisciplinarity analysed in this thesis usually meant significative series of dialogic and visualization processes, that represented a counterbalance to the usually isolated and asynchronous pace of research work.

7.2 Participatory design for the formulation phases of research

The first research question of this project is how can co-design help to integrate diversity for the collaborative ideation of research processes in transdisciplinary contexts. In relation to participatory design techniques and materials, for the foundation and formulation of this type of collaborative project, results were mainly based on the experience of citizen science experiments, but also on observations and answers from some key interviewees about participation in other research contexts. In this respect, results suggest that co-design can contribute to a “co-created” modality beyond the usual “contributory” paradigm in transdisciplinary research. Describing in detail how participatory design and collaborative research can interconnect in practical ways, integrating diverse sources of knowledge and personal perspectives, results from the interviews and surveys reflect the importance of adapting and tailoring beforehand co-design materials to the context and to the community of practice objective of the process.

Data obtained from the citizen science case study demonstrate the critical importance of facilitation and the determinant role of the researcher as an "interface" between non-expert participants and co-design materials. Thanks to this, co-creation approaches in groups with diversity of stakeholders can contribute to developing the needed aspects of trust, creativity and transparency for effective scientific collaboration. Additionally, results from this experience allowed for the establishment of a connection between the theoretical frameworks of design and science of team science for informing the development of a methodological tool: a research co-design toolkit. This novel approach, from an action research perspective, also meant the iterative improvement of the toolkit as a resource that can be adopted, reused and even serve as the object of derivative work. In this sense, the toolkit development process itself, as described, represented an opportunity for internal reflection and methodological discussion among researchers. Further adaptations of this copyleft material (as it has been the case in other projects, referred in the fifth publication of the compendium) support the utility of this toolkit for collaborative and reflexive research planning, contributing to the generation of ideas and agreements, and specially channeling tacit knowledge (from participants' perceptions and know-how) into explicit knowledge (in visual and direct representations of research plans).

Other results from this exploratory approach support the consideration that research questions in transdisciplinary contexts can be formulated as a collaborative effort, instead of the usual top-down schema. In addition, co-creation methods in early stages of research planning can contribute to increasing participants' motivation. In this respect, additional data obtained in relation to participatory design for transdisciplinarity points to the convenience of sequencing co-design phases, allowing experts from different disciplines and facilitators to coherently observe, analyse and sequence the process itself in an iterative approach. Rather than concentrating co-creation stages in short periods of time, the experiences analysed in this study also point to the positive aspect of sequencing participatory sessions and workshops in a way that outputs can be properly documented, analysed and discussed from the facilitators' perspective in phases. This can allow to progressively adapt materials and methods to the context and pace of co-creation, and at each phase share the documented outputs among participants (via online channels or face-to-face presentations) as starting points for new iterations.

7.3 Agile management for the sustainment phases of research

The second research question of the project is to what extent is it possible to co-develop complex transdisciplinary projects following agile project management principles. Results in this case reflect how between the formulation and sustainment stages of collaborative project development, agile frameworks such as scrum can serve as an inspiration and set of practical principles for adoption by scientific teams. In this sense, one important consideration, in the first place, is to differentiate the adoption of agile principles and practices in the context of short-term, defined research projects, and, on the other hand, the same methodologies applied in entire teams and organisations for the management of the whole activity as a research group across

time (and therefore all its projects and regular tasks). Results in the first case indicate that communication benefits from adopting agile approaches like kanban boards or daily standup meetings around clearly defined projects. In contrast, in the case of large networked organisation without predefined projects, introducing agile co-creation frameworks like scrum can be counterproductive if too ambitiously or rigidly implemented. This coincides with extensive literature about agile frameworks adopted in software development processes, as well as in other project management practices outside the IT sector.

However, in both cases results point to relevant benefits when flexibly adopting agile practices in collaborative research processes, in terms of offering an engaging, transparent and easy-to-adopt coordination framework when dealing with the uncertainties of scientific activity. In contrast to the usual absence of a project management culture in academia and research organisations, participative methods such as daily standups and tools like kanban boards, according to the analysed case studies, can provide a useful way for coordinating and discussing research and administrative related plans and tasks. This is particularly applicable when considering transdisciplinary projects from the perspective of diversity of participants and knowledges, whereas in community-based research or in scientific teams with different levels of expertise among members. In those contexts the regularity and pace of communication derived from agile co-creation seems to increase the chances for discussion and jointly decision-making. Although for intellectual and specific research-related tasks (such as reading, reviewing literature and writing) it has also been observed that the tempos and timing differs significantly to other type of logistics or administrative tasks, and therefore the need to adapt the practices and expectations of agile methods. But also in this case the results suggest that such adoption can be positive and useful for a shared perspective on research tasks, via feedback loops that contribute to transparent coordination.

Data obtained from observation, surveys and interviews in relation to this co-creation paradigm for teamwork coordination, point to the same need for facilitation roles as described in the case of participatory co-design techniques. Although in this case it seems that agile project management could be more easily adopted in the absence of such an expert facilitation role (whereas in the case of co-design it is a clear prerequisite). As stated by researchers familiar with this agile facilitation role, especially for scholars experienced in research methods and management of case studies, it can be relatively straightforward to experimentally perform the specific role of coordinator or “scrum master” in projects. It requires adaptation from the point of view of a methodological framework, similar to other facilitation roles in qualitative research. In relation to this, however, the results also suggest that agile practices cannot be adopted as a fixed formula in research projects, nor can they invalidate the importance of applying high degrees of flexibility and “learn by doing”.

Furthermore, results from this specific attention to agile co-creation in the management of complexity in transdisciplinary projects and groups, also indicate that as a new phenomenon in academic organisations it can be experienced as a challenging way of working by certain individuals and personality types. In that respect,

another important factor identified in relation to the efficiency of applying agile methods for research, has to do with the level of digital literacy and familiarity with specific digital tools by potential participants. Data obtained from the interviews and participant observation reflect as well how adopting agile methods can be counterproductive depending on the level and balance of administrative work and research projects carried out by participants at the personal level. This seems particularly the case given the current context of structural changes in academia and specially challenges related to multitasking, life-work balance and sometimes pressure derived from teams competition for excellence and funding. While as in the case of co-design, results seem to indicate that agile management can contribute to the effective integration of perspectives in a research process (in parallel to other forms of coordination such as meetings), it is important to indicate that in this study there was no relevant perception of improved quality of results due to the adoption of agile methods, which is another key aspect when considering current challenges in transdisciplinary research.

Finally, as prerequisites for adopting this type of co-creation in semi-collocated or distributed and networked research organisations, the study's outputs provide the following recommendations on how some agile key aspects should be considered prior to their experimental, progressive implementation: (1) need for balance between efficiency and autonomy of participants, avoiding the use of agile methods as a mechanism of top-down control within teams or groups; (2) limiting the online context ahead of the offline context for coordinating activity, where specially digital tools need to be introduced and adopted beforehand (considering personal attitudes and learning curves towards them); (3) tendency to a proliferation of coordination tools such as kanban boards, which relates to the previous question and can be an initial tendency to be aware of beforehand; (4) need to build trust in relationships, considering additional ways for integration of diversity and informal knowledge exchange (such as co-design methods); (5) type of research activity and projects when exploring coordination mechanisms (and the suitability of new approaches); (6) time and resource constraints, making sure there's enough time and proper work conditions for familiarising with the agile framework; (7) importance of tailoring agile principles to activities, not taking it as a rigid and fixed methodological formula; and (8) the institutional culture of academic and research organisations, making sure leadership roles are aware and supportive about agile adoption.

7.4 Co-creation for strategic planning of research

In answering the third research question on how both co-design and agile co-creation techniques can be combined for the strategic planning of transdisciplinary research, results indicate that this is not only possible but convenient. This can be accomplished by a combined application of visual materials, digital tools and facilitation techniques, which can enable better communication, transparency and trust building among participants during the planning process. However, a key aspect identified in this respect is the importance of adapting and tailoring participatory design processes in the early stages of strategic planning to each circumstance, context and type of participants.

For this, the results of this case suggest that co-creation can contribute to collaboratively identifying individual research approaches, areas of interest, methodological orientations, research mission and guiding principles, as well as for mapping the institutional and social ecosystem of the organisation. Specifically for strategic planning, around the SWOT technique (used to help the research organization identify strengths, weaknesses, opportunities and threats) methods like concept clustering or online participation mechanisms like surveys can be combined for a shared understanding and for decision-making mechanisms, to establish strategic objectives as well as key performance indicators afterwards.

In relation to how a combination of co-designed strategic planning with agile project management can contribute to transdisciplinary research, results from the Dimmons case study align with the additional consideration of participatory design as an action research method itself. Results suggest that such formula can help to assess the development of day-to-day activity aligned with strategy, in parallel to maintaining a shared vision and engagement with the planning process. In this sense, the studied approach to participatory and co-created strategic planning for research coincides with other academic research, pointing to its value as an integrative practice for teams, especially in contexts of distributed and decentralised organizations.

7.5 Limitations of the study

Exploratory in its nature, and focused on a reduced number of case studies, this research has limited its scope to diverse contexts of transdisciplinary research in the field of social sciences, but not to others in the wide range of unidisciplinary or different cross-disciplinary characteristics. With the aim of analysing how collaboration aspects of transdisciplinarity represent a clear complex challenge for the different phases of research processes, my choice as a researcher has been to concentrate on relevant practices in team science, action research and citizen science.

This scope could be perceived as relatively narrow, also taking into account that the research questions and general methodology are not comparative, but on the other hand they configure a valid contribution if we consider that the object of inquiry and type of co-creation practices described and studied here represent a very novel way of managing scientific activity. The amount and type of evidence gathered, as well as the diversity of scope of the fields represented in the articles of this compendium (in design, communication, team science, social sciences and digital humanities publications), represent a concrete and useful contribution to the field of science and technology, but at the same time on an area of study in need of greater analysis based on more cases and stages of collaborative research processes.

On the other hand, the analysis of regular communication via digital channels and the content analysis of the majority of kanban boards has been limited to the activity of teams with participants being researchers (with different levels of expertise and diverse backgrounds), but apart from some exceptions, not to other types of stakeholders such as non-scientists or members from civil society. This represents the main flaw in the

evidence gathered in that part of the research, and should be considered when addressing the issue of agile project management adopted beyond the boundaries of team science in transdisciplinary projects.

Finally, another clear limitation of this study has to do with a not enough transversal and integrated gender perspective. As indicated in the introduction, the conditions for the selection of the case studies included, as an alternative measure of their success, a balanced gender composition, and this was also a precondition when gathering qualitative and quantitative data about co-creation and collaboration (via the various surveys and interviews). Precisely for this, it could be considered that the various contexts and cases studied did not have a significant gender inequality condition, due to their selection and representation. Also, the general concept of diversity, as addressed in each case, already included conceptions about gender (in parallel to personal backgrounds, disciplines, roles, etc). However, my late personal awareness of the importance of this issue (once the study was advanced and main data gathered), as well as other practical and theoretical priorities, did not allow for a wider gender approach to the main questions of this thesis. This is something that deserves further research in the future, where I hope the foundations of methodologies and results of this dissertation could serve as inspiration or resource.

8. Research discussion

Since the main results obtained in this study have been summarised in the previous chapter, in response to the project objective and its research questions, the discussion presented here relates them to the context, issues and other considerations raised in the general introduction of this thesis and through the compendium. Concretely, this discussion is structured, first, around collaborative work in networked organisations, secondly around transdisciplinarity and collaboration in research, and finally about co-creation applied in scientific collaboration, differentiating participatory design and agile project management. This discussion draws some relevant implications that are derived from experimentally applying co-creation practices in transdisciplinary research, and offers some general recommendations that can be useful for practice. It also covers, eventually, reflections oriented to possible future lines of investigation in this specific area of meta-research.

8.1 Collaboration in networked knowledge organizations: participatory management within “adhocracies of practice”

Throughout this study I have argued that the co-creation practices of participatory design and agile project management, widely applied today in different fields beyond their original context (Ciric et al., 2018; Manzini & Coad, 2015), can be beneficial and useful when adopted in transdisciplinary research. In this sense, a first important consideration has been to frame such argument considering the project and knowledge management implications of collaborative research (Bozeman & Boardman, 2014), as a specific type of knowledge generation process within a special type of organization.

According to Lauren (2018) and his wide study of communication in project management in today’s organizations, there’s currently a shift from an efficiency to a participative model, where teamwork requires new strategies for engagement and collaboration. This coincides with the approach and outputs of this study, in terms of understanding how beyond the need and pressure for efficiency and excellence in research organizations, when it comes to transdisciplinary practices, the “participatory turn” of science studies (Jasanoff, 2003) seem critical for generating value and meaning. According to Lauren, in networked organizations communication practices for project management are (1) generally reactive and intentional (with the need of a shared vision), (2) focused on future action (and thus dependent on trust among participants) and (3) system-based (integrating not only effective tools, but also feedback loops in its communication), which are three characteristics that have also been detected through the case studies of this project. In this respect, transdisciplinary research organisations can also be considered as sociotechnical systems (Lievrouw & Livingstone, 2002) and hence the main results of my analysis under a “project-as-practice” approach (Hällgren & Söderholm, 2011) that has focused on action

and actors, as well as some of relevant principles, values and routinized behaviours while planning and conducting research.

Secondly, another important element for framing this project contribution in the context of organizational management (before discussing other issues related to transdisciplinary research and co-creation practices), has to do with the key aspect of knowledge itself, since we can consider research organizations as a specific type of networked knowledge organizations. As explained in the introduction of this compendium, for Nonaka and Takeuchi (1995) the creation of knowledge within organizations can be seen as a continuous process of dynamic interactions between tacit and explicit knowledge. Coincidently, the results from my study can also be considered from the point of view of how co-creation, as a mechanism of organizational learning, can facilitate key techniques of socialization and "after action review" (AAR), which are essential for transforming tacit knowledge into explicit knowledge (Pérez-Montoro, 2008). The cycles of knowledge generation observed in the scientific projects object of this study are characterised, according to this, by the "research attitude" of reflection-in-action described by Schön (1983). This is particularly the case with participants socialised in the foundation and formulation stages of research via co-creation practices, and also when they shared progress in its sustainment stages, following the time frame classification of Sonnenwald (2007).

Another relevant set of considerations, from the point of view of project management in transdisciplinary knowledge contexts, as derived from the empirical data and observations (as well as from the different bodies of literature reviewed), has to do with organizational structuring. Taking into account the five basic configurations of organizational design described by Mintzberg (1980) under an "effectivity paradigm", these are classified into (1) simple structures, (2) machine bureaucracies, (3) professional bureaucracies, (4) divisionalized forms and (5) adhocracies. According to this classification, the combination of teams and communities of practice studied here seem to fall mainly under the latter category, but also under the third. That is, transdisciplinary research organizations can be considered as a hybrid form of adhocracy and, at the same time, as professional bureaucracies, or somehow in transition from the professional bureaucracy model to the adhocracy model. On the one hand, as professional bureaucracies, transdisciplinary research organizations seem influenced by a scholarly tradition of coordination mechanisms that allow for decentralization. With highly specialized professionals (in this case scientists, under its classic definition) and with considerable autonomy in their work, as well as with basic units of support staff. On the other hand, operating as adhocracies, when approaching co-creation, the transdisciplinary organisations studied here have a tendency to adopt flexible and adaptable ways, usually with significant creative and integrative behaviors based on non-permanence and diversity, in order to face complex and dynamic contexts.

In this sense, what has been observed in this transition to the organizational mode of adhocracy structures is a clear tension between opportunity and timing: while the means of co-creation seem ready to be adopted (both methods and tools), the pace of organizational changes evolves at different speeds depending on the composition of

research groups and the academic institutions they belong to. Something that connects with the extensive analysis of Spinuzzi (2015) on "all-edge" adhocracies, and the extent to which new workplace networks, in front of complexity, can experience profound and dynamic changes in communication, coordination and cooperation. The author condenses the six characteristics of this emerging type of adhocracy as project-oriented, agile, innovative, allied, decentralised and autonomous. Among its drawbacks there is the focus on temporary projects, as well as its tendency to act reactively, in the absence of a shared strategic vision. Again, this seems to connect to the background contradictions expressed through this study, specially by interviewees working in academia: usually experiencing as a positive aspect the opportunities and advantages of this type of new organizational structures (due to the benefits of using ICT for managing explicit knowledge, and for communicating in agile ways within networks), but in several cases with concerns at the same time about the stress and changing implications derived from the readiness or not of their academic institutions (which can be driven by these same possibilities, principles and tools).

From this double perspective of organizational structuring and knowledge dimensions, prior to wider conclusions related to transdisciplinary research from the perspective of co-creation, it is also important to address the key question of the intersection between communities of practice and collaborative knowledge generation (Martos & Pérez Montoro, 2009). Community of practice theory has developed further the notion of tacit knowledge as a social process and the "art of knowing", learned usually in local, face-to-face interactions (Duguid, 2005). But on the other hand, the notion of "networks of practice" refers to organizations and practitioners that collaborate online from distributed settings, connecting disparate communities of practice, like the epistemic cultures in high-energy physicists laboratories analysed by Knorr-Cetina (1999). In this respect, from the observed transition stage from professional bureaucracy models to adhocracies, in the transdisciplinary setting of the research projects I analysed, emerges the possibility of a new concept for classification: rather than communities of practice, or networks of practice, the focus on temporary project objectives in this context could provide space for a more accurate term such as "adhocracies of practice". As transdisciplinary organizational forms (aided by co-creation mechanisms, like the ones applied in this study for research processes) adhocracies of practice would constitute in a similar way processes for transforming tacit knowledge into explicit knowledge, by diverse interpretations of what it means to be "a researcher". Moving from dynamic ideation and management methodologies into valuable and innovative knowledge generation cycles, those adhocracies of practice reorganise and learn constantly through temporary "projectification" (Midler, 1995), which constitutes their main organising principle: "the organization of work around teams oriented to defined projects, as opposed to departments oriented to narrow functions" (Spinuzzi, 2015, pp. 32).

8.2 Transdisciplinarity in research: experimenting the interrelations of complexity and diversity

The foundational concept that this thesis forwards is that, given the collaborative management complexities of doing science and research in transdisciplinary mode,

co-creation principles and practices can incorporate beneficial logics and techniques when integrating diversity in projects, which is a prerequisite for generating knowledge and impact in science (Liao, 2011). Through the case studies analysed in the publications, and also my daily participation in a networked research group (within the research institute of an online university), I have had the opportunity to observe and contrast from different perspectives several transdisciplinary projects and their inherent complexities. As described by Sonnenwald (2007), scientific collaboration can be considered transdisciplinary not only when there is a need to integrate all knowledge relevant to a particular problem, but also the involvement of multiple stakeholders. In line with the "Mode 2" of knowledge production (Gibbons et al., 1994), this perspective coincides again with the cases analysed in this study. From the way citizen science has integrated through co-design professional scientists, teenagers and teachers in the basic definition of human behaviour experiments, to the collaboration with policy makers and evaluators in the case studies of a distributed research center about public policies, as well as the day-to-day of a research group operating at the intersection of action research and ecosystemic participation around the platform economy.

Such integration of diverse types of participants and perspectives, in what I consider clear examples of transdisciplinary research, has to be understood twofold in relation to complexity: in front of complexity at the level of external context of research, when facing new wicked problems (Katz & Martin, 1997), and at the level of "internal" complexities for the management of collaborative research activity itself (Cooke & Hilton, 2015). This coincides with the systemic view and current moment of profound restructuring of university organisations (Miller et al., 2018), with strategies involving multiple disciplines and cutting across key missions and their implementation, as in the adoption of "quadruple helix" models (Holm-Nielsen et al., 2013). On the other hand, collaboration in research processes is a widely studied topic in different disciplines (as reflected in the introduction of this compendium), which has lead to situate the question under concepts like the "collaboration imperative" (Bozeman & Boardman, 2014). In this sense, the profound changes and challenges in scientific activity derived from ICT and from practices of digital culture (Lassi & Sonnenwald, 2010; Aibar & Dunajcski-Maxigas, 2014), as can be interpreted from some of the results in this study, probably represent one of the major challenges in today's academic adhocracies.

In order to deal in greater depth with the importance of these changes in transdisciplinarity and collaboration in research (verified both theoretically in the existing literature, and in the results of the investigations that I have carried out), it is necessary to divide the analysis into two separate parts, following what has been exposed up to now. On the one hand, at the level of profound changes in the context of more diverse research teams, paying attention to the challenges of management and daily activity of team science (Stokols et al., 2008; Vom Brocke & Lippe, 2015). On the other hand, delving into how another scale of diversity and complexity stems from the wider involvement of participants in research projects (Hadorn et al., 2008), whether in citizen science, action research or in collaboration with policy makers. This is the aim of the following sections, which unfold keeping the same previously utilised analytical framework.

8.2.1 Team science collaboration: beyond the opportunities and drawbacks of acceleration in academia

When addressing transdisciplinarity in team science it can be useful to depart from the classic conceptual framework of the four research programs in scientific communication defined by Lievrouw (1988), derived from the disciplines of the sociology of science, information science and knowledge sociology. According to the author, it is possible to distinguish the way in which researchers communicate and collaborate between four categories or programs: (1) *artifact studies* (where scientific information is an objective commodity); (2) *user studies* (where that same commodity is no longer objective and its value depends on the needs of the individual user); (3) *network studies* (a perspective of social value, and therefore network-oriented); and finally (4) *lab studies* (which emphasize the social construction of knowledge and its value in the perception from the actors). Without considering them as watertight compartments, and halfway between the last three programs (based on questionnaires, interviews and participant observation), my approach recovers that framework perspective and connects it with the need expressed by Sonnenwald (2007) to delve in how work practices and technological practices are interconnected in scientific collaboration. These interrelations between the possibilities of ICT for collaboration within the framework of the network society (Castells, 2004), together with the profound changes in the day-to-day work at the heart of the academic activity and the university institutions themselves (Gill, 2017), has been observed as an interrelated influence in the context of the present study.

Considering how the sociotechnical configuration of the Internet is intimately linked from its origins to the networked academic scientific culture (Castells, 2004; Serra, 2015), it is doubly justified to mention here the bidirectional influence detected through co-creation methodologies in my study, in terms of how digital and scientific culture influence each other. In this respect, both the co-design and planning practices (and specific techniques and materials such as dotmocracy or estimation poker), as well as the appropriated digital tools in chats or kanban boards, would be part of a wide range of "sharing information artifacts" (Borgman, 2010, pp. 173). They currently represent ways of working and doing research that, under this networked perspective, can also be more meritocratic, transparent and decentralized (Aibar, 2008), given the current global process of diversity and integration of disciplines and knowledges (Holm et al., 2013; Pedersen, 2016).

Secondly, and as a reaction to the latter, and the so-called "acceleration of the academy" (Vostal, 2016), another corpus of results of this study point to the need to review the way in which cross-disciplinary collaboration takes place within research teams, and at the same time in scientific networks. For this, the application of agile project management has revealed that collaborative teamwork in research projects continues to be governed by a series of fundamental rules such as those established by Olson and Olson (2000). In their study of scientific collaboration (comparing collocated and non-collocated research environments) the authors identified four keys in relation to technology and research practices. These have also been observed as determinants

during the adoption of co-creation in the environments studied here, constantly overcoming as a condition for their adequate adaptation: (1) a *common ground* among participants (therefore a common vocabulary, and ideally previous experience collaborating together); (2) *coupling in work* (and how more ambiguity or lack of definition in tasks, the greater difficulty in collaborating remotely); (3) *collaboration readiness* (that is, willingness to invest some effort in pursuit of collaboration); and finally (4) *technology readiness* (fundamental and decisive when there is reluctance from some participants to adopt new digital tools or routines). In this sense, new managerialism in scientific institutions and competition for excellence in research represent an additional layer of complexity (Carpintero & Ramos, 2018), and from my observations new key determinants for transdisciplinary collaboration. Agile project management, under this lens, can represent for researchers an opportunity for a new culture of transparency and shared and synchronized teamwork, but at the same time reluctance in the face of extra learning curves and new demanding skills. Or in some cases the perception of a gender-biased meritocratic system derived from software culture (Nafus, 2012) that could contribute to perpetuating inequality in science (Müller et al., 2011) and in academic life (Franklin, 2015).

My published results, and additional observations in the different case studies analyzed, also coincide with the analysis of other authors about scientific collaboration in teams of different dimension, as cited in the state of the art section. From the observation, from a "laboratory studies" perspective, of how meanings around research projects and daily tasks are constantly (re)negotiated in informal communication channels (Latour & Woolgar, 1979), to how collaboration in this context moves constantly between research design activities, collaborative writing, conceptual discussions and administrative tasks (Suchman & Trigg, 1986). However, given the previously mentioned and somehow exponential impact of ICT and of digital culture in academia, these and other frameworks like the one from Laudel (2002) (considering horizontal specialisation and non-specialized contributions in team science, in parallel to theoretical tasks and experimental ones), seem to be somehow surpassed and challenged by co-creation practices. In this sense, organizational learning behaviours in teamwork, such as seeking feedback, sharing information, asking for help, talking about errors or experimenting, which are critically related to trust among team members and to psychological safety (Edmondson, 1999), cannot always be easily channeled through digital tools. On the other hand, in the context of the transdisciplinary groups studied, offline co-creation sessions and face-to-face coordination routines properly introduced (with methods for personal positioning, or other ways of “breaking the ice” among participants) have contributed to the needed trust building and interpersonal transparency.

8.2.2 Public participation in research: new transdisciplinary challenges around adhocracies

I will put the focus now on the emerging paradigm of public participation in research (Shirk et al., 2012), as an additional layer of complexity to the previously discussed developments and challenges in team science collaboration. It has also been considered in different ways here how the increase of diversity in the sources of

knowledge represents, inevitably, an increase of complexity for the various, critically interrelated stages of scientific collaboration (Sonnenwald, 2007). Again, with the decisive irruption of new ICT possibilities, and in parallel to how the networked society and global capitalism evolves, we can witness the emergence of other knowledges, experiences and agents in the scientific ecosystem (Alonso & Lafuente, 2012), which undoubtedly constitutes a key factor that goes through much of what has been addressed here. Whether from the perspective of community-based research for the solution to “glocal” problems (where, as we have seen, there are clear lines of connection between the action research tradition and the current evolving environment of citizen science) or the involvement of other stakeholders and institutions under the Responsible Research and Innovation European approach. This complexity is not only about finding participation formulas that expand progressive and situated knowledge (Reason & Torbert, 2001), but also about exploring another of the key perspectives of this project: the necessary consideration of the researcher and scientific teams as subjects of study themselves (through co-creation) for urgent "meta-research" approaches (Ioannidis et al., 2015). From this perspective, the corresponding case studies broaden the participation of agents with the help of co-design as well as agile and transparent management of projects, and the key role of researchers as co-creation facilitators, where fostering diversity in the research processes can result in positive spirals of creativity and problem solving, again coinciding with previous studies in this regard (Phillips, 2014).

On the one hand, from the classic but constantly renewed paradigm of action research in the field of social sciences, it is found that the fit with participatory methods of co-creation at a "meta" level seems especially coherent and viable. Something that coincides with the importance that action research gives to “knowledge ecologies” (Santos & Hissa, 2011), as well as strategic thinking, the construction of relationships and the overcoming of hierarchies (Fuster Morell, 2009). This emerges again as one of the key perspectives adopted for the study: a critical view of the researcher as an involved actor, inserted under different bureaucratic and economic pressures in an academic institution, which is in constant evolution and under a systemic crisis (Do Mar Pereira, 2016). But as a key difference with the “internal” dynamics of team science as described previously (not necessarily connected with other stakeholders as partners or contributors), complexity in this type of transdisciplinarity increases due to the general lack of effective models of project ideation and research management in academia (König et al., 2013). As a contribution to the depth of the structural changes necessary in this sense, the type of co-creation mechanisms applied and analysed here could be considered, to some extent, as an additional "meta" turn to teamwork, from the perspective of action research: exploring how to improve the way of working and interacting with other actors in the collaborative management of research projects. In this way, it can connect also with the original empowerment principles of the action research discipline, from its initial development in the industrial environment (Trist & Bamforth, 1951).

On the other hand, in relation to new forms of public participation in research, this project has also addressed co-creation in the relatively new phenomenon of citizen science and its own, current challenges regarding participation (Bradbury, 2015). As

another clear paradigm of transdisciplinary activity, I was guided in this case by the critical importance of studying how non-scientists can meaningfully contribute to scientific research (Pettibone et al., 2018). However, prior to analysing my contribution to the field in detail (by applying participatory design principles), it seems important to consider the connection between action research and citizen science, and how evolutions from the latter resonate with the fundamental principles and goals of action research. As analysed from participant observation and a comparative approach when considering results, it is possible to find a similar set of motivations to generate social impact in the case studies analysed in the second and final paper of the compendium (both in the context of research groups working with specific communities in Barcelona). In one case, co-developing citizen science experiments about human behaviour in public spaces, and in the other, planning strategies and action research activities in collaboration with the wider ecosystem of collaborative economy. In both settings, motivations and perceptions from the leading scientific teams were intrinsically related to both the *ethos* and guiding principles of action research, and at the same time, to the need of effectively generate new ways of collaborative knowledge by experimenting with new tools and mechanisms, which clearly characterizes citizen science (Cigarini et al., 2018). Taken as an indicator of transdisciplinarity as well, on how citizen science and action research are getting closer to each other, in this way connecting social sciences and other fields more common in citizen science (like natural sciences), through my thesis project I had the opportunity to confirm this confluence, which is now just starting to emerge in academic literature (Evans-Agnew & Eberhardt, 2018; Gregory & Atkins, 2018; Vicens et al., 2018). In both cases the recurrent orientation to social impact of transdisciplinary collaboration, and the need to connect it with policy makers (which was also a key question in the third case study, related to policy evaluation) again resonates with the foundational principles of Open Science (Hecker et al., 2018) and Responsible Research and Innovation (Ribeiro et al., 2016).

8.3 Overview of co-creation practices: from participatory design to participatory management

As described by some academic literature, in the majority of scientific organisations there's in general terms a relevant lack of adaptive and inclusive mechanisms for research co-design (Wilbon, 2012), as well as for research project management (Vom Brocke & Lippe, 2015). This clearly represents a need at the methodological and relational levels, in parallel to the current increase of complexity in research contexts and institutions, especially as just mentioned when dealing with novel participatory mechanisms like Responsible Research and Innovation (Bajmócy & Pataki, 2019), or related practices like Open Science (Whyte & Pryor, 2011). In relation to such challenges, results from the different case studies described in each publication of this compendium (as well as other sources of evidence and observation gathered during the project), point to co-creation as a possible way to effectively orchestrate the dynamic nature of transdisciplinary knowledge creation. As a common attribute of co-design and agile project management, observed in the development of transdisciplinary projects in each case study, co-creation can contribute to reflection-in-action mechanisms among participants, in line with the principles of the action research tradition (Schön, 1983). This coincides with the need from organizations

to transform tacit knowledge into explicit knowledge in transparent and participative ways (Nonaka & Takeuchi, 1995). In this regard, derived from digital culture and early practices of user-centered design and software development, results from the mechanisms and approaches studied here seem to point to co-creation as a phenomenon in the midst of a paradigm shift from an efficiency management model to a participatory one (Lauren, 2018).

Using a variety of approaches and methods in my dissertation, therefore, I have tried to demonstrate that co-creation applied to transdisciplinary research represents an opportunity at different levels. First, cultivating participation by precise mechanisms and principles seems that could lead to effective collaboration and engagement in different types of research processes. Both in the co-design and collaborative ideation of scientific activity, the diversity of participants can benefit from adopting a visual language and techniques derived from participatory design for iterative discussion, while with the application of agile project management principles, research projects can be improved through the coordination aspects of the day-to-day of cross-functional and cross-disciplinary teams.

At this point of the analysis, however, it may make sense to consider how it is not very usual to find co-design and agile frameworks in academic literature under the same conceptual umbrella of co-creation. But as previously mentioned, today they represent the same set of recurrent practices in many sectors, related to areas such as innovation (Schaffers et al., 2009), software engineering (Ferrario et al., 2014) or large-scale collaborations (Näsholm & Blomquist, 2015). Thanks to recent contributions from the field of project management (Lauren, 2018) and action design research (Keijzer-Broers & de Reuver, 2016), which correlate with my perspective in this respect, it is possible to advance in the understanding of how both co-creation practices are closely related in their common perspective around user-oriented design principles. This complements the perspective of studies in the emerging field of co-creation, where according to key authors like Sanders and Stappers (2008) we can frame the question around how co-creation refers to all kinds of participatory and collective creativity, while co-design would be a specific set of practices and principles within the broader co-creation paradigm.

This conceptually intricate relationship, between co-design and agile under a similar conceptual umbrella, has also been detailed in very recent significant contributions, that pose exactly the same questions as the ones developed through this thesis, connecting agile and co-design as "meta-methodology" in research contexts (Twidale & Hansen, 2019). Although in this latter reference just at the theoretical and speculative levels (without relying on empirical data), the authors point to the intuitive and informed consideration of how the issue relates to key questions of organizational learning, explicit knowledge management and group iterations adapting with flexibility to the research context. Coinciding in this sense with the results and case studies of this dissertation, in the following sections I will elaborate separately a more detailed discussion on the adoption of co-design and agile principles. Afterwards I will address them together again, in an effort to explicate some other implications behind the experimental adoption of this type of agile co-creation in research environments.

8.3.1 A transversal perspective on co-design for research ideation and planning

When considering participatory design for research, an important differentiation has also to be made in relation to the approach of this study: between co-design as a method for research (that is, adopted mainly for data gathering, as a qualitative or quantitative approach) and co-design for a previous, internal stage of "co-creating the research" within teams (and also with stakeholders), and this way collaboratively defining the approach of a given transdisciplinary project. Although it is under this second "operational" perspective where this project, at a meta level, has addressed the adoption of co-design for research ideation and planning, it is important to clarify that these boundaries have not always been easy to distinguish. Several participatory design sessions with research teams and communities also generated data and knowledge *for* research as clear outputs (like the processes described around citizen science, or during the strategic planning co-creation of Dimmons), in parallel to articulating useful information and discussions for the design of the research process itself. In relation to this, from the perspective adopted and explained here about the implications of transdisciplinarity as participation, this fully coincides with the tradition and core value of co-design, in concordance with the detailed analysis by Spinuzzi (2005), who argues that participatory design *is* in fact research, and even that its foundational practices (like user-centered design, prototyping, etc) have a fundamental origin in the field of action research.

Just as citizen science can adopt this way of working, beyond its current predominant contributive paradigm (Ruiz-Mallén et al., 2016), and in a similar way and with a philosophy similar to action research has been articulating epistemological and methodological bridges with the communities and contexts it works with (Hecker et al., 2018), participatory design can facilitate the opening of the early stages of scientific activity to a myriad of possible perspectives and new questions. In this sense, this compendium has addressed how co-creation, by its integrative nature, allows such openness (Sanders & Stappers, 2014a), contributing to *ad hoc* and situated shared languages between experts from different disciplines working together, but also involving if needed "non-experts" (whereas amateur researchers, junior scientists, or citizens in a wide sense). Since co-design as presented, applied and analysed here has a solid and clear approach to the key aspect of decision-making mechanisms (Sanders & Stappers, 2008), we can also consider how the opportunity provided by this type of co-creation is not at all a formula for chaotic inspiration. Instead, it represents a systemic source of convergence and divergence phases (Brown & Katz, 2011) for interactively setting a common ground and the best strategies for knowledge generation in complex and transdisciplinary settings. In other words, this means adopting visual and highly symbolic mechanisms, usually offline, as a formula for generating the constructivist and co-productionist framework of science as postulated by Jasanoff (2004).

Having said this, there is also the need to differentiate and define facilitation as a special type of expertise in transdisciplinary processes, because integrating diversity in research ideation and management requires effective approaches to facilitation for generating and channeling collaboration (Katz & Martin, 1997). This expert (or expertise,

if distributed within the team or organization) would be an emergent actor in a transitional phase from “academic expertise” to some sort of hybrid “facilitation expertise”, which seems currently a critical skill for more permeability in the formulation stages of a given research, in order to avoid the traditional tendency of adopting research design decisions at the individual level, via non-explicit processes (Verschuren et al., 2010). Apart from my demonstration of the critical importance of facilitation materials and methods in this context, in line with reference experiences of co-design (Sanders & Stappers, 2014b), of design methods for collaboration (Halpern et al., 2013) and of action research (Ruiz-Mallén et al., 2015), it seems relevant as well how the facilitator or co-facilitator role, when adopted by researchers, is perceived as a key task and a needed skill. Although in some cases it is viewed as yet another challenge, among the current complexities derived from technology, scientific and bureaucratic conditions of academic life (Valero et al., 2019), what has been observed here through the various contexts of transdisciplinarity, clearly links with studies on the importance of facilitation and leadership in contexts of communities of practice (Martos & Pérez-Montoro, 2009) and of action research (Reason & Bradbury, 2001).

Another relevant conclusion, derived from the results of the study in relation to participatory design, highlights again the question of the relationship between knowledge co-creation and the digital environment versus the offline one. The experiences of dozens of facilitated co-design workshops, in this case, connect with analyses, such as those by Kanfer et al. (2000), on how there is an important tension between the quality and intensity of the generation of knowledge in embedded, interpersonal and face-to-face exchanges, as opposed to the type of mobile knowledge required by digital infrastructures to articulate distributed collaboration. This issue is in turn linked to the need for openness in mechanisms for diversity of participation, mainly through shared methods and rhetorics, in such complex processes of invention and production (Simmons & Grabill, 2007). The question also relates to the importance of co-designing research in properly defined spaces and time frames, in front of the usual conditioning factors of work with constant connectivity via ICT: multitasking, procrastination and lack of shared vision, among other potentially negative consequences (Wajcman, 2014).

Contextualized in the general field of design thinking, the different co-design processes analyzed here within the framework of the ideation and planning of scientific research, show in different ways how design, instead of a process in itself, can also be understood as a way of "shaping processes" (Lindberg et al., 2010). In this sense, participatory design can be considered an effective and flexible way to integrate diversity and to confront uncertainty in the parameters of research (Cross, 2001). From that perspective, transdisciplinarity processes would clearly connect with a wider conception of laboratory studies, derived from technoculture, which is expanding and allowing new ways for citizens and users to contribute to knowledge through co-design (Sangüesa, 2014). On the other hand, in connection with the need for a shared vision in teamwork when addressing collaborative research efforts (Bennett & Gadlin, 2012), this study also contributes to proving that the participatory paradigm (through co-design mechanisms, properly applied) can expand to the still relatively marginal but critical aspect of strategic planning for research (Derrick & Nickson, 2014)

8.3.2 Benefits and limitations of agile frameworks: the researcher as a knowledge worker in transitioning institutions

At the beginning of this study in 2016, the practice of agile project management in the academic and research context was relatively unknown and unpractised, as studies about this field were marginally present in the existing literature, either in areas such as knowledge management or organizational learning. Unlike participatory design, with its close and old link with action research (as it has been defended in several parts of this thesis), agile frameworks would seem at first to arise exclusively and by spontaneous generation from the practices of software programmers, as some research on the phenomenon often seem to reflect (Abbas et al., 2008). However, as already mentioned, in recent studies such as that of Twidale and Hansen (2019) the relationship between agile project management and key principles of co-design emerges as very relevant at the conceptual level. This question is also addressed in other recent, speculative but significant approaches, such as those of Pope-Ruark (2017). In this case the author elaborates how agile methods would connect in several ways with design thinking, in parallel to the current need to renew the management and application of different types of academic projects. Although it is also possible to find previous evidence of interest in “agile research” in studies about industry and academia collaboration (Barroca et al., 2015; Ota, 2010; Sandberg & Crnkovic, 2017), coordination of large-scale research projects (Marchesi et al., 2007), management of R&D laboratories (Lima et al., 2012) or other sectors, the two previous ones represent the more significative evidence of similar approaches and motivations to explore this subject as those defended here.

However, the analyses in these two cases (both in Pope-Ruark and in Twidale and Hansen), not being based on experimental adoption and applications in real contexts, differ significantly with my approach, which provides an initial empirical assessment about the adaptation of agile project management in collaborative research initiatives. Pope-Ruark, in her book *Agile faculty,* develops an inspiring and theory-based argumentation of the potential connection between the principles of agile frameworks and the needs for more efficiency and “purpose-based, people-driven, learning-focused approach” in academic activity (Pope-Ruark, 2017, p. 3). Her "evangelizing" approach resembles that of other authors such as Mayer (2013), who from the field of software development raises the salience of "agile values" in organizations as an emancipatory process, and as a catalyst of the day to day empowerment of knowledge workers and networked teams. Despite having a clear connection in both cases with the original principles of the Agile Manifesto (Beck et al., 2001), which have also been shared by some participants interviewed for the case study of the third and fourth article of this compendium, these more “utopists” views differ in some aspects with what has been experienced and exposed here.

In this sense, the work of Twidale and Hansen (2019) coincides more with results gathered in my study, in its presupposition that agile frameworks don’t represent a series of fixed and prescriptive ways of applying such type of teamwork management (unlike what Pope-Ruark seems to suggest with her examples), but that it is a much

more adaptive, experimental and learn-by-doing type of managerial paradigm. It also coincides with Lauren (2018, pp. 55) in the analysis of communication and participatory mechanisms in project management for organisations: "Adopting methods and methodologies is about making space for teams, not to just change practices but to respond to the unique needs of a given context and problem to be solved". This connects with my results on how in the different research contexts where agile management has been experimentally tested, seems critical to heuristically tailoring it, as something more evaluable and adaptive than mere methodological "templates".

Another key claim of this study, based on academic literature from various fields and on the empirical basis of my work, is the relationship between some agile principles and those of action research. In this sense, the value of the described adaptations of agile frameworks (like scrum) lies in how they facilitate guidelines that articulate the self-management of teams favoring collaboration (Ciric et al., 2018). This connects with the principle of workers proactivity to make decisions and self-evaluate results, which also lies in the origins of action research (Bargal, 2006). Some other observed benefits, when agile is adopted in transdisciplinary contexts, coincide in this sense with principles of reflection in action for surfacing complexity and unblocking people's participation (Schön, 1983). They also remind of the most common communicative functions of "project management language" as defined by Friess (2018): knowledge exchanges, coordination questions and indicators of agreement (and to a less extent with progress summaries, small talk and introductions).

On the other hand, several limitations and contradictions have been detected and pointed out throughout this process of experimental agile research management. They reflect what has been exposed until now about the current academic context in times of accelerated adoption of ICT, and the consequences of the increasing need to compete and demonstrate excellence by universities and other research institutions. Taking place in the current context of performance-based university funding systems (Hicks, 2012), such a trend in the present study has meant finding a wide range of perceptions by participants and interviewees critically regarding project management, and in particular the agile methodology. For addressing this, it is important to highlight that it was relatively recurrent to find reflections and attitudes from researchers towards co-creation, and especially agile project management, that situated the discussion in terms of the power and control of participants (by communities of practice, or inside academic teams). This was followed by reflections about the accelerated pace of intellectual work and the increasing number of tasks within academic organizational structures. Coinciding with numerous studies on the barriers of adoption of agile in software development teams (Hovorka & Larsen, 2006; Convoy et al., 2011), about personal constraints around the needs of socialization, the lack of management or technical training, or simply general demotivation, the cases studied in this project have resulted in an unequal long-term experience. While some researchers have continued on their own, adapting tools such as the kanban board to their needs in specific projects, other groups have incorporated synthetic communication into their daily routines, like the "standup" meeting format. But it has also been the case of networked research projects, with the already described conditioner of the face-to-face distance (Olson & Olson, 2000), in which the main

tendency of participants to try out, stop and abandon agile methods has been recurrent, leaving only small groups of very active users. This behaviour, as described in the fourth article of the compendium, is somehow reminiscent of the usual power law in other contexts of online participation and knowledge generation (Fuster Morell, 2010).

8.4 Additional observations, contribution and lines of future research

As a tension that reflects how this participatory approach via co-creation represents also a challenge in the role of the action researcher, as facilitator and manager of participation interfaces and tactics (Lee, 2008), the current experimental and trial-and-error stage of adopting co-creation points to the need for generating proper training, for wider and effective meta-research approaches like the ones explored here. Not only for identifying good practices and areas of improvement in co-creation for research collaboration, but also for generating tools, materials and methodological practices that could be of specific utility for replicating experiences. In this line, for a wider dissemination, potential reuse and possible new results replicating these meta research processes, the other contribution of this project has to do with the development of a series of derived open knowledge materials under a copyleft license (compiled in the Appendix section). That is, the parallel co-creation of the collaborative research toolkit (tested, co-developed and applied beyond the case study referred to in the first two publications of the compendium), but also the materials and surveys for strategic planning of research analysed in the final publication. As well as the Sharing Cities co-creation canvases (not reflected or discussed in this compendium, but derived from my research following similar co-design patterns and logics, currently in use for research co-creation around public policies for the platform economy)[19]. Another practical contribution in this sense is the customization of the open source Kanboard (https://kanboard.org/), as an online kanban board platform suitable for agile management of research.

These resources have been generated as an action research output in parallel to applying participant observation (in my continuous deductive-inductive role of co-designer and facilitator during the last years, inside and outside academia). They have been developed, in this sense, with the aim of contributing in practical ways to the complex challenges described here about transdisciplinary teamwork compatible with creativity in research, which constitutes and important topic that is far from new in science (Bush & Hattery, 1956). Having said this, another key conclusion of my study is the confirmation that co-creation materials *per se*, without proper adaptation to the context and without some facilitation experience, are not useful or can even be counterproductive and demotivating in some cases.

An additional observation relates the evident challenge in today's tendency to acceleration in knowledge work and the pressing influence of ICT tools for constant connectivity and quest for innovation, taking place in all areas of academia. Rather than

[19] See http://www.share.barcelona/sharing-toolkit/

representing an opportunity to apply time and energy to the adoption of co-design or agile tools as a fixed formula, which in some fields represents a fad and an entire consulting industry in vogue (Johansson-Sköldberg et al., 2013; Cram & Newell, 2016), this study points to the important question of agile co-creation as a management strategy for dealing with complexity in well-defined and structured periods of time. It is from this perspective that, oriented to specific projects (rather than the complete activity of a research organisation), these visual and fluid co-creation mechanisms can generate easy-to-access methods for ideation and coordination in academic work, as well as straightforward tactics for inclusive communication and coordination, ideally embed in a perspective of doing action research *from* but also *for* the university institution itself (Larrea, 2018).

But in order for this to happen, it seems that there should be in the background of transdisciplinary projects a certain level of shared vision and interest among participants, with a clear and defined research strategic goal (Pohl et al., 2017). This coincides with the ongoing experience in the Dimmons research group for "ecosystemic" action research planning (Fuster Morell, 2009). In line with a Commons-oriented approach to science that brings together the participation of diverse actors, be they professional scientists, amateurs or active citizens (Callon, 1994; Estalella et al., 2013), and instead of command-and-control derived from some still remaining academic hierarchies, results from this dissertation seem to indicate that a key strategy is to adopt co-creation in a bottom-up way, incrementally. Furthermore, the concept of *commoning* itself, as derived from Ostrom's design principles (Ostrom, 1990) and the deep philosophical critique of neoliberalism that it represents (Bollier & Helfrich, 2015), can also establish via co-creation solid bridges with new cultures of transdisciplinary research (Marttila et al., 2014).

As another fundamental set of considerations around the respective case studies, finally the importance of social impact of research requires also understanding co-creation mechanisms as a possible way of activating organizational learning (that is, expanding "how to" knowledge) and problem-solving knowledge outside the scientific legitimating structures (Gibbons et al., 1994), especially in the field of social sciences (Estalella & Sánchez-Criado, 2015). However, beyond the human-centered and user-centered paradigm that characterises the different approaches described here, the emergence of new complex socio-technical contexts and perspectives in science and technology studies points also to the urgency to constantly renew and question co-creation itself. From now possible (and needed) posthuman perspectives (Forlano, 2017), to considerations about how the concept of justice in design can counterbalance paradigms of social domination (Costanza-Chock, 2018). In this sense, I really believe that co-creation can influence transdisciplinarity practices to overcome the mismatch between knowledge production in academia and knowledge requests for solving societal problems (Hadorn et al., 2008). That is, contributing to the reincorporation of imagination, socialization and intuition to the guiding principles of science and its impact.

9. Bibliography

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10. Annexe: Collaborative research toolkit

Research Co-creation Toolkit Guide (v1.3)

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This practical guide is a complementary resource to the copyleft download materials available for reuse in English (https://figshare.com/articles/Untitled_Item/5331190) and in Spanish (https://figshare.com/articles/Toolkit_de_co-dise_o_de_investigaci_n/5048302)

The research co-creation toolkit is aimed at researchers who wish to facilitate co-design dynamics of projects, as well as communities or groups that want to investigate, for themselves, topics affecting them or situations that must be solved. In both cases, if the objective is to formulate and select questions collectively, and plan a collaborative research process, I hope you find it useful :)

Introduction

The toolkit in its current version has been developed within the framework of a doctoral research project by Enric Senabre Hidalgo, from the Dimmons research group (IN3 / UOC), on how co-creation can contribute to the design and development of research processes. It combines a variety of learnings and formulas, methodologies and materials previously tested in areas such as software development, free culture or social movements.

Its first version and development phase has been possible thanks to a close collaboration with the OpenSystems team from the University of Barcelona for the European project STEM4youth. Through 2017, the various phases of the toolkit were developed and tested together with the scientific team of OpenSystems. It was put to the test in a co-creation environment of citizen science with three groups of secondary schools in the Barcelona area. The material and its different phases, in turn, are based on facilitation dynamics I developed with Platoniq in 2015 and 2016 during the Europeana Creative project and two first editions of the IdeaCamp with the European Cultural Foundation.

It is, therefore, material under development that should work in specific contexts. For this, tailoring and other factors that we detail here are key. The toolkit can be used modularly (or added to other methodologies and co-creation materials). The results of its first pilot phase were successful and met the objectives; they were studied and reflected in an academic publication that demonstrates the benefits of following this approach in a sequential and dedicated manner.

What is this toolkit for

The toolkit has been conceived to guide the collective ideation and planning of a research process. It includes materials to print and use in different sessions that allow common concerns and problems to be solved, objectives and research questions collectively generated, diagrams of the process created and tasks and their assignment agreed on. It is conceived as a modular sequence that can be executed by adapting the material to different contexts, so that it is suitable for the desired phases of collaborative research.

Considering how broad the world of science and research is, it is important to mention that this toolkit may not be appropriate for various types of projects. In contexts characterised by citizen science initiatives, action research or participatory research, transdisciplinary initiatives, as well as for groups of students or people who are starting out in the world of research (such as PhD students) -- I believe that this type of resource can be of help.

Previous requirements

There are several factors that can favor or harm a co-design process, in any context, and others that must be taken into account when doing so in a research or science framework. For this reason, this guide tries to specify what should be prepared and done during the process, starting from the basis that the best way to move forward and succeed is to dare to try things out and practice regularly!

Selection of participants to achieve diversity

For collaborative research, one of the main requirements is to define who will participate in the process, where a key factor will be diversity. For this, it is very important to think about who is going to be invited to join the process: specific professional profiles, experts in the fields of knowledge that may be complementary, representatives of groups or communities with a shared problem, stakeholders from institutions that may have something to say about it, students or neighbors from a certain local context.

These are just some possibilities, but the point is that it will be important to think in advance about who will participate, and ideally try to ensure that they can engage on a regular basis, not just occasionally. As we will see, given the maximum diversity possible, a key aspect is to try to start off on the right foot, so people feel safe and recognize who is starting to work with whom on a specific project.

Importance of the time factor

Another key aspect to keep in mind is that co-creation takes time, and it requires different moments, intensities and capacity to reflect progressively on what is being done. At the same time, it must be a modular process that allows generating ideas and then taking decisions, but also changing the course of things, or accelerating, if at some point things are not working as expected.

In the case of this research co-creation toolkit, it is conceived as having five different stages with a sequence that goes from joint discovery to planning and assigning tasks. At the same time, it is designed in a way that any of these stages can be carried out independently, in case it is just needed to identify problems, or to formulate research questions, for prototyping a concrete experiment or intervention, etc.

In any case, each of these stages will require working sessions that have their own rhythm and timing. Ideally, such sessions should last a minimum of 2 hours each, on average. The best approach is that between each session and stage some time is allocated for the facilitators to talk and discuss the proceedings, and to be able to process the data generated (to prepare the next stage incorporating it). For this, the guide indicates the ideal time to be dedicated to each phase, but it is also important to consider that this will vary depending on the number of participants, as well as other factors such as how well they work together, or the distribution of space, complexity of the project, etc.

Who facilitates?

As with all co-creation processes, it is essential that someone is responsible for carrying out the facilitation during each of the sessions. This means preparing the dynamics in advance, having a script of the sequence to be worked on, and during each session to explain what is going to be developed, to clarify doubts and especially to control the time necessary for each phase, being very flexible in accordance with how the group evolves.

In my experience, facilitation is a type of task that requires a lot of intensity and a lot of effort, and if done in tandem or by a small group (instead of being carried out individually), then it works much better. One possibility is to divide the roles in advance, and who will do what, knowing that facilitation means more than just presenting and giving instructions. It will also be very important to pay attention simultaneously to questions or issues arising from different sub-groups, unblock and motivate specific people at specific moments, moderate, ask questions or summarise results, etc.

As for the preparations, here is a basic list of items to keep in mind so that nothing important is forgotten:

- Printed materials: those canvas or cut-out materials that will be used, in the proper size and a copy for each sub-group in which participants will be divided (plus some extra ones).
- Content to present: slides about the subject to be treated, written instructions as reminders, summary about how the previous session unfolded, etc.
- Infrastructure: tables and chairs necessary for group work, screen projector, coffee and/or cookies, more food if you are going to work for a long time.
- Consumables: sticky notes of various sizes and colors, markers, green and red sticker dots, scissors, double-sided zeal or putty to display the results on the wall at the end of each session.

General concepts about group facilitation

Since this is a key factor, here are some tips regarding facilitation with this type of toolkit material. Also taking into consideration that research between different disciplines, knowledge and personal baggage needs a common language and a good dose of patience, as it advances iteratively in agreements and shared visions.

- Interest in the context or problem: facilitators must have a high motivation, similar or even higher that the initial motivation of the participants, to promote the intensity required for the challenge.
- Open mind: although key aspects of each session depend on the facilitation role, when different people work together intensively in co-creation, anything can happen. If facilitators have a predefined idea of the result and what is going to happen, they will soon see the opposite :)
- Importance of examples: indications and instructions need to be contextualized, and they work better if a clear example has been prepared in advance. So it helps if each canvas is introduced with sticky notes or sentences added previously, to clarify the type of desired output.

- Do not repeat indications if not necessary: when there is more than one facilitator, sometimes they fall into the mistake of repeating the same things to reinforce this or that instruction, but you should try to avoid that if possible. You don't want to give the sense of disorganization, or that things are not working.
- Flexibility with timing: although you should have a rough idea of how much time to devote to each activity, it is usual in practice to take a little more time or lengthen the moments when a group discusses or puts forward things in common. For the same reason, it is key to know how to indicate what is still missing at specific moments, or interrupt interventions if they get longer.
- Use questions: if you have a real interest in the context and the process that is being facilitated, a fundamental tool is to ask the group, or specific people, each time the results of an activity are shared. That contributes to breaking the ice and motivates others to do the same.

Is the space ready?

The characteristics of the space where the co-creation takes place are also very important. Many of the dynamics can be influenced for good or bad by how comfortable or uncomfortable the place is, or its lighting, and especially its size, and how people can be distributed to work. Ideally, large rooms with good natural light are best.

As there are moments for sharing progress, alternating with others to work in small groups, it is important that (usually after an initial presentation format) chairs can move easily around tables that are sufficiently separated. Also, it is important that the rooms have wide and clear walls, and there is no problem in displaying there the materials produced in each session, in a small exhibition that will show everything together at the end.

Stages and sequence of steps

The toolkit proposes a series of activities based on a fundamental principle of design thinking, which is to alternate phases of divergence with phases of convergence. That is, first for generating ideas and possibilities in a participatory way (sequence of divergence: normally through the formation of subgroups) and afterwards a phase of jointly selecting options (sequence of convergence: by clustering of concepts and decision-making mechanisms).

For this, it is very important to ensure that each phase of divergence begins with a clear indication of what is proposed (ideally presenting an example, keeping it visible during the exercise). Also, when clustering concepts or ideas at the moment of convergence (usually sharing the results of what was developed in each subgroup), the speaking times of each person involved should be well managed. The latter is sometimes the most difficult thing to achieve, since flexibility and empathy is needed so that there is no one who talks too much, as many voices as possible are heard, and all potentially interesting possibilities are exposed.

Co-creation stages

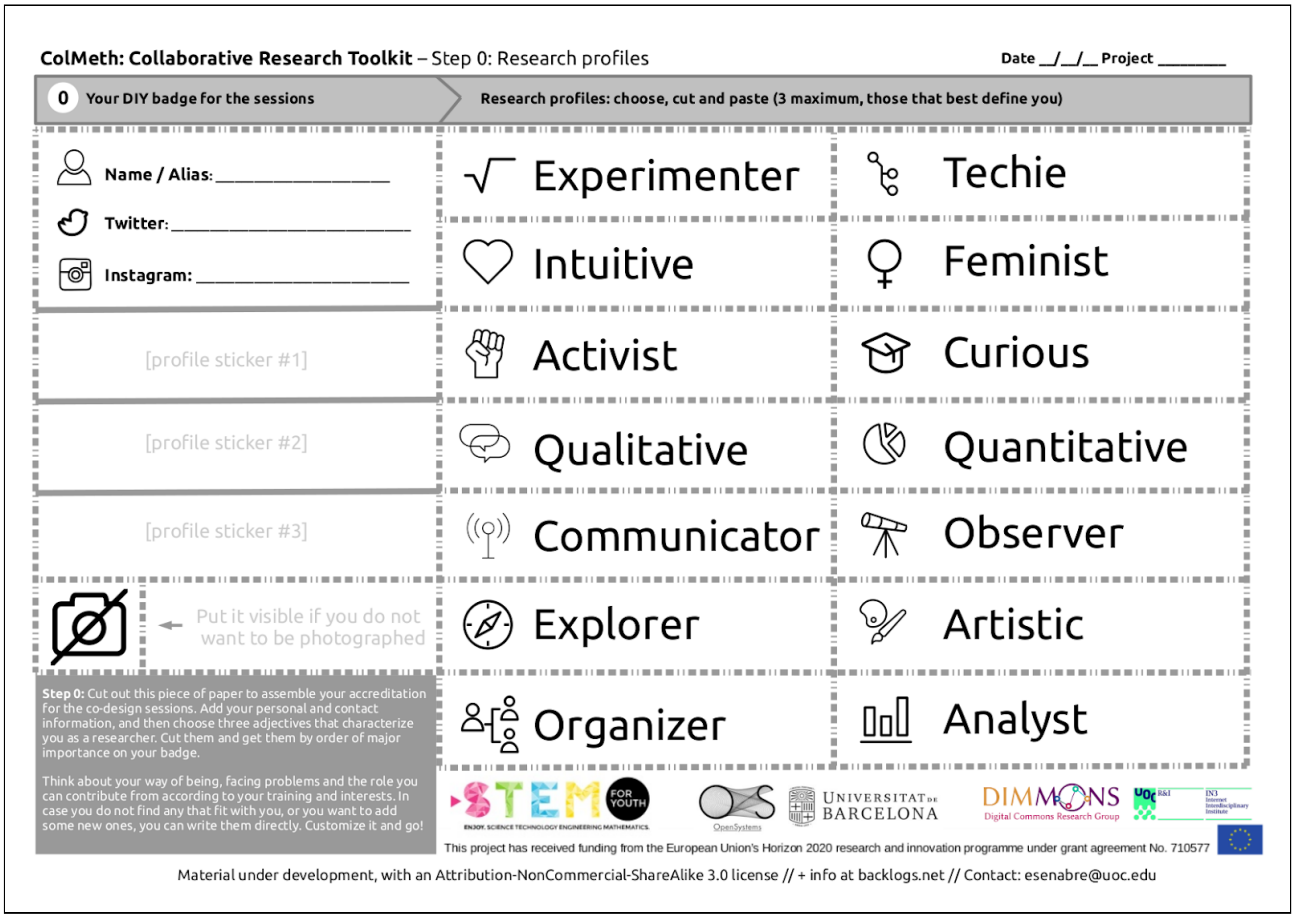
(EACH STAGE CORRESPONDS TO A WORK SESSION)		
(Divergence sequence)	**>>**	***(Convergence sequence)***
Preliminary step: General presentation + Accreditation of participants according to roles and aptitudes		
Stage 1: Definition of the problem to be addressed		
Brainstorming on issues of concern at the local level	**>>**	Clustering, discussion and selection based on thermometers of concepts (social impact, viability, motivation)
Stage 2: Generating research questions		
Structured formulation of questions according to models: descriptive, comparative or relational	**>>**	Selection by subgroups according to voting, sharing and grouping of selected questions
Stage 3: Conceptual diagram of the research process		
Prototyping/low fidelity chronogram of research steps: With key concepts, time development and methods to be employed	**>>**	Presentation by each subgroup and discussion prior to individual voting
Stage 4: Task and logistics planning		
Brainstorming on logistics tasks, dissemination and definition of research	**>>**	Sharing and subsequent processing to perform the experiment

The other aspect to be taken into account in each stage, as will be seen, is to constantly document results. The most usual and simple thing is to take pictures after each session of how each piece of work material was generated. There may also be cases in which it is useful that someone takes notes, specially when summarising and discussing results at the end of each stage. Usually that role works better if not done by someone with an important facilitation role, but instead a notetaker dedicated almost exclusively to that task.

Preliminary step: research profiles

Duration: 15 to 30 minutes
Material: Canvas printed on adhesive paper, scissors, colored threads and transparent CD cases.

When starting, an important step is to "break the ice" and allow all participants to identify themselves in relation to the concept of research, thinking about their role and abilities. As a preliminary step in the development of the first stage of co-creation, and to promote the diversity of skills in each work subgroup (ideally comprised of 6 to 8 participants), the toolkit proposes a set of identifying badges, for which the participants have to select between different profiles or research roles.



Sequence

1. Print this canvas of the toolkit on adhesive paper (one copy per each participant), and cut out the various stickers and place them neatly on a table.
2. Each participant must complete the accreditation with their own data (name or alias and contact information) and select three roles that connect with their individual nature, experience or ability.
3. When everyone has done it (ideally, the facilitators as well) you can proceed to a round of personal presentations. This facilitates getting to know who is who, and jointly discovering those types of profile that are most repeated among participants, as well as those that may be less reflected.

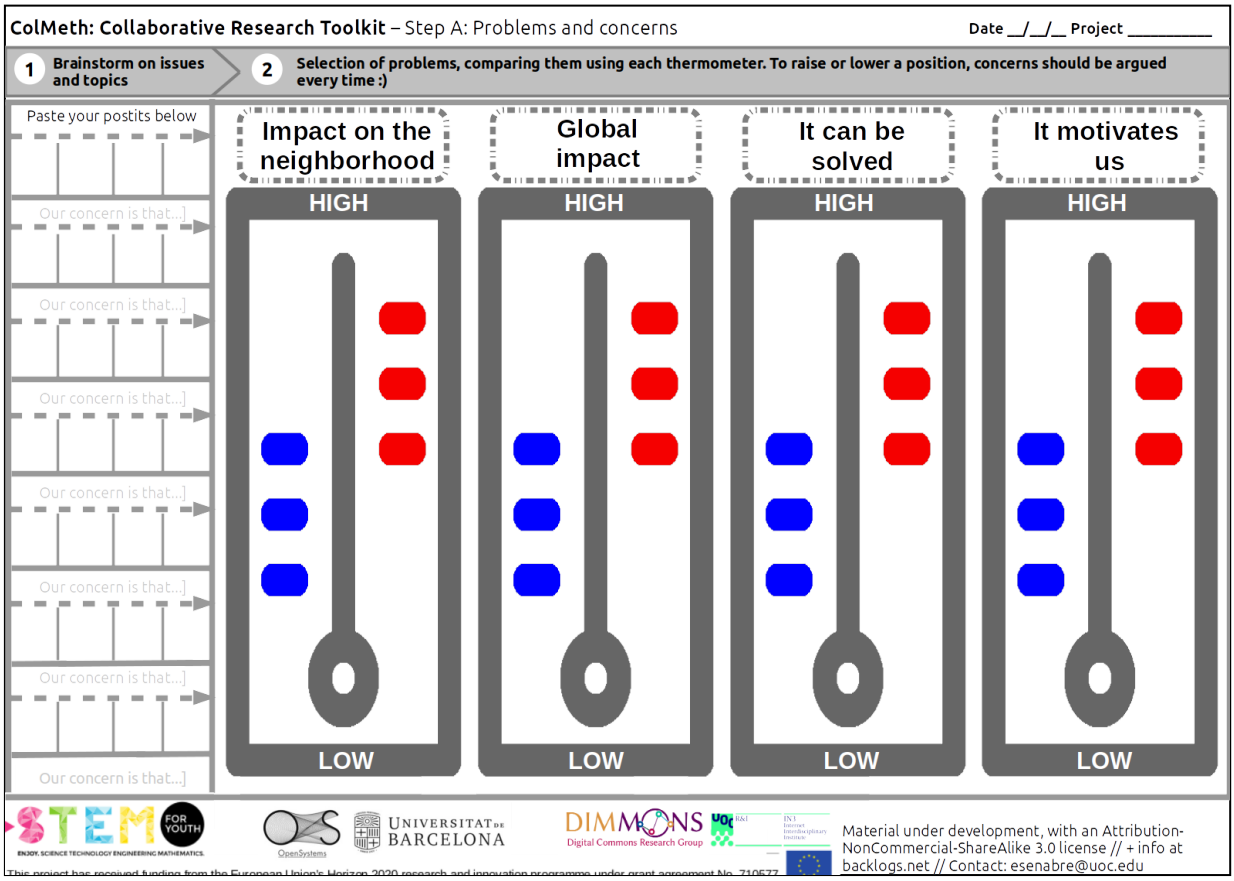
Tips

- When choosing three adjectives that characterize each participant as a researcher, interesting issues or questions may arise that lead to a group discussion about, for example, what it means to be a feminist or activist researcher in a certain area, or differences between what is understood as qualitative and quantitative methods, etc.
- When giving the indications so that each participant can customize their accreditation, they can be told to think about their way of being and the role they can bring to the project, according to their training and interests. In case there are no predefined features that fit someone, or you want to add a new one, you can customize the stickers.
- In addition to initiating the project with the collective identification and visualization of different possible roles, this step can help to promote the complementarity and diversity of the participants when forming subgroups.

Step 1: Identification of the problem to be addressed

Duration: 1 to 2 hours
Material: Canvas of thermometers, rectangular post-its, markers, numbered cards.

The first step of this method is designed for a session in which participants jointly explore and agree on those problems or concerns that can be addressed through a joint research process.



Divergence stage: Brainstorming on issues of interest

1. First, after summarizing the purpose of the session, participants should be invited to form groups of 4 to 6 people. On each table they will find markers and a pack of sticky notes (long ones better than squared, which do not have much writing surface).
2. Then they must write individually everything that comes to mind concerning a specific problem. They must dedicate a sticky note to each point (avoiding listing them all in a single post-it). It is best to indicate, by means of an example, that each problem to be addressed needs a phrase that begins with "My concern is that ..." (this usually allows the sentences to be more concrete than a simple word or title).
3. After about 10 or 15 minutes, a first round is indicated for each subgroup to present and discuss outputs among themselves.
4. Each subgroup must dedicate a few minutes to select the 2 or 3 concerns or topics of interest that they consider most important (for example, they can vote by using green dot stickers).

Convergence stage: Cloud of post-its and thermometers for comparing outputs

1. To initiate the sharing of main outputs, a couple of representatives from each subgroup places the post its they have selected in their group on the main wall or board, briefly explaining the problems that they reflect.
2. Each time new representatives come out, with the facilitator's guidance, they can be asked to try to group together common problems (if a very close relationship is noted between some).
3. Once this shared visualization and clarification of the problems selected by the different subgroups has been completed, as well as the way in which they are grouped or related, it is likely that there will still be a high number of issues to be addressed. To solve this, a second phase should be proposed in which the toolkit thermometers are used, which should lead to more detailed discussion and comparison of the possibilities that have arisen.
4. Placing the thermometers on a visible part of the wall, next to the area where the post-its have been placed, each problem (or grouping thereof) must be assigned a number, that facilitates moving it up or down in front of all the participants.
5. Proceed in order, and commencing with problem #1, applying each point on the thermometer (e.g., impact, viability, motivation, etc.), taking a moment to ensure that there is agreement among participants on whether the level is "high" or "low". For this, the convention to adopt is that the facilitator (or a volunteer from each group) does not move the number up or down on the thermometer unless the person requesting the move gives a brief explanation of the reason why (which is an excuse to specify and discuss the maximum possible criteria during this key moment of selection).
6. You should repeat the process with the remaining problems identified on the post-its (e.g., #2, #3, etc) following the same pattern. As it unfolds, it will become increasingly evident (in comparison to previously calibrated problems) whether they are higher or lower in significance than the others.
7. Finally, once each thermometer reflects all the main problems or concerns identified, now compared and discussed according to different criteria, it will be possible to choose the one with the highest position in proportion to the others, or at least a couple of them as finalists (if for the next session it is preferred to leave that element still open).

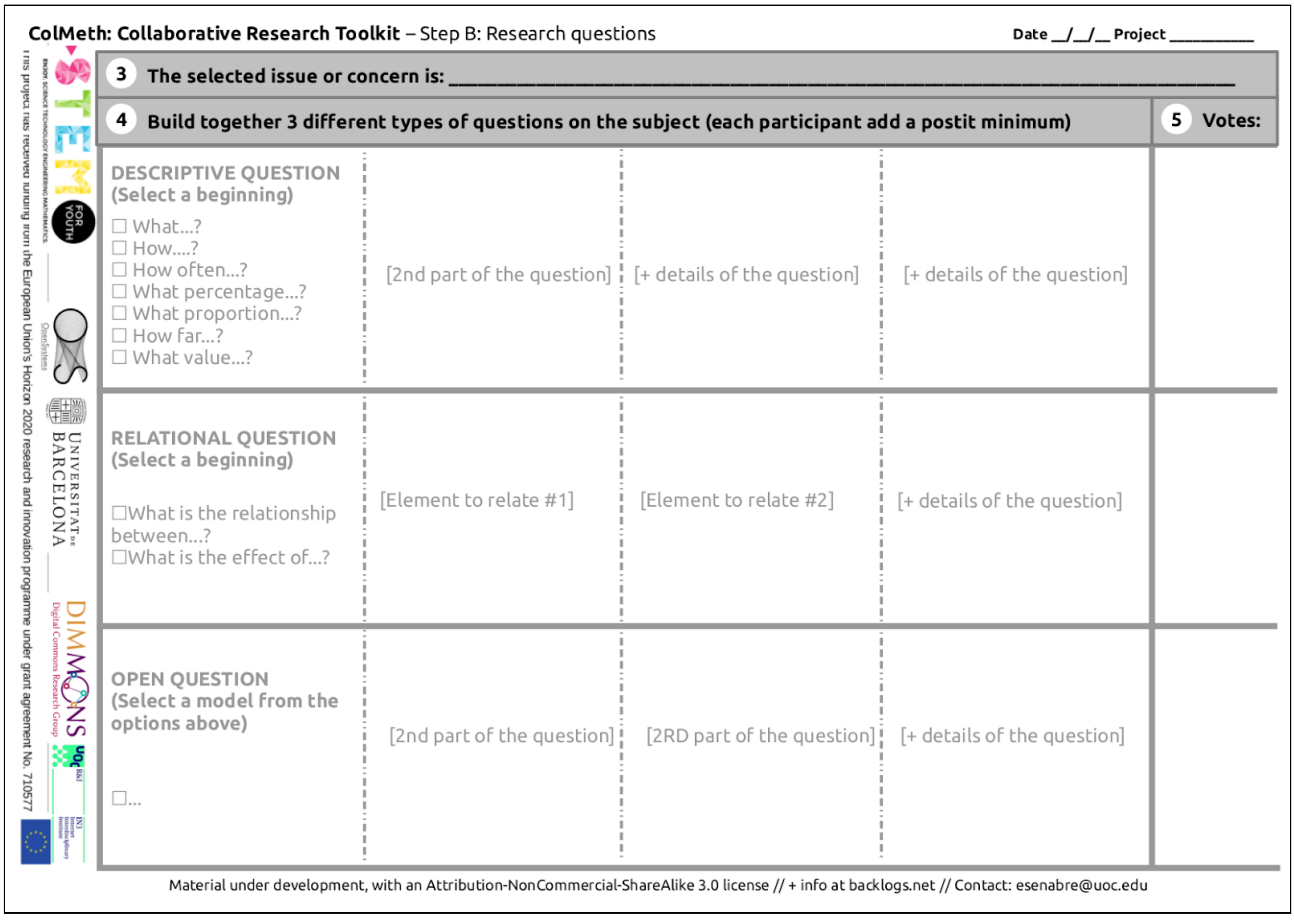
Tips

1. When preparing this session, the ideal is to adapt each thermometer (up to an advisable maximum of four) to criteria that allow the project to fit in its scope. That is, it can be specified if the concept of "impact" refers to a more local or global environment, or if for example academic impact is a better option, etc.
2. The same with questions of viability or motivation. The important thing is that they are criteria that can give rise to discussions of a certain depth, comparing ideas and thus assessing which of them should be retained for further work.
3. Both the cluster of post-its on the wall, as well as the ones that may have been arranged on each table, and the results with the different numbers on each thermometer, are the material that after this session will be worth photographing and thus documenting. For example, for the creation of a summary presentation that will serve as the starting point for the next session.

Step 2: Preparation of research questions

Duration: 1 to 2 hours
Material: Canvas of squares (DinA3), post-its, markers, adhesive points.

This second stage proposes that starting from the specific themes selected, participants jointly formulate research questions, and then select all those that should guide the project.



Divergence stage: Modular generation of questions

1. As a first step, it will be important to start the session by remembering the main subject or topics in which the research will be framed, specifying everything that is considered important and even clarifying doubts or debating if those aspects should still be clarified.
2. Organizing again in subgroups of between 4 and 6 participants, on each table you will place standard square post its and markers of different colors, a canvas template printed with question boxes and pre-cut strips, with three green dot stickers each.
3. For the co-creation of specific research questions, each participant must provide at least one post it to complete one of the three possible sentences on each template. It should follow the proposed structure, and be written individually.

4. In this way, participants will utilise the predefined phrases ('What value ...', 'What is the relationship between ...', How often ... ', etc) that contain in a modular way different options for formulating a research question: descriptive, comparative and relational.

Convergence stage: Voting and discussion rounds

1. After cooperatively generating at least three sentences following this structure, each subgroup proceeds by voting on the research questions that most interest them. For this, each participant has three green adhesive points to place next to the question or questions they prefer.
2. Optionally, if enough time is available, brief rotation phases can be done in which each subgroup visits the questions on the next table (where there is a representative of each group, to better explain the questions generated). This can establish another round of generation or improvement of questions, as well as voting by points.
3. To end the session, we proceed to share the best valued questions from each subgroup. They are written or placed on the wall so that everyone can read them, and the people who have intervened in their preparation present them and clarify doubts if needed.
4. If possible, by similarity or complementarity of the questions, you can try to merge or improve them together, to generate a shorter list of questions that will guide the next phase of defining the research process.
5. Through a final round of voting or discussion, the final list of questions should be agreed on (i.e., those to be finally discarded and those on which participants will continue to work (and polish, if necessary).

Tips

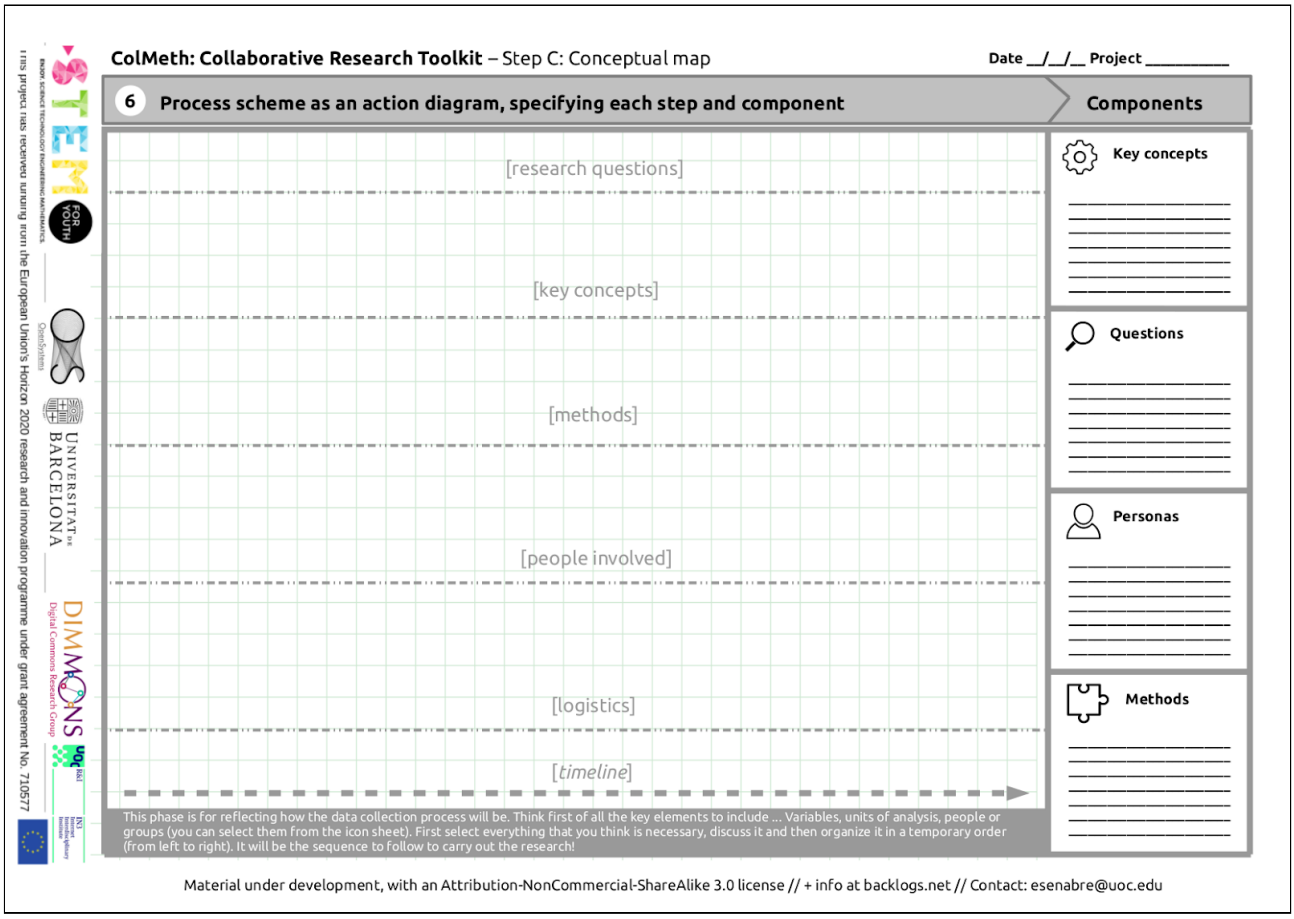
- For the selection of questions, which must be formulated as concretely as possible, you can add a mechanism that will assist in identifying discrepancies. That is, participants assign additional red adhesive points to a proposed question, signifying that he or she has some important objection or warning comment about it (which must then be explained).
- When documenting the different questions generated, you can again photograph the individual canvases, as well as the wall or board where the final questions have been located. Additionally, a digital document can be created as a table or a list of all the questions generated.

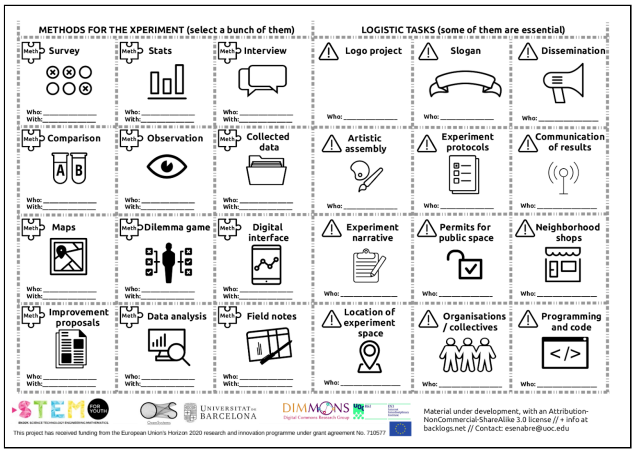
Step 3: Conceptual diagram of the investigation

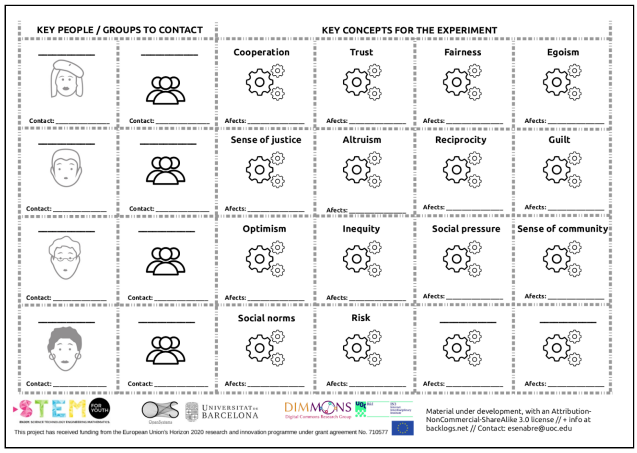
Duration: 2 hours

Material: Canvas grid (DinA1), canvas with icons of methods, concepts and people (DinA3), voting cards, glue, scissors, colored markers.

This third phase of co-creation focuses on a joint visualization of how the research process could unfold, step by step. It covers the different elements to be taken into account at a methodological level, and also logistically, as well as for communication or for dealing with the subjects of study. It is a more explorative and creative stage, which allows linking a sequence of concepts as a flow of actions along a timeline.



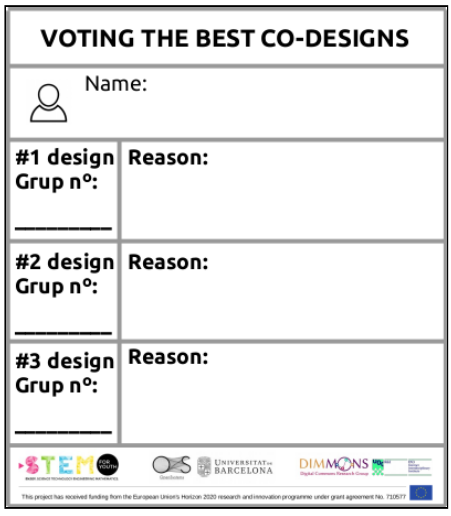




Divergence stage: Collage of the research process

1. In groups of 4 to 6 participants, grouped again around work tables, there will be a big canvas (empty timeline) and a series of icons previously cut out as cards (from the other two canvases). Participants will also have colored markers, and glue or adhesive putty.
2. Each card kit will have icons related to these categories: research methods; logistics; key concepts or variables; participants and groups. It is very important to clarify here that this part of the material is the one that needs more adaptation according to the context and type of project in which it is framed. If needed, I recommend personalizing them and generating new cards through the use of new icons.
3. On the empty canvas, which indicates the timeline from left to right at the base, participants have to place and organize the icons they consider key to carrying out the research.
4. Starting at the top of the canvas is recommended (writing the research questions selected in the previous stage), and progressively adding the rest of the layers below: key concepts (derived from the research questions); methods for obtaining data; people or groups to address, and finally aspects of communication and logistics to be taken into account.
5. As participants agree on the elements that must be considered for the research design, those icons can be fixed with glue or adhesive paste, as well as drawn with colored markers around them (to highlight concepts, establish connections, etc).

Convergence stage: Exhibition format and presentations



1. Once each group has generated through collage the diagrams of the respective research processes, each of the posters is placed on the wall, each one next to the other in "exhibition mode".
2. The participants are invited to look at the different diagrams elaborated by the other groups, and to decide which could be reflected in a more detailed and efficient way in a viable sequence to be applied in the research.
3. Next, two representatives of each group must present each of the diagrams so that all the participants can understand the potential implications of each design, and clarify any doubts that may arise.
4. Subsequently, using the voting card, each participant must select in order of priority those prototypes that he or she thinks are most suitable for the investigation (without considering the diagram made in his or her group). For this, participants must briefly specify the reason or reasons for their choice.
5. Finally, results should be checked according to the votes, to decide which design will guide the research process. Optionally, in case of more than one final possibility, if there's time the final designs could be merged into a new one, describing the best strategy and sequence of the research process.

Tips

- When deciding the groups, it will be important to consider if the design or artistic profiles (as reflected in the badges) are well represented among them. Is also important to

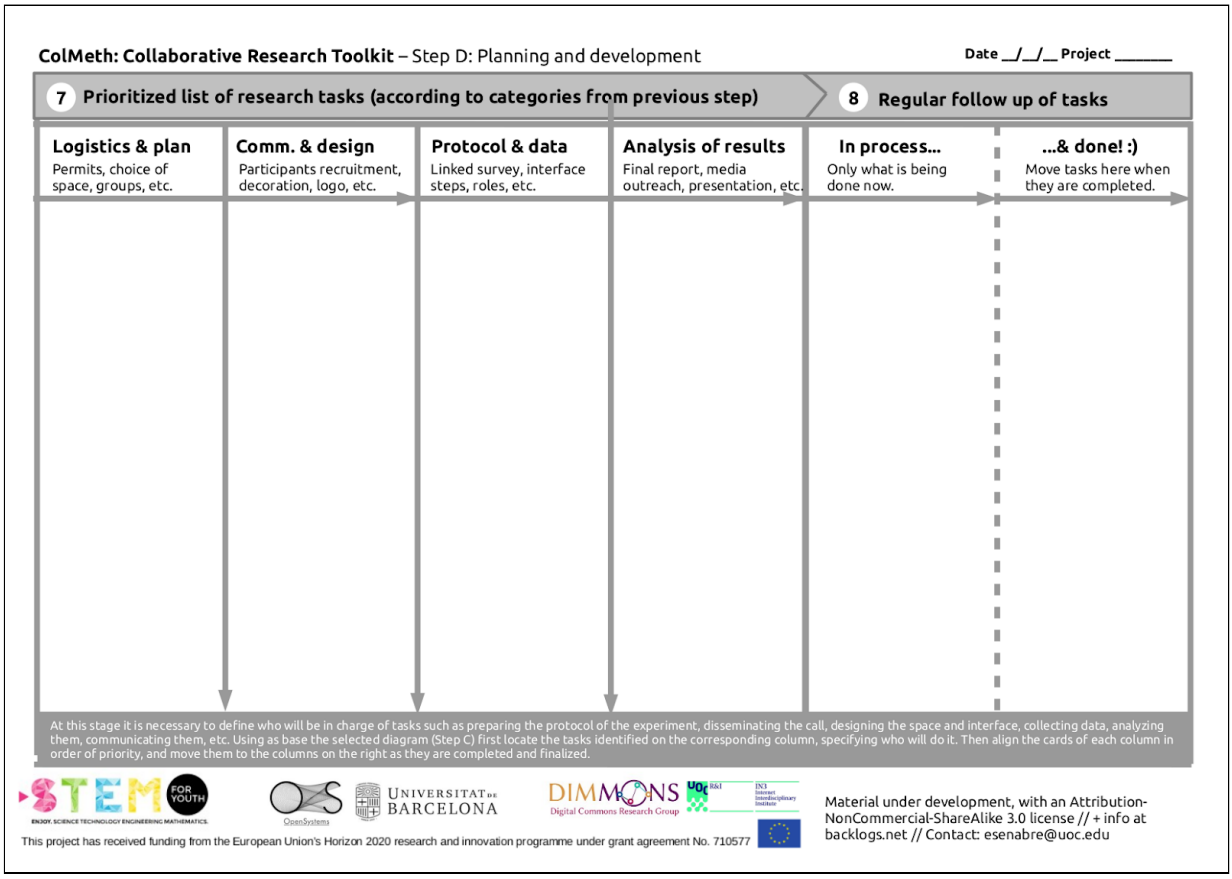
explain in detail each set of icons and their importance, ideally based on a previous example: methods, logistics, key players, concepts and groups.

- Additionally, you can experiment with more open techniques such as having magazines or newspapers available (ideal for collage techniques), from which participants can cut out fragments that would help in describing the intended research process.
- For this crucial phase of the co-creation process, a key piece of advice when facilitating is to approach each group and wherever an in-depth discussion or debate is taking place, recommend that in parallel participants begin to cut and place on the canvas those icons that are discussed or thought to be useful. In this way, simultaneously, those basic elements will be added and will begin to relate to each other, without the need for prior consensus that normally blocks the possibility of moving forward.
- This material can be documented easily in a graphic way, photographing each canvas and archiving it or sharing it later with the group (especially at moments when it is necessary to remember the starting point of the research).
- If participants can detail in each icon, on the section dedicated to it, who will be involved in that particular task or concept, this will help in the next stage and the necessary assignment of future tasks.

Step 4: Task and logistics planning

Duration: 1 to 2 hours (and periodically during the research process)
Material: Canvas with columns (DinA1), regular post-its of different colors.

This last phase of co-design represents a joint reflection and discussion about the different tasks or needs involved in carrying out the research, their priority and who can be responsible for and develop each one of them.



Divergence stage: Brainstorming of possible tasks

1. Starting from the diagrams finally selected in the previous stage, this is the moment of moving from the co-design paradigm to one of preliminary planning. For this purpose, the selected research design, printed or visible for each of the working groups, must be the focus of the session. Again in small groups, post its in a variety of colors should be available on each table.
2. The selected design will be accompanied by this new canvas, which will be located in the middle of each table. This presents a surface divided into different columns, as a basic “kanban” board, inviting explicit tasks that could otherwise go unnoticed.
3. Participants should brainstorm on tasks to be placed on each column, which describe a category of action points derived from the icons used in the selected prototype: logistics and planning; communication and design; methods, protocols and data; analysis of results.

4. They will describe each possible task on coloured post its, placing them on the corresponding column.
5. Then, once each subgroup has generated the maximum number of possible detailed tasks, a second round should be done in which they agree on their level of priority, rearranging the post-its so that the tasks with the highest priority are located in the top positions of each column.

Convergence stage: Joint priority list of tasks and responsibilities

1. In this second round, participants will proceed to present the tasks identified by each group in a gradual way, using a large canvas with different columns, that must be placed on a wall or central space of the room, clearly visible to all.
2. By iterative rounds, column by column, starting with the first one, a representative from each subgroup will refer to the post-its with highest priority according to their results.
3. This will progressively allow each column to be completed with everything that has been identified, reorganizing it in order of priority when discussing it among the whole group. Also to ascertain whether any element not yet mentioned could be missing, before finishing one column and moving on to the next.
4. Once all the columns have been completed, and consensus has been reached that there is no lack of important tasks to be able to start the research, a second round will be made in which post-its with specific tasks must be moved (from the top of the list) to the column "In process ...". This should reflect everything that needs to be done at the very beginning of the project.
5. When moving post-its with specific tasks to that column, it is important to specify and agree on who in the group can take charge (either individually, in pairs or as a group), specifying the name(s) on the same post it. In this way, participants will have a shared visualization about the first steps of the process and who is doing what.
6. Periodically, whenever possible, the same type of iteration should take place again, as tasks are completed, moving post its to the "Done" column (and moving those which follow to "In process... "). Time for reflection and discussion should also be assigned to new unforeseen tasks, which need to be prioritized and carried out by someone in the group.

Tips

- This stage can also be adapted to other Agile project development principles[20], by which this part of the process is inspired, which include many more elements of ideation and monitoring of collaborative project management.
- In contexts where it is not possible to have a permanently dedicated physical space, where a paper canvas with the flow of tasks in progress can be displayed, it is recommended to transfer the content of the post its to digital tools that fulfill a similar function[21].
    - We recommend the https://kanboard.org/ open source tool for this, which can be installed on a dedicated service and customized for research purposes taking advantage of a wide list of extensions[22].

[20] See https://en.wikipedia.org/wiki/Agile_software_development#Agile_management
[21] See https://trello.com/, https://asana.com/ or https://slack.com/
[22] See https://kanboard.org/plugins.html

Credits

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The icons used for the various parts of the toolkit (and the cover of this dissertation) are from thenounproject.com, under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0, from the following authors: Celina Chang, Thomas Le Bas, corpus delicti, Rihards Gromuls, Isabel Foo, Alezander Gruzdev, Ralph Schmitzeb, Piola, Creative Stall, Thomas Hirter, Shmidt Sergey, Stock Image Folio, Bernar Novalyi, Arthur Shlain, Vasil Enchev, Liang Shi, Icon Fair, Magicon, Viktor Vorobyev, Eynav Raphael, Oliviu Stoian, art shop, Gregor Cresnar, Nicholas Menghini, bezier master, Josie Schultz, Douglas Santos, Kaplan, Milky, Remco Homberg, Jose Moya, Iudovic gicqueau, shashank singh, Daniela Baptista, Mauricio O'Brien.