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SUPPORTING THE CHALLENGES OF CROSS- BOUNDARY TEAMWORK THROUGH DESIGN SCIENCE RESEARCH

Avdiji Hazbi

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SUPPORTING THE CHALLENGES OF CROSS-BOUNDARY TEAMWORK THROUGH DESIGN SCIENCE RESEARCH

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Docteur ès Sciences en systèmes d'information

par

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ABSTRACT

In this doctoral dissertation, I relate six studies I have performed to address three challenges that cross-boundary teams (teams with great knowledge diversity) face: the challenge of coordinating knowledge and contributions, the challenge of forming cooperative attitudes, and the challenge of solving wicked management problems. These studies are inscribed in design science research, which is a paradigm of research aiming to develop prescriptive knowledge through artificial and theoretical contributions for practical problems. The artificial contributions in this research project are (1) the Coopilot App which addresses the coordination challenges by allowing individuals to evaluate how much shared understanding there is between them on the four requirements for coordination (joint objectives, joint commitments, joint resources, and joint risks), and (2) the Team Alignment Map which addresses the cooperation challenges by supporting the emergence of shared leadership through a process of cooperative joint inquiry into the four requirements. Design principles for managing coordination and supporting cooperation (the two first cross-boundary challenges) are drawn from the two artifacts. This manuscript also provides a design theory for managing the third cross-boundary challenge, i.e. wicked problem solving. By comparing the Team Alignment Map with two other similar design science research projects (the Business Model Canvas and the Data Excellence Model), I develop a design theory for visual inquiry tools that help practitioners inquire into specific wicked problems. The theoretical contributions of my research project consist in prescriptions on how team members should interact between them to collaborate effectively and overcome the three cross-boundary challenges. I propose a new conceptualization of cross-boundary teamwork as a process of joint inquiry. The view I propose is different from traditional accounts, in that I stress the importance of language. I highlight the cognitive conditions that should be met through communication to done down the boundaries between cross-boundary team members.

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LEXICON

COMMON GROUND	Mutual information created through language that helps people coordinate. The set of knowledge, beliefs, and suppositions people believe they share. Ex: I know that you know that I know, and so you do.
COOPERATION	The willful contribution of personal effort to the completion of interdependent jobs. A collective effort between individuals who interact for mutual gain and benefit.
COOPERATION CHALLENGE	Difficulty of aligning interests and agendas to a shared purpose. Stem from pragmatic knowledge boundaries.
COORDINATION	The process through which individuals predict their peers' intentions and actions to perform contributions that are aligned and integrated in a harmonious way.
COORDINATION CHALLENGE	Difficulty of coordinating due to the challenge of establishing and maintaining common ground. Stem from syntactic and semantic knowledge boundaries.
CROSS-BOUNDARY TEAM	Group of three or more diverse individuals that work together on a joint project and which have different functions and come from different organizations or departments.
DE/PRESCRIPTIVE KNOWLEDGE	Descriptive knowledge is composed of theories and constructs that describe, explain, or predict phenomena. Prescriptive knowledge is composed of theories, constructs, and artifacts that prescribe a course of action that should be undertaken to solve a problem.
DESIGN PRINCIPLE	Formalization of the characteristics of form and function of an artifact.
DESIGN SCIENCE RESEARCH	Specific research paradigm that focuses on the artificial. One of the main objectives is to develop prescriptive knowledge by designing artifacts for practitioners.
DESIGN THEORY	Theory that explains how to do things. Explains the characteristics of an artifact (design principles) and how it interacts with the social environment in which it is used.
EVIDENCE OF UNDERSTANDING	The linguistic acts through which individuals signal how they understand (construe) what a speaker says.

JOINT INQUIRY	The process through which, people who face a shared problem, jointly explore and define the problem, and jointly develop and evaluate alternative solutions to the problem.
KNOWLEDGE BOUNDARY	Differences of knowledge due to novelty. Consists of three types of boundaries. Syntactic boundaries represent differences in vocabulary. Semantic boundaries represent differences in interpretations. Pragmatic boundaries represent divergent interests and agendas between team members.
SHARED LEADERSHIP	Cooperative dynamics through which team members influence and support each other toward the achievement of their shared purpose. Contrasts with the top-heavy, heroic model of leadership.
SHARED VISUALIZATION	The quality of a tool that provides visual support to all members of a team simultaneously.
TEAMWORK	The contributions, thoughts, and feelings by two or more individuals, and the interrelation of these toward the achievement of some value-added collective outcome.
VISUAL INQUIRY TOOL	A tool that frames the elements of a wicked problem and represent them in a shared visual problem space that team members can use to inquire into the problem.
WICKED PROBLEM	Problems that are complex, uncertain, intangible, and hard to describe as the requirements change continuously. They have no single or optimal solution.
WICKED PROBLEM SOLVING	Difficulty of solving a wicked problem as there is no standard procedure or best practice that can be followed due to the novelty and uncertainty of the problem.

CHAPTER 1

INTRODUCTION

The philosophers have only interpreted the world, in various ways. The point, however, is to change it.

- Karl Marx

1 Motivation

Cross-boundary teamwork has emerged in the past two decades as an important strategy for organizations to solve wicked problems, produce knowledge, and develop innovative solutions (Edmondson and Harvey 2017). Cross-boundary teams are teams which are constituted of members across different functions (e.g. information systems, marketing, project management, engineering, research and development) and across organizations (e.g. contractors, suppliers, customers, and consultants). The emergence of cross-boundary teamwork as a new way for organizations to carry out some of their projects has been accelerated with the digital transformation of work, which has extensively facilitates the collaboration between individuals across space, time, and organizations. Cross-boundary teamwork is particularly interesting and valuable because such teams are able to tap on the diversity of their expertise, resources, and skills to solve problems or provide innovative solutions that would not be possible for single individuals or homogeneous teams (Bittner and Leimeister 2014; Kozlowski and Bell 2003). It has been shown that, under certain circumstances, cross-boundary teams perform better than homogeneous groups on complex tasks (Bowers et al. 2000; Derry et al. 1998; Hall et al. 2002; Wegge et al. 2008) and provide more innovative solutions (Harrison et al. 1998; Mortensen 2014). In fact, cross-boundary collaboration is particularly appropriate when the project involves some novelty, which requires the intregration of unique types of knowledge that one single individual cannot hold alone (Carlile 2002; Cummings and Kiesler 2007). Cross-boundary team members can thus integrate their variety of skills to generate specialized knowledge that they can use to address the complexity of most organizational challenges (Kleinsmann et al. 2010; Nonaka 1994). This diversity expands the range of perspectives and ideas that can be produced to innovate and solve wicked problems (Pelled et al. 1999).

However, knowledge diversity represents a paradox for organizations as it is both a prerequisite for success and a potential barrier to success. On the one hand, knowledge diversity is crucial to develop innovative solutions to complex problems (Carlile 2002). On the other hand, knowledge diversity hinders effective teamwork as it translates into difficulties to communicate, coordinate, and align interests (Carlile 2004). In practice, this translates into a difficulty for cross-boundary team members to collaborate across their boundaries (Dougherty 1992; Hansen and Nohria 2004; Van Der Vegt and Bunderson 2005). Edmondson and Nembhard (2009) show that the challenges of teamwork are particularly intense for cross-boundary teams. Very often, cross-boundary teams have differences in language, interpretations, work styles or behaviors that make it difficult for cross-boundary teams to understand each other and communicate effectively (Seidel and O'Mahony 2014). Cross-boundary teamwork not only poses the challenge of managing the knowledge diversity between team members, it is also characterized by the difficulty attached to the type of work these teams perform. In fact, cross-boundary teams are particularly relevant for addressing complex problems. These problems become challenging as there is no proven procedure or standard that cross-boundary teams can use to solve them due to their novelty, forcing them to proceed through trial-and-error (Edmondson and Nembhard (2009).

These challenges are the motivation for the current research project. More specifically, I seek to help cross-boundary teams overcome three cross-boundary challenges that impede their collaboration: coordination challenges, cooperation challenges, and wicked problem solving. There are, of course, other challenges that cross-boundary teams might face, such as boundary spanning (Kellogg et al. 2006; Levina and Vaast 2005; Stamper and Johlke 2003; Tushman and Scanlan 1981) and overcoming the barriers posed by organization structures and process (Hackman 2002). However, my aim with this research project was to equip cross-boundary teams with prescriptive guidance for their intrateam interactions in order to help them collaborate effectively. Boundary spanning or organization barriers are challenges that are usually addressed outside the team's environment by a few members. I am interested in the problems that emerge with the team and are caused by poor dynamics and interactions between its members. Therefore, I focus on coordination, cooperation, and wicked problem solving.

Before detailing what these three challenges are, I will first define three terms that I will use extensively in this manuscript, but that are very often confused: teamwork, coordination, and cooperation. The definitions may differ across (and sometimes within) disciplines, so it is crucial that I relate my conceptualization of these constructs. Teamwork refers to the contributions, thoughts, and feelings by two or more individuals, and the interrelation of these toward the achievement of some value-added collective outcome (Salas et al. 2005). It describes the act of working within teams, which can be regarded as individuals who with predefined roles and with interrelated goals and contributions. Cooperation is the "willful contribution of personal effort to the completion of interdependent jobs" (Wagner 1995, p.152). It describes a collective effort between individuals to interact for mutual gain and benefit (Chatman and Flynn 2001) and involves mutual assistance and influence towards these mutual goals (Liang et al. 2015). Coordination describes the process through which participants predict their peers' intentions and actions to perform contributions that are aligned and integrated in a harmonious way (Klein et al. 2005; Strode et al. 2012). These three concepts are of course interrelated. Teamwork (collaboration) is the overarching concept describing that individuals work together it and includes coordination, as individuals must perform aligned contributions to carry on their work (Hoegl and Gemuenden 2001). Cooperation is the condition for teamwork and coordination to happen (Wagner 1995). When individuals do not have cooperative attitudes, they simply do not work together and, consequently, coordinate (Jones and George 1998).

That being said, coordination challenges relate to the difficulty for team members to communicate effectively and develop shared understanding for the purpose of integrating their contributions. These challenges are to a large extent caused by the knowledge diversity within the team (Carlile 2002). For example, health professionals and IT developers working on the development of software for operating rooms may use different vocabularies and interpret things differently. Cooperation challenges emerge when individuals have different interests and agendas. They are mainly due to their different functions and disciplines, as their ways of perceiving the problem are framed in ways that are specific to individuals' functions (Carlile

2002). Functions and experience within one domain will create a set of values, beliefs, and intentions that serve the purposes of that function and that can thus come into conflict with those of other functions (Black et al. 2004). For example, managers will seek control while professionals will value autonomy and expertise (Jarzabkowski and Fenton 2006). This creates the challenge to find a shared purpose that can fuel cooperation. Finally, the challenge of solving wicked problems is due to the nature of the problems that cross-boundary teams face. These are often characterized by uncertainty, shifting requirements, and no optimal or straightforward solution (Buchanan 1992). Examples of wicked problems include information systems development (John and Kundisch 2015), strategic management (Bruce and Bessant 2002; Sosna et al. 2010), and new product development (Boland et al. 2008; Détienne 2006).

Despite the extensive research on cross-boundary teamwork, these challenges still remain crucial issues and obstacles to team success (Edmondson and Harvey 2017). I attribute this problem to the lack of practical and prescriptive knowledge that could provide practitioners with guidance on how to go about these challenges. In fact, as noted by van Aken (2004), most research in management and organization has remained purely descriptive, translating into a lack of practicality and relevance. Several scholars have argued that design science research is particularly tailored for helping practitioners solve problems that are complex and for which knowledge is still too descriptive (*e.g.*, Gregor and Hevner 2013; Mandviwalla 2015; Peffers et al. 2007; Winter 2008). One of the aims of design science research is to address practical problems that are faced by practitioners in the field by developing artifacts (e.g. constructs, models, methods, and tools) that help practitioners address these problems (Hevner et al. 2004; March and Smith 1995). This makes design science research a paradigm of research that is different from the traditional paradigms in the social sciences (positivist or interpretivist descriptive research). This guidance constitutes the basis of the prescriptive knowledge that design science researchers produce, along with formalization of the artificial knowledge into design principles or theories (Chandra et al. 2015). This paradigm is thus not only concerned with describing and understanding phenomena, but also developing knowledge on how to address these phenomena. This echoes the objectives of my research project which relate to the need to provide more actionable guidance on how to deal with the three challenges that are faced by cross-boundary teams.

2 Description of the research project

In my doctoral research project, I sought to address the three cross-boundary challenges through six studies, five of which have been accepted for publication and one being under review. My manuscript is structured as a hybrid manuscript, meaning that it is based on these six studies but that I very often extended the original papers with additional insights. I have chosen to proceed this way because the links between the contributions of the studies are not explicitly mentioned in the original papers. Not only does a hybrid manuscript allow me to bridge these contributions, it also allows me to compare them and explain how they add up to form higher-level contributions and perspectives. This is important because all studies are not concerned with the same phenomena – they treat different cross-boundary challenges – even though the context remains cross-boundary teaming in all six studies. For this purpose, I group the studies in pairs which I present in specific and dedicated chapters, that each address one of the three cross-boundary challenges. However, I did not amend the evaluation and the results of the studies in neither of the six articles. Therefore, these parts reflect the ones that were presented in the original papers.

My dissertation is structured as follows (Table 1). Before presenting the studies, I will review the literature on the three cross-boundary challenges in Chapter 2. The goal of the literature review is twofold. On the one hand, I will provide an account of how prior studies have proposed to address the three cross-boundary challenges. On the other hand, I will argue that there is a lack of prescriptive and actionable knowledge for the three cross-boundary challenges. The literature review thus provides the motivation for the six studies of my dissertation.

In Chapter 3, I will describe the design science research methodology as it is not yet a well-known paradigm in the social sciences. I describe the ontological, epistemological, and methodological foundations of design science research. I will then relate the design science research process of my doctoral research project. The methods for the evaluation of each of the six studies will be provided in their related chapters.

Table 1- Overall structure of the dissertation		
Chapter	Title	Main content
Chapter 2	Literature review on cross-boundary challenges	- Definition of the three cross-boundary challenges. - Overview of how previous studies have regarded these challenges. - Identification of the research questions and the motivation for my research.
Chapter 3	Methodology	- Description of the design science research methodology. - Presentation of the overall design science research project that I relate in my manuscript.
Chapter 4	Supporting cross-boundary coordination challenges	- Study 1: Designing for coordination challenges (presentation of the Coopilot conceptual model and its instantiation into the Coopilot App). - Study 2: Process model of team coordination (extension of the Coopilot conceptual model).
Chapter 5	Supporting cross-boundary cooperation challenges	- Study 3: Designing for cooperation challenges through shared leadership (presentation of the Team Alignment Map). - Study 4: Bridging coordination and cooperation challenges through joint inquiry (extension of the Coopilot conceptual model).
Chapter 6	Supporting wicked problem solving	- Studies 5 and 6 (combined as study 6 is an extension of study 5): Designing for wicked management problems (design theory for visual inquiry tools).
Chapter 7	Synthesis and perspective	- Synthesis of the main contributions of the six studies to descriptive and prescriptive knowledge for the three cross-boundary challenges. - The contributions are put in perspective regarding cross-boundary teamwork in general.

In Studies 1and 2 (which I will relate in Chapter 4), I was interested in addressing the coordination challenges of coordinating knowledge and work between team members with diverse knowledge and across boundaries. The extensive research that has been done on coordination in prior studies has flourished in a scattered way, but if accumulated, it suggests that cross-boundary members should rely on the power of language and objects to create common ground across boundaries to coordinate effectively. Common ground is the set of knowledge and suppositions that people believe they share[1]. It is one of the main mechanisms to address coordination challenges (Bittner & Leimeister 2014; Clark 1996; Klein et al. 2005). Cross-boundary teams have difficulties establishing common ground due to their knowledge boundaries, which may lead to a failure to coordinate effectively (Mastrogiacomo et al. 2014). Therefore, the first question that is raised in my thesis is: *How can we support cross-boundary teams in measuring and augmenting their common ground to coordinate effectively?*

In Study 1 which was published in 2014 in the proceedings of the *European Conference on Information Systems (ECIS)*, I introduce the Coopilot conceptual model for cross-boundary team coordination, which is based on Clark's (1996) theory of common ground and language. I describe its instantiation into the design of a mobile application – called the Coopilot App – the first artifact that allows individuals to measure their level of common ground. Team members state their individual perceptions of understanding, on their individual devices, regarding four requirements for coordination: joint objectives, joint commitments, joint resources, and joint risks. It displays the level of common ground as an aggregation of the distribution of the individual perceptions of understanding.

I have evaluated the usability, usefulness, and validity of the App with four professional cross-boundary teams working on innovation projects in various organizations and thirteen teams of undergraduate students working on group projects. The evaluation was done using qualitative methods, mainly semi-structured interviews. Results of the evaluations suggest that the use of

[1] Common ground is similar to the concept of shared understanding, with which the information systems (IS) discipline is more familiar (Bittner and Leimeister 2014). But they are not the same. Common ground includes the recursive notion that individuals know that they know a piece of information, while shared understanding describes the overlap of the knowledge that individuals have without necessarily implying recursivity (Akkerman et al. 2007). I will get back to this point in Chapter 4 when introducing our conceptual model based on Clark's (1996) theory of common ground and explain why the notion of common ground provides a better foundation for understanding coordination.

the Coopilot App supported effective coordination. As team members could assess the level of common ground between them, they engaged in repair discussions in case they realized that there were common ground breakdowns and perception gaps between them. I have derived a set of three design principles (i.e. physical or functional characteristics of the tool) that support the evaluation of common ground for the purpose of coordinating effectively.

In Study 2 which was published in 2015 the proceedings of the *International Conference on Information Systems (ICIS)* and which was awarded the Best Research-in-Progress Runner Up, I sought to understand the process through which the establishment of common ground, its evaluation, and the repair discussions are leated. I have developed a process model of team discursive coordination which advances that cross-boundary teams coordinate through two fundamental discursive activities: (1) they interact to establish common ground, and (2) they interact to monitor their level of common ground, by identifying any common ground shortages and repairing them so that they can perform coordinated contributions. Through this study, I contribute with descriptive knowledge on team coordination that is more actionable and practical that traditional accounts on team coordination.

In Studies 3 and 4 (which I will relate in Chapter 5), I was interested in addressing the cooperation challenges that cross-boundary teams face when it is difficult for them to create cooperative attitudes and motives due to their divergent interests and agendas. Literature on the subject has suggested that among all the perspectives on cooperation (e.g., shared intentionality, interpersonal ties), the concept of shared leadership is particularly relevant to create a cooperative climate of mutual support and influence. Shared leadership is a cooperative dynamic of mutual influence between team members toward the achievement of a common goal. It stands in contrast to the individual top-heavy traditional conception of leadership. I have focused on shared leadership over other approaches to cooperation as it provides an umbrella concept that allows for the integration of the other perspectives through the antecedent conditions that lead to shared leadership. Carson (2007) identified three antecedent conditions that must be met for shared leadership to emerge: shared purpose, social support, and voice. However, to date, no inquiry has been done into how shared leadership might be supported with objects and tools. Therefore, the second question I address in my dissertation is: *How can we support cross-boundary teams in developing shared leadership to cooperate effectively*?

In Study 3, which is being published in 2018 in the proceedings of the *European Conference on Information Systems (ECIS)*, I aimed to design a tool that supports the emergence of shared leadership by addressing its antecedent conditions. I presented the Team Alignment Map which is a paper and digital tool that allows individuals to jointly inquire into the four requirements of coordination (joint objectives, joint commitments, joint resources, and joint risks). The tool builds on the Coopilot conceptual model and displays the four requirements as empty columns that cross-boundary team members fill with sticky notes through collective conversations. I evaluated the Team Alignment Map with ten cross-boundary teams working on different innovation projects. The findings showed that the Team Alignment Map allowed for the emergence of shared leadership as it supported the three antecedent conditions identified by Carson. I have identified that the design principles that allow for the emergence of shared leadership are shared visualization and shared problem spaces. Results also show that teams displayed dynamics that could not be described with the Coopilot conceptual model. They rather reflected a process of joint inquiry, which I introduce as a means to overcome cooperation challenges. Joint inquiry is a process through which individuals jointly explore and define a problem, and jointly develop and evaluate alternative solutions to the problem.

In Study 4, which is being published in 2018 in the journal *Travaux Neuchâtelois de Linguistique (TRANEL)*, I sought to understand whether the process of joint inquiry is also relevant to cross-boundary coordination as it appeared as an interesting lens to understand the emergence of shared leadership. I analyzed the dynamics of interactions of the ten cross-boundary teams in the previous study, and added the evaluation done with 12 teams of undergraduate students working on real-life innovation projects. The results of the evaluation confirm the relevance of the process of joint inquiry to understand how coordination happened in these teams. With the results of this study, I bridge the challenges of cooperation and coordination through the process of joint inquiry. I extend the Coopilot conceptual model with this process. This allows me to have a coherent and comprehensive conceptual model.

In Studies 5 and 6 (which I will relate in Chapter 6), I sought to address the third cross-boundary challenge, i.e. that of solving wicked problems. A recent trend of visual inquiry tools has emerged in the management practice to support cross-boundary teams in the process of joint inquiry for specific management problems. One notable example is that of the Business Model Canvas which allows cross-boundary teams to jointly inquire into the nine elements of business modeling. However, most developments have remained in the commercial sphere and for which their designers proceeded through the mere imitation or adaptation of existing tools such as the Business Model Canvas. There is yet no theoretical and design knowledge on how to develop effective visual inquiry tools. Therefore, the last question I address is: *How can we design visual inquiry tools that guide cross-boundary teams in solving wicked problems?*

To answer this question, I have undertaken two studies, one being the journal extension of the other. Study 5 was published in 2018 in the proceedings of the *Hawaii International Conference on System Sciences (HICSS)* and presented three design principles that we drew from the design science research projects that resulted in the design of the Team Alignment Map and the Business Model Canvas. Study 6 is under review for a special issue of the *Journal of the Association for Information Systems (JAIS)* and extends the initial design principles into a nascent design theory for visual inquiry tools with the inclusion of an additional design science research project: the Data Excellence Model. The theorization of the design of these three tools resulted in three general design principles (that should allow for the rigorous design of visual inquiry tools: (1) frame the wicked problem with a parsimonious ontology that outlines its main dimensions and is based on academic justificatory knowledge, (2) represent the ontology into a shared visualization by structuring the components logically into a visual problem space, and (3) define and specify techniques that allow for joint inquiry.

I will conclude my dissertation in Chapter 7, in which I will provide a synthesis of the main contributions of the six studies to both the descriptive and prescriptive knowledge bases. I will then put these contributions in perspective and underline three overarching contributions of my dissertation. Firstly, I will outline how my dissertation provides a new conceptualization of cross-boundary teamwork. With the six studies, I have integrated theories from different disciplines (e.g., psycholinguistics with Clark's theory on coordination and language use, and sociology with Dewey's theory on joint inquiry), and this integration has allowed me to depart from the predominant accounts which regard teamwork as a collection of parallel processes. I propose that cross-boundary teamwork should primarily be considered as a process of joint inquiry into a variety of wicked problems (e.g. cooperation, business modeling, data management). This new conceptualization stresses that emphasis should be put on the wicked problems. The phenomenon of interest for researchers should shift from cross-boundary teamwork to the wicked problems they face, cross-boundary teamwork becoming the context.

Secondly and relatedly, I relate the importance and need for researchers interested in cross-boundary teamwork to engage with design science researcher more extensively. This research paradigm encourages researchers to develop practical guidance to address the challenges of cross-boundary teamwork. I suggest that these developments should be directed towards supporting cross-boundary teams in jointly inquiring into specific wicked problems. Such developments could accumulate into a toolbox for cross-boundary teams, with a range of tools covering the variety of wicked problems that cross-boundary teams need to solve.

CHAPTER 2

LITERATURE REVIEW ON CROSS-BOUNDARY CHALLENGES

ABSTRACT OF CHAPTER 2

In this chapter, I will review the literature on cross-boundary teamwork and explain the three challenges that teams face (coordination, cooperation, and wicked problems). The main purpose of this literature review is to provide an overview of how prior studies have proposed to address these challenges and underline that cross-boundary research might gain in practical relevance if it is complemented with design science research to develop artifacts that help address the cross-boundary challenges. I will not cover the conceptual background that I build on to design these tools for the purpose of clarity. There are no clear guidelines on how and where to present the conceptual background in design science research studies as they can both be included in the literature review or be presented in a separate section (Gregor and Hevner 2013). I will present the conceptual background separately as it is more useful to inform the design of the artifacts than informing the research questions and research gaps. Therefore, I will leave the explanation of the conceptual backgrounds that I used for each challenge in their related chapters: Chapter 4 for coordination challenges, Chapter 5 for cooperation challenges, and Chapter 6 for wicked problem solving. This will allow me to articulate the research questions that I address in my doctoral research. Since cross-boundary teamwork is a special type of teamwork, I start this chapter by providing a general contextualization of teamwork, before diving into the specificities of cross-boundary teamwork and the related challenges.

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1 Introduction and contextualization

Teamwork has become a ubiquitous concept and activity in most organizational life (Weiss and Hoegl 2015). Teams are a collective of three or more individuals who share responsibilities and collaborate toward the achievement of a joint outcome that cannot be reached by individuals alone (Ilgen 1999). Teamwork has proven to be an effective strategy for enhancing performance and addressing complex problems in management (Mathieu et al. 2008), healthcare (Kydona et al. 2010; Taylor et al. 2013), scientific research (Stokols et al. 2008), or education (Oakley et al. 2007). This interest in teams is not only limited to research as a survey by Garvey (2002) concluded that while only 20% of organizations relied on teamwork for some of their tasks, the proportion surged to 80% in the early 2000s. This increase of the reliance on teams is mainly due to the changing nature of work, which has moved from a focus on production to knowledge-based services (Bell and Kozlowski 2002), the latter being particularly well-addressed by teams (Pearce 2004). Teamwork can have several benefits such as an increase in performance (Gemünden et al. 2005; Hoegl et al. 2003; Stajkovic et al. 2009), greater creativity and innovation (Hoegl and Gemuenden 2001; Paulus 2000; Sethi et al. 2001), faster delivery and task completion (McDonough 2000), a collective experience of well-being (Jex and Bliese 1999; Salanova et al. 2003), the promotion of cooperative and pro-social behaviors (Hu and Liden 2015; Ramamoorthy and Flood 2004), and learning from one another (Druskat and Pescosolido 2002; Edmondson 1999; O'Donnell 2006; Van den Bossche et al. 2006).

Given this profusion, Hollenbeck et al. (2012) reviewed the literature on teams across organization and management research. They found that studies had accumulated into 42 different types of teams. They suggested three overarching dimensions that are relevant to categorize them: hierarchical structure, temporality, and skill differentiation. In that sense, teams can have more or less flat structures, with hierarchical teams and autonomous (self-managing) teams on each side of the spectrum. Also, individuals can gather in teams for a one-shot task or can span over long periods of time. Finally, teams can be composed of individuals with similar skills and functions or with a diverse set of knowledge and expertise.

This diversity in skills has received great attention from research as it has been shown that, under certain circumstances, cross-boundary teams perform better than homogeneous groups on complex tasks (Bowers et al. 2000; Derry et al. 1998; Hall et al. 2002; Wegge et al. 2008) and provide more innovative solutions (Harrison et al. 1998; Mortensen 2014). Compared to homogenous teams, cross-boundary teams are those that are composed of members across functional boundaries (different sets of knowledge and expertise such as teams of individuals with expertise in marketing, IS, and engineering) and organizational boundaries (members come from different organizations such as teams composed of contractors, clients, and consultants) (Edmondson and Harvey 2017). The very existence of cross-boundary teams is motivated by the increased specialization of knowledge that is required to address the rising complexity of the challenges that organizations face today. In fact, cross-boundary collaboration is particularly appropriate when the project involves some novelty which requires unique types of knowledge that one single individual cannot hold alone (Carlile 2002; Cummings and Kiesler 2007), such as for strategic management (Bruce and Bessant 2002; Sosna et al. 2010), information systems development (John and Kundisch 2015), and new product development (Steen 2011). Knowledge diversity increases the ability for teams to analyze and elaborate information related to their joint activity, as there are multiple perspectives that can provide a more comprehensive and accurate representation of that information (Van Knippenberg and Schippers 2007). Moreover, cross-boundary teams have access to more information as they are more likely to have nonredundant sources of information (Hansen 1999). They thus have a higher ability to absorb information and knowledge (Cohen and Levinthal 2000; Lovelace et al. 2001), which in turn may be used to produce creative ideas (Edmondson and Harvey 2017).

Yet, these knowledge boundaries represent a paradox (Carlile 2002). On the one side, they represent the conditions for success as they are the very reason that allow teams to perform well on creative and complex projects. On the other side, knowledge boundaries are the main reasons that hinder the success of cross-boundary teamwork. Due to their differences, cross-boundary team members will have difficulties communicating and coordinating as they may fail to understand each other (Carlile 2004). These knowledge boundaries make cross-boundary teamwork even more challenging than collaboration within homogenous teams (Edmondson and Nembhard 2009). In practice, these knowledge boundaries translate into a difficulty for practitioners to collaborate across boundaries (Dougherty 1992; Hansen and Nohria 2004; Van Der Vegt and Bunderson 2005).

I will now review in detail three challenges that are typical of cross-boundary teams and will show how current literature proposes to address them. These challenges are the difficulty of coordinating everyone's understanding and contributions, the difficulty to develop cooperative attitudes and commit to a joint project, and the difficulty to define the course of actions for manage the complex projects they usually face. I will outline that despite the extensive research on the three cross-boundary challenges, insights from the literature have not clearly translated into actionable and practical guidance that cross-boundary team members can use in real time to overcome these challenges. I will summarize the main insights from the literature and argue that, if combined with design science research, they can be instantiated into artifacts and tools that can influence the course of action of practitioners in a way that helps them overcome the challenges. These arguments will allow me to define the research questions and motivation of the six studies of my doctoral research. The six studies are combined in pairs of two, each pair addressing one of the three cross-boundary challenges.

2 Overview of the challenges in cross-boundary teamwork

The demanding nature of cross-boundary collaboration can be attributed to three challenges that are inherent to the team (Edmondson and Nembhard 2009): coordination challenges, cooperation challenges, and wicked problem resolution (Table 2). I will explain these challenges and outline their causes and consequences in greater detail hereafter. Coordination challenges relate to the difficulty for cross-boundary team members to integrate their interdependent contributions effectively. Coordination is challenging because it requires team members to overcome their interpretive boundaries to create shared understanding (Bittner and Leimeister 2014; Edmondson and Harvey 2017). Cooperation challenges refer to the difference in interests that team members may have due to their functions (Boughzala and De Vreede 2015; Carlile 2002, 2004). Functions and experience within one domain will create a set of values, beliefs, and intentions that serve the purposes of that function and that can thus come into conflict with those of other functions (Black et al. 2004). Finally, wicked problem solving relates to the challenge of knowing how to go about a task in a context that is characterized by novelty, complexity, and uncertainty (Edmondson et al. 2003). In such cases, team members do not only need to manage their boundaries, they also need to develop knowledge on effective ways to solve the wicked problems they face (Carlile 2002).

Table 2 - Overview of the intrateam cross-boundary challenges

Cross-boundary challenge	Description	References
Coordination challenge	Difficulty of developing shared cognition to coordinate contributions and communicate effectively	Bittner and Leimeister (2014); Carlile (2002; 2004)
Cooperation challenge	Difficulty of developing a shared mission and intentions to fuel cooperation and collaboration	Bougzhala and de Vreede (2015); Carlile (2002; 2004)
Wicked problem resolution	Difficulty of knowing how to undertake a task with complex, uncertain, and ambiguous requirements.	Edmondson et al. (2003)

There are other challenges that teams face and that relate to their environment, but I will not consider them in my dissertation as I focus on the challenges that impede the interactions between team members, that is intrateam interactions. External challenges include the need to gain organizational support and resources which is often done through boundary spanning (Kellogg et al. 2006; Levina and Vaast 2005; Stamper and Johlke 2003; Tushman and Scanlan 1981), and overcome disabling organizational structures and processes such as individual-based rewards that would not fuel cooperation (Lee et al. 2004; Robbins and Finley 1997; Young-

Hyman 2017) or organizational barriers (Hackman 2002). However, in this thesis I am interested in designing tools to support the interactions within the team, i.e. the interactions between the members of cross-boundary teams. Boundary spanning or requesting organizational support are usually done by one or a few cross-boundary team members with individuals outside the team. These describe interteam dynamics.

I will first describe the three intrateam cross-boundary challenges and explain their antecedents. In section 3, I will cover the coordination challenges and review the four research streams that have analyzed team coordination. In section 4, I will relate the cooperation challenges and how they are addressed through the lens of shared leadership. In section 5, I will conclude with the challenge of solving wicked problems and outline recent approaches that have emerged in supporting teams for their resolution, especially in IS. For each cross-boundary challenge, I will provide an overview of how they are usually addressed by current literature and the practical guidance that practitioners can draw from these prior studies. I will argue that there is still a need for prescriptive knowledge and guidance for practitioners and that current literature has left this need unaddressed. In fact, as I will show, most studies on the three cross-boundary challenges have provided descriptive and context-specific guidance that is difficult to use and follow by practitioners in settings outside those analyzed by the specific studies. I conclude the literature review by making the case of design science as a strategy to overcome this shortcoming, by designing tools that embody the prescriptive knowledge and make users act in a certain and more efficient way.

3 Coordination challenges

In this section I will first describe what coordination challenges are by outlining their antecedents and consequences. I will then relate how prior studies have suggested to address these challenges. These studies have accumulated into four separate lines of research: coordination through mechanisms, coordination through shared cognition, coordination through language, and coordination through objects. I will conclude the section by arguing that the mechanistic perspective is too difficult to apply in practice, but that the combination of the other three perspectives (shared cognition, language, and objects) can provide solid ground for the design of an artifact to address coordination challenges. I will finally outline the research question that bridges these three perspectives and that I will address in Chapter 4.

3.1 The antecedents and consequences of coordination challenges

Coordination challenges correspond to a difficulty yet crucial need for team members to integrate their interdependent actions and knowledge to deliver aligned contributions (Klein et al. 2005; Rico et al. 2008; Zackrison et al. 2015). The difficulty for cross-boundary team members is to overcome the differences stemming from their different functions and mental models to create shared understanding (Bittner and Leimeister 2014). On the one hand, the integration of the diversity of specialized knowledge fuels performance and innovation. On the other hand, this diversity creates the boundaries that might impede collaboration (Rahrovani and Pinsonneault 2017). As related by Carlile (2002), knowledge diversity is both a source and a barrier to innovation. It is crucial for such diverse teams to overcome the problems of understanding each other across disciplines and functions (Seidel and O'Mahony 2014), especially given that a lack of shared understanding is likely to impact all other teamwork processes such as coordination (Cronin and Weingart 2007; Huang and Newell 2003) and communication (Bechky 2003a). In fact, the need for shared understanding has often been stressed as a significant predictor for collaboration effectiveness (Bittner and Leimeister 2013) and performance (Mathieu et al. 2000; Van Knippenberg and Schippers 2007).

The concept of knowledge boundaries by Carlile (2002; 2004) provides a detailed explanation of why such differences of understanding are particularly present in cross-boundary teams. Carlile identified two types of knowledge boundaries according to the level of novelty of the situation faced by cross-boundary: syntactic, semantic, and pragmatic boundaries. The first two – syntactic and semantic boundaries – are particularly insightful for explaining the coordination challenges. The pragmatic boundaries are more relevant to explain cooperation challenges and I will explain this type of boundaries in Section 4, when covering the cooperation challenges.

On the lower-level of the spectrum of novelty, cross-boundary team members might face syntactic boundaries, i.e. boundaries of communication as members have different lexicons and vocabularies. For example, health professionals and IT developers working on the development of software for operating rooms may use different terms and communicate with different habits. One can think of the different meanings that a developer might attach to a "need" which would describe a requirement or a good-to-have functionality, while the physician will attach a more binary meaning to it, in that a need is mandatory and non-negotiable as lives might depend on their surgeries. While such differences may impede effective communication and interaction between boundaries (Kotlarsky et al. 2015), Pawlowski and Robey (2004) showed that communities of practice that are different usually notice that they have differences in how they use language and can relatively easily develop a common vocabulary to communicate more easily.

As the novelty increases, individuals will need to develop new knowledge that must be integrated effectively. Here, individuals might face semantic boundaries which exist when there are differences in interpretation and understanding that can happen across practices. This is due to the difference in thought worlds (what people know and how they know it) such that people will interpret things differently (Edmondson and Harvey 2017). In fact, communities of practice and individuals have different experiences, cognitive schemes, and functions that will shape how they interpret reality. For example, a physician will not construe what was talked about during a team meeting the same way as the software developer, even if they both attended to the same events. As illustrated by Dougherty (1992), people do not only know different things, they also know things differently. A study by Mohammed and Ringseis (2001) concludes that semantic boundaries can also lead to dissatisfaction about the solution and teamwork.

There has been considerable research on coordination and the processes and material artifacts that allow cross-boundary team members to address these knowledge boundaries and coordinate effectively. In the remainder of this section, I will cover four streams of research that have gained prominence. A summary of these research streams is provided in Figure 1. The first research stream (1, in Figure 1) views coordination as mainly achieved through a variety of coordination mechanisms, i.e. strategies that individuals use depending on the situation. The second stream of research (2) considers the role of shared cognition in cross-boundary coordination. There are two perspectives on shared cognition among which the socio-cultural one which considers the central role that language plays in coordination. The third research stream (3) focused on the linguistic acts through which coordination is done. Finally, a perspective on the material dimension of coordination (4) has produced theoretical contributions on boundary objects (those that convey information that is interpreted similarly across boundaries) and communication technologies.

As I will show in this literature review, the literature on coordination mechanisms has mainly proven interesting for researchers and has not provided any useful guidance that can help cross-boundary team members overcome coordination challenges. However, the other three streams (shared cognition, language, and objects) can be translated into practical guidance, but only few studies have done it. I will thus show how these three perspectives can be integrated to provide the baseline on which the design of an artifact for cross-boundary coordination can be envisioned. I follow here the argument by van Aken (2004) and researchers in IS (Gregor and Jones 2007; Peffers et al. 2007) who considered that social sciences should engage with design sciences more intensively in order to provide prescriptive knowledge in the form of a course of action that practitioners would follow to solve their problems. I will then identify the research question that bridges the descriptive literatures on coordination with the need for practitioners to have practical guidance.

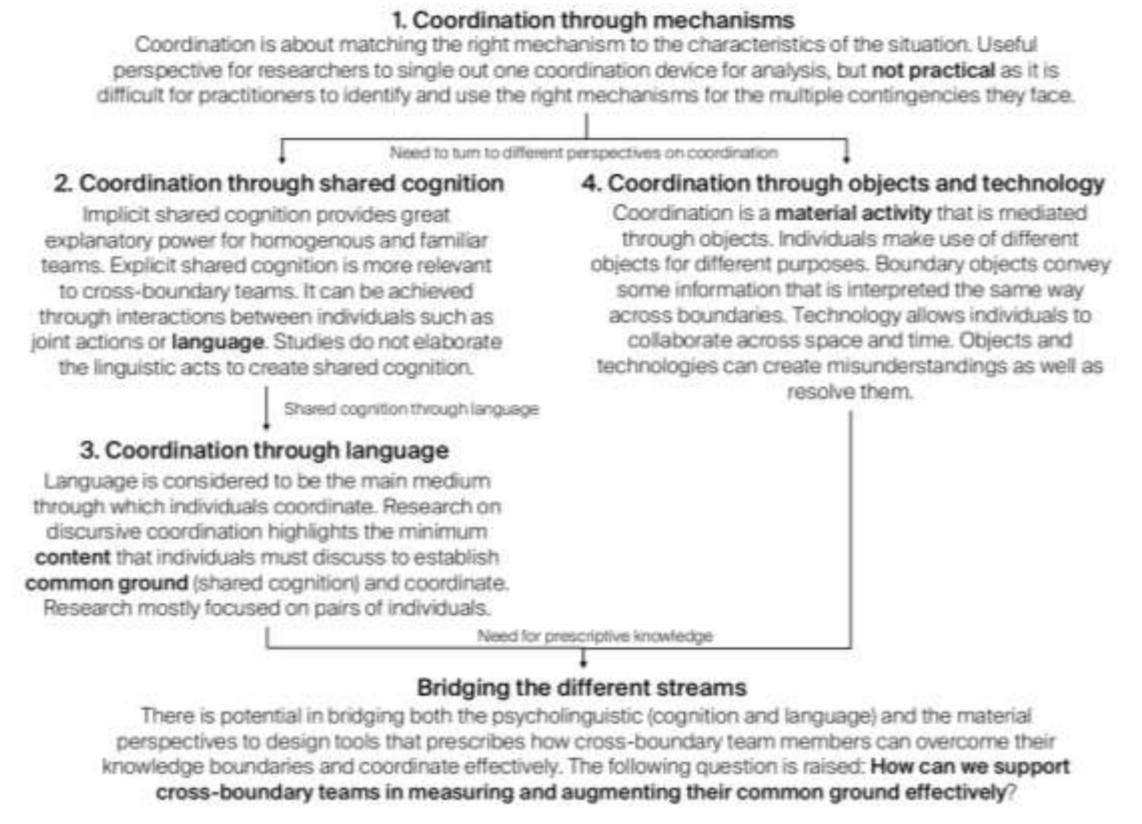

Figure 1- Overview of the literature on coordination challenges

3.2 Addressing coordination challenges through mechanisms

The stream of research initiated by Malone and Crowston (Crowston 1997; Malone and Crowston 1990, 1994) has led to a particular and influential perspective on coordination. This perspective considers coordination as a problem of managing interdependencies between individuals as soon as work is divided and specialized. Such interdependencies are managed through specific coordination mechanisms (device). Given the type of interdependency, a coordination mechanism may prove more or less effective, and the goal is then to find the most appropriate and efficient one (Cataldo et al. 2006; Sosa et al. 2004). For example, when the activity of one participant depends on the output of the activity of another, the authors suggest that ordering activities sequentially will allow for effective coordination. This approach is often called the contingency or mechanistic approach due to this need to match the right mechanisms with the contingencies of the situations that practitioners face. It built on Galbraith's (1973) information processing model and the fit and contingency models (Lawrence and Lorsch 1967; Thompson 1967). The mechanistic perspective has not been applied to cross-boundary teams exclusively, but it has led to an important record of publications on coordination some of which address cross-boundary teams specifically (Strode et al. 2012).

Keith et al. (2013) analyzed how informal (e.g. face-to-face meetings) and formal (cross-departmental communication, structure, planning) coordination mechanisms are used over time in software development projects. They showed that an extensive use of formal coordination mechanisms at the beginning of a project will decrease the need for informal coordination in later stages of the project. Ahern et al. (2014) have suggested that the mechanism of planning all the activities ahead for complex problems is not as effective as the mechanism of only defining clear goals while letting other aspects prone to emergence. Mani et al. (2014) came to a similar conclusion as they found that a division of labor in the form of activity breakdown structures are less effective than intensive information sharing for complex and less routinized tasks. Nidumolu (1995) differentiated between horizontal (mutual adjustment and communication) and vertical coordination mechanisms (formal decision making procedures) depending on the task structure and its uncertainty. Espinosa et al. (2004) suggested that depending on the task and the configuration of team, task organization mechanisms such as plans, schedules, and specifications may increase coordination effectiveness. Coordination mechanisms also include tools and technology. For example, Ren et al. (2008) showed how interactive white boards can be useful for staff allocation in operating rooms at hospitals. They also suggest that location-based systems might reduce the need for operating teams to communicate as they could automatically provide some information such as where a patient is located.

Given the variety of coordination mechanisms and types of interdependencies between people and tasks, some scholars have provided frameworks and classifications to suggest which coordination mechanism should be used given a situation. For example, Tillquist et al. (2002) suggested that dependency networks where dependencies between goals, roles, and tasks are mapped can allow to define which activities to perform. Dietrich et al. (2013) provided a classification of a variety of coordination mechanisms where they differentiated between impersonal modes of coordination, group modes of personal coordination, and individual modes of personal coordination.

This perspective provides a useful framework for researchers to situate their research and single out the coordination mechanism(s) they want their analysis to focus on (Zackrison et al. 2015). This might explain its popularity in organization and management research on coordination, which is concerned with rich settings and cases where teams coordinate using a variety of coordination devices. Considering coordination as an array of coordination mechanisms allows researchers to analyze the variance on coordination effectiveness or performance of specific coordination mechanisms. However, the mechanistic view of coordination poses several practical problems for cross-boundary coordination. As the projects cross-boundary teams work on are typically prone to emerging requirements, continuous change and low visibility, the mechanistic perspective is too difficult to implement for practitioners as they would need to dynamically adjust an enormous number and type of coordination mechanisms (Faraj and Xiao 2006; Williams and Karahanna 2013). It is difficult for individuals to identify and manage interdependencies between participants and use the right coordination devices (Sosa et al. 2004). Also, such mechanisms do not necessarily prevent coordination breakdowns (van Fenema et al. 2004). In general, this perspective is not practical and actionable enough for practitioners (Cataldo et al. 2006).

3.3 Addressing coordination challenges through shared cognition

As boundaries represent impediment on the creation of shared knowledge, an extensive number of studies have addressed how cross-boundary teams can develop shared cognition to coordinate effectively. Shared cognition – the fact that individuals share the same perceptions and understanding of their situation – is often considered as a central and critical issue in effective cross-boundary teamwork as it allows team members to understand, predict, and integrate their interdependent contributions (Ancona and Caldwell 1992). In fact, shared cognition is necessary for communication and coordination (Clark and Brennan 1991), and is positively related to team performance (Peterson et al. 2000). Without shared cognition, individuals do not act as a whole and their divergent views will make them perform contributions that cannot be aligned, or they perform no contributions at all (Klein et al. 2005). Other scholars suggest that shared cognition helps cross-boundary practitioners understand different viewpoints and see them as legitimate (Engeström et al. 1995; Tsoukas 2009). All these reasons have motivated a great number of scholars to investigate the characteristics of shared cognition and how it can be created and maintained.

Several scholars have provided frameworks that identify and delineate the different strands of research on group cognition (*e.g.*, Akkerman et al. 2007; Mohammed and Dumville 2001; Theiner et al. 2010). Generally speaking, studies on group cognition have two separate ontological premises (Table 3). On the one side, studies inscribed in the cognitive perspective as termed by Akkerman et al. (2007), conceptualize group cognition as an overlap or similarity of individuals' cognitions. On the other side, scholars in the socio-cultural perspective conceive of group cognition as situated in the interaction between participants and defined by the extent to which these participants contribute to the joint activity. That is, if a group shows patterns of effectively aligned contributions and interactions, then one may consider that there is some group cognition emerging.

Research in the cognitive perspective was mostly dominated by the theory of team mental models which was introduced as a concept to understand how effective teams manage to collaborate in situations that are complex, ambiguous, and dynamic (*see* Cannon-Bowers et al. 1993; Klimoski and Mohammed 1994; Mohammed et al. 2010). Team mental models are the shared representations that team members have on the tasks, equipment, relationships, and situations (Cannon-Bowers et al. 1993). For teams to collaborate and coordinate effectively, they need to share four different types of knowledge: task-specific knowledge (all the knowledge that is necessary to perform a task), task-related knowledge (general knowledge about teamwork and how it operates), attitudes or beliefs (similarities in attitudes and interpretations between team members), and knowledge of the other team members (knowledge on who knows what and others' intentions and preferences) (Cannon-Bowers and Salas 2001). When team members share such knowledge implicitly, they can form accurate expectations and, thus, coordinate effectively (Levesque et al. 2001). It is important to note that the similarity in attitudes or beliefs that such models promote is hard to apply to cross-boundary teams, in which members with different practices hold different beliefs about the project and have diverse intentions and preferences. Also, this perspective – contrary to the socio-cultural perspective – is more inscribed in what is defined as implicit coordination (Banks et al. 2016). Implicit coordination occurs when individuals adjust and anticipate their peers' actions without any explicit communication or prior planning (Rico et al. 2008). Implicit coordination is considered to be supported by the team mental models.

Table 3 - Overview of the literature on shared cognition

Perspective	Ontological premises on shared cognition	Techniques and processes that support the creation of shared cognition
Cognitive perspective	Similarity and overlap between individual cognitions within the team.	Team training, experience working together, reflexivity, shared displays.
Socio-cultural perspective	Enacted in interaction and corresponds to the extent to which team members deliver aligned contributions.	Interaction, making assumptions explicit, discussing issues, psychological safety.

Regarding the development of team mental models, various causes have been identified such as training teams on how to interact and generate shared mental models (Marks et al. 2000; Prichard and Ashleigh 2007), interaction between team members (Klimoski and Mohammed 1994), reflexivity and feedback (Rasker et al. 2000), learning and positive conflict management attitudes (Bossche et al. 2011), and the use of shared displays (Bolstad and Endsley 1999). However, most developments in this perspective have focused on how to measure team mental models for research purposes (DeChurch and Mesmer-Magnus 2010), with little emphasis on how these models can be created in practice.

The socio-cultural perspective is less focused on the similarity of knowledge structures as it considers that both cognitive consensus and divergence are important to effective performance (Kilduff et al. 2000), and that knowledge to perform a task is spread across team members (Akkerman et al. 2007). This stream of research is more interested into understanding how practitioners with different functions enter the group setting and manage to overcome the differences of perspectives and interpretations to coordinate their contributions (Mohammed and Dumville 2001). For example, Yoo and Kanawattanachai (2001) described that virtual teams used knowledge on who knows what (transactive memory) and created a collective mind during interactions to coordinate their contributions. Bruns (2013) suggested that when individuals perform their specialized tasks alone within a project, they both attend to what had been agreed on in the previous interactions with other team members and they anticipate (or project) the others' future needs. Both these processes lead to an effective coordination of specialized contributions. The socio-cultural perspective is anchored in the explicit view of coordination as it considers the role of interactions as crucial to the development of shared cognition and coordination. This perspective is more appropriate for tasks that are complex and uncertain so that participants cannot simply rely on implicit coordination but need to explicitly discuss and plan their joint actions.

In fact, this is reflected in how studies suggest that shared cognition is developed in teams. Various processes and techniques have been identified such as team interactions and discussions on the task requirements (Clark and Brennan 1991; Fusaroli and Tylén 2012; Klein et al. 2005; MacMillan et al. 2004), the explicit management and discussion of the expertise held by each participant (Faraj and Xiao 2006), trading zones in which practitioners agree on the minimal requirements for the task without necessarily understanding each other (Kellogg et al. 2006), talking about problems and mistakes (Carmeli and Gittell 2009; Edmondson 1999), discussing and reflecting on team goals and processes (Schippers et al. 2003), or by revealing implicit assumptions that people hold across practices (Hargadon and Bechky 2006). Despite this extensive inventory of what leads to shared cognition, prior studies do not detail how cross-boundary team members must concretely interact when they face misunderstandings or shared cognition breakdowns. They provide a list of consequential mechanisms that can be used to improve the emergence of shared cognition, but they do not suggest the linguistic acts for cross-boundary teams to establish shared cognition during team meetings. For example, how do we interact to know what perspectives others hold? How do we get to know who knows what? How do we get to know how goals are construed across practices? How do we talk about all these assumptions?

The strand of research on team reflexivity is concerned with similar questions, yet does not provide clear prescriptive answers as I will argue in the following paragraphs. Team reflexivity represents "the extent to which group members overtly reflect upon, and communicate about the group's objectives, strategies (e.g., decision-making) and processes (e.g., communication), and adapt them to current or anticipated circumstances" (West 2000, p.296). It is a transition process using Marks and colleagues' (2001) nomenclature for team processes, during which team members reflect on their performance and generate new ideas on how to improve their performance and organize their work (Schippers et al. 2012). In the original definition by West (2000), team reflexivity was viewed as a process with three phases, namely reflection (during which teams consider work-related issues), planning (which translates the reflection into objectives), and action (the adaptation to changes and implementation of the newly formed objectives). However, as noted by Widmer et al. (2009), this distinction is less present in recent works as the three parts of reflexivity are regarded as highly interrelated and less clearly delineated in practice.

Teams who engage in reflexive processes increase their team performance as they can develop better strategies and plans to cope with errors and changing circumstances (Carter and West 1998; Gevers et al. 2001; Pieterse et al. 2011), make higher quality decisions (van Ginkel et al. 2009) are able to learn from each other and the situation as they process feedback from others or their advancement on their performance and mistakes (De Dreu 2007; Müller et al. 2009; Vashdi et al. 2007), and undertake innovative projects more effectively as they are more likely to integrate and critically discuss divergent and diverse opinions and implicit knowledge (Lee 2008; Schippers et al. 2015; Shin 2014; Tjosvold et al. 2003).

Team reflexivity is typically associated with coordination and increased shared understanding as they engage more intensively and extensively into sharing relevant information and understanding informational requirements of all team members (Schippers et al. 2014). Members of reflexive teams are typically more inclined to notice that their peers need some implicit information they hold, thus engaging in the elicitation and externalization of their knowledge (Müller et al. 2009). Teams who reflect on their performance communicate more effectively on the requirements for their work activities and develop a better view of their strategy and the task representations that teams who do not engage in reflexive processes (Hedman-Phillips and Barge 2017; Ginkel et al. 2009). This is particularly the case in activities for which the individual contributions of the team members and their outcomes are highly interrelated, in which case the relationship between team reflexivity and effective coordination is stronger (De Dreu 2007).

Given that teams do not engage in reflexive behaviors spontaneously, scholars have been interested in the interventions that promote team reflexivity (Müller et al. 2009; Schippers 2003).

In fact, most teams prefer to focus on action rather than reflection (Di Stefano 2014). Most interventions fall under the category of guided reflexivity or structured reflection (Gabelica et al. 2014). The goal of such guidance is to ask team members to reflect individually (individual reflexivity) or in groups (group reflexivity) on the team's past performance and how they can improve it in the future, in order to identify better courses of action (Gurtner et al. 2007). Guided reflexivity may also be triggered by feedback given from external parties on the team's performance (Schippers et al. 2013). Guided reflexivity can take the form of debriefs (Tannenbaum and Cerasoli 2013) or self-correction (Smith-Jentsch et al. 2008). While such interventions have been shown to increase team performance and learning (Konradt et al. 2015) and thus might prove valuable for addressing the coordination challenge, they usually concern the entirety of the team's outcomes and processes with only few studies focusing on specific processes (*e.g.*, Hedman-Phillips and Barge 2017 *on communication*). Also, these studies do not specifically address the boundaries that might impede coordination in cross-boundary teams, as they mostly focused on homogenous teams of students or familiar team members. This strand of research, however, highlights the need to drive cross-boundary teams to reflect and discuss their strategies and improved courses of action to build shared cognition so that team members can align their individual contributions effectively.

3.4 Addressing coordination challenges through language

Given the importance of interactions and language to the development of shared cognition, there has been a significant body of research on the role of language in coordination. In fact, organization scholars have emphasized the critical role that communication plays in coordination (Okhuysen and Bechky 2009), but very few have explicitly analyzed the particular role and processes of conversation in cross-boundary teamwork (Zackrison et al. 2015). Gittell (2001, 2002) suggested that during uncertain and fast-paced joint tasks, individuals resort to relational coordination during which they interact and build relationships around shared goals and knowledge. This conceptualization of coordination considers that relationships have a central function in coordination, as individuals will interact and coordinate better if they have strong ties and appreciation for each other. Also, the more boundaries there are between individuals, the more necessary relational coordination is (Vashdi et al. 2013). Other scholars consider that teams resort to conversation when there are surprises (Bechky and Okhuysen 2011) or disruption of routines (Minssen 2006), although these studies focus on homogenous teams. In such cases, explicit communication is used to make sense of the new situation and to agree on a course of action to coordinate everyone's contributions.

Another perspective on the role of language in coordination and cognition lies in the fields of psycholinguistics and cognitive psychology. In general, this stream of research considers language as a coordination device that will provide an extensive set of information that individuals can use to coordinate their actions, understanding, and perceptions (Fusaroli and Tylén 2012; Knoblich et al. 2011). These studies usually fall under two categories even though not mutually exclusive: those that account for the role of cognition and language in coordination (*e.g.*, Clark and Brennan 1991; Clark and Schaefer 1989; Grice 1975; Pearce and Pearce 2000) or on the perception-action link for coordinating simple joint actions (*e.g.*, Bangerter and Chevalley 2007; Goodwin and Goodwin 1996; Richardson et al. 2007; Sebanz et al. 2006; Tomasello 1995). I will not cover the latter perspective as it is mainly concerned with how individuals coordinate their behaviors in the here-and-now in collocated situations, such as moving a table from one room to another together. This perspective is less applicable to the coordination over time and space that cross-boundary teams typically experience and need. Cross-boundary teams usually undertake projects that last from several weeks to several years and these projects are structured around an extensive number of recurrent project meetings, during which team members integrate everyone's previous contributions (i.e. what actions everyone has performed until the meeting), monitor the situation, and plan the actions that everyone must perform until the next meeting. Therefore, I will focus on the perspective that accounts for the role of cognition and language in coordination.

In this stream of research, the notion of common ground was developed by Clark and Schaefer (1989) as a means to explain how individuals create common ground through linguistic acts at a micro-level (utterance) level of interactions between individuals. Common ground is the set of knowledge, beliefs, and suppositions that two or more individuals believe they share. This stream of research is particularly interesting as it sheds light on a dimension that is often overlooked by organization scholars: when people communicate, they coordinate both the joint activity they are performing and the very act of speaking to each other (Bangerter and Clark 2003). That is, at the basic level, individuals coordinate their interaction through turn-taking (coordinating when interactants speak) (Goodwin 1986; Sacks et al. 1978) or evidence of understanding (Clark 1996). Individuals display their understanding of what speakers say through simple words such as "uh-huh" or with repetitions and paraphrases of what has just been said. This allows them to establish common ground with varying levels of certainty, simple words providing less accurate displays of understanding than paraphrases for example. Clark (1996) also defined the minimum themes that individuals must have common ground on whenever they are to perform a joint project: (1) the identification of the purpose of the joint project (i.e. the objectives), (2) the ability to perform one's part toward the attainment of the joint project, and (3) the willingness to do one's part.

The coordination of linguistic acts allows individuals to construe predictions and common ground so that it allows them to coordinate higher-level joint actions such as scheduling the next meeting or defining what everyone contributes to the joint activity (Vesper et al. 2010). This view of coordination has the potential to provide a more fine-grained analysis of team coordination than the accounts of organization and management scholars as it allows for a better understanding of the coordinative processes both of the language itself and the higher-order joint activities. This perspective has the potential to explain how breakdowns in conversation impede the coordination of higher-order joint activities and the creation of common ground. In fact, such knowledge would prove useful as discursive coordination in teams is difficult and not innate (Minssen 2006). However, despite some exceptions, most of these studies have analyzed discursive coordination mainly between pairs of individuals as the analysis of cognitive and linguistic processes with more than two individuals poses serious methodological challenges (Svennevig 2000). Also, these studies have focused on how common ground is created at the level of utterances which does not necessarily translate into shared understanding at the level of a whole conversation (Cherubini et al. 2005). These studies thus need to be adapted and extended in order to be relevant for the understanding how *cross-boundary* teams coordinate. I will explain in section 3.6 how this perspective can be combined with research on objects to be applicable to cross-boundary team coordination.

While the definition of common ground may, at first, imply that it is similar to shared cognition, the two concepts are different on two dimensions. First, common ground includes reflexivity (e.g., I know that you know that I know and so do you) contrary to the notion of common ground. Second, common ground is established at the micro level of interactions (at the level of utterances) while shared cognition is construed at a macro level of the interaction (at the end of an exchange or conversation) (Cherubini et al. 2005). Common ground at the micro level is often regarded as a resource that is both available prior to the conversation between individuals and created during the conversation to facilitate the interaction (Kecskes and Zhang 2009). In fact, common ground is both needed for the joint activity and the choreography of the joint activity (Klein et al. 2005). In fact, when considered in its literal definition, common ground is a concept that is most useful to understand how individuals coordinate their contributions in the here-and-now through conversation. It states how individuals create some shared reference that can help them navigate through a conversation with a minimum of breakdowns (Clark and Krych 2003; Horton and Keysar 1996). However, understanding each other at the utterance level does not necessarily lead to the creation of shared understanding as there may be the illusion of understanding as outlined by Ross et al. (1977). In fact, common ground may fail to account for additional processes that take place in joint activities such as intentions (e.g. divergent personal interests and agendas), contextual background, and the reliance on tools to create shared understanding (Baker et al. 1999).

However, while the notion of common ground in its literal meaning at the micro-level may not automatically translate into shared understanding at a macro-level (Cherubini et al. 2005), I consider it as the most promising candidate to shed light on how shared understanding between team members at the level of a whole conversation. In fact, this notion has long been confined to interaction studies, but several studies in management and organization have highlighted how a conceptualization of team coordination as establishing and maintaining common ground can provide valuable insights on team interactions (Klein et al. 2005; Mastrogiacomo et al. 2014). Other researchers have instantiated the concept of a common ground at a macro level such as Bechky (2003b) who showed common ground, if complemented with the concept of appropriation (the act of perspective taking and perspective making) leads to the emergence of shared understanding at the knowledge level. Cherubini et al. (2005) advance the same conclusion regarding the need to consider grounding at the macro-level for the creation of shared understanding as heavily mediated by perspective making and taking in which, not only the process of the conversation is considered, but also the content. In fact, the notion of common ground may fail to encompass the creation of (mis)understandings if no attention is paid to the content of the interactions and how these are integrated by the different parties. Kecskes and Zhang (2009) advanced that the translation from common ground to shared understanding was heavily mediated by not only linguistic tools but also material tools that convey some information that is more difficult to represent verbally. What can be concluded from these studies is that the concept of grounding, if coupled with objects and other means to evaluate and integrate the perspectives of others, can provide a more comprehensive account of how shared understanding is construed at the macro-level. Therefore, I will now turn to the analysis of how objects support the creation of shared understanding.

3.5 Addressing coordination challenges through objects and technology

Collaboration across boundaries has also been looked at from a material perspective. The basic assumption underlying this stream of research is that collaborations form around and are mediated through objects (Latour 2005; Nicolini et al. 2003) and that knowledge is developed and used through material artifacts (Jarzabkowski et al. 2013; Orlikowski 2006). Objects can be any kind of artifact that practitioners use and manipulate in doing their work, such as blueprints, parts, tools, and machines. The various paradigms and perspectives on human activity – whether activity theory (Engeström 1999; Vygotsky 1978), distributed cognition (Hutchins 1995a), pragmatism (Clark 2005; Habermas 2015), actor-network theory (Callon and Law 1997; Latour 2005; Law 1999), situated action (Goodwin 2000; Suchman 1987), and sociomateriality (Leonardi 2012; Orlikowski and Scott 2008) – all tend to consider that objects play a central role in everything we do and that they should be considered as being fully part of human activity. While they may differ on the conceptualization of the dynamics that relate humans to objects and the functions that the latter perform, they all underline the central role of objects in collaboration, coordination, acting, and learning (Susi and Ziemke 2001; Svabo 2010).

Carlile's (2002) seminal paper has channeled most subsequent developments in organization and management around the concept of boundary objects. Such objects allow cross-boundary team members to coordinate and understand each other as they act as interfaces between different domains (Brown and Duguid 2001; Star and Griesemer 1989; Trompette and Vinck 2009). They provide information that is interpreted similarly across boundaries (Okhuysen and Bechky 2009), thus allowing for shared understanding to be created (Bechky 2003a). Examples of boundary objects include prototypes (Bechky 2003a; Doolin and McLeod 2012; Fleischmann 2006), project plans and timelines (Barrett and Oborn 2010; Wheelwright and Clark 1992), process maps (Carlile 2002), engineering drawings and representations (Hargadon and Bechky 2006), digital modeling of the final deliverable (Bergman et al. 2007; Fischer 2001; Gal et al. 2008), public displays of the project progress (Mark 2002), slide presentations (Kaplan 2011), and strategic plans and market analyses (Levina and Vaast 2005; Spee and Jarzabkowski 2009).

Also, boundary objects trigger the emergence of interpretive differences between cross-boundary team members so that they can understand the assumptions made by others and take their perspectives (Boland and Tenkasi 1995). This allows team members to reify their misunderstandings (Wenger 1998). Kellogg et al. (2006) suggested that objects that rely on socially conventional representations of information – such as timelines with the advancement and arrangement of tasks – can convey information without requiring explicit agreements or explanations. Boundary objects can also reveal the dependencies between individuals so that they can take them into account for coordinating (Sapsed and Salter 2004).

However, boundary objects are not always effective for coordinating. As shown by Bechky (2003a) boundary objects might reveal the differences between individuals which might drive some individuals to accentuate them and impose their own interests or agendas. Levina (2005) highlighted that boundary objects can cause fragmentation and prevent the exchange and integration of knowledge across boundaries. Most importantly, Nicolini et al. (2012) concluded that boundary objects can solve misunderstandings just as well as creating them. These contingencies raise the question to what makes boundary objects more or less effective. Carlile (2002; 2004) is the only one to provide such an account. According to him, boundary objects should incorporate two characteristics to allow for coordination: (1) they address syntactic boundaries by establishing a shared syntax or way of communicating so that practitioners can transfer their knowledge (e.g. documents, communication standards), (2) they address semantic boundaries by allowing individuals to specify and translate their knowledge so that differences across boundaries can be understood (e.g. engineering drawings).

IS scholars have also analyzed cross-boundary team coordination mainly regarding two phenomena: how expertise is coordinated in information system development projects (Diegmann and Rosenkranz 2017; Espinosa et al. 2007; Houtman et al. 2014; Lee et al. 2015; Scheerer et al. 2014), and the role of technology for coordination across space and time (Anders 2016; Dombrowski et al. 2013; Modi et al. 2017; Montoya-Weiss et al. 2001; Poltrock and Handel 2010). Regarding the role of technology on virtual team coordination, research contributions have accumulated into three streams: media richness theory, media synchronicity, and knowledge coordination (Karoui et al. 2010). The main focus of the first stream has been on media richness theory and how certain tools allow for more information to be conveyed (or to what extent virtual meetings are similar to face-to-face encounters) (Daft and Lengel 1986; Ferry et al. 2001). This stream of research suggests that as the complexity of the tasks and the number of interdependencies between team members increase, technologies which provide greater information richness might be preferred (i.e. virtual conference rooms preferred to emails) (Kirkman and Mathieu 2005; Mihhailova et al. 2009). For example, Redlich et al. (2017) show how shared visualization for virtual teams through an online whiteboard can enhance coordination and the creation of shared understanding. Researchers in the second stream have analyzed the role of social media in coordination and have found that social media platforms help create social connections and process more information (Delerue and Sicotte 2017; Liu et al. 2014; Zhang et al. 2016). The other stream, called media synchronicity, analyzes the mix between technologies that distributed teams make use of to work synchronously (e.g. virtual conference rooms) and asynchronously (e.g. document repositories) (Chattha 2013; Karpova et al. 2009; Sutanto and Kankanhalli 2006). For example, Cummings et al. (2009) analyzed how synchronous communication technologies allow teams to overcome their spatial boundaries but did not necessarily ensure that temporal boundaries were not impeding due to time zone differences. The third stream focuses on knowledge and how it can be supported in distributed settings. For example, Gupta et al. (2009) found that distributed teams who depend highly on virtual communication to coordinate should look for technologies that allow them to store, structure, and codify their knowledge so that it can easily be accessed and retrieved by others. Kanawattanachai and Yoo (2007) found that communication about the task is critical in the early stages of collaboration, while as time passes, the coordination of task knowledge becomes critical for team performance.

In general, Hinds and Bailey (2003) propose that no matter what technology is introduced within distributed teams, it will necessarily have a negative impact on cohesion, knowledge exchange, and coordination. These findings were later confirmed by Schweitzer and Duxbury (2010) and ven der Kleij et al. (2009). Penarroja et al. (2013) came to a similar conclusion regarding coordination which becomes less effective over time. This is due to the inability by such technologies to support shared understanding (Alavi and Tiwana 2002; Andres 2012). Nguyen-Duc et al. (2014) also found that coordination becomes ineffective when cross-boundary teams face the issues of a decrease in communication frequency, the size of the communication networks between all stakeholders, and the difficulty to find relevant knowledge and expertise within the stakeholders. Other studies, however, found that the use of technology by distributed teams can have a positive impact if teams use it to create an awareness of the presence of others and the advancement of the joint task (Malhotra and Majchrzak 2005; Modi et al. 2013).

These studies suggest that the link between collaborative technologies and coordination effectiveness is not straightforward. The literature on collaborative objects advances similar conclusions as objects are considered both as supporting or hindering shared understanding and coordination. Therefore, there is considerable room for further improvement and investigation into the material perspective on coordination.

3.6 First research gap: Guidance for coordination across boundaries

In this literature review I have outlined the main streams of research on coordination: coordination mechanisms, shared cognition, language, and collaborative objects. These studies have produced considerable contributions to help us understand what coordination is concerned with in cross-boundary teams. The mechanistic approach provides an interesting framework to categorize and single out coordination mechanisms but it has failed to provide practical guidance. On the contrary, the research streams on shared cognition, language, and objects have all provided interesting insights that can inform how coordination unfolds and what are its main barriers and catalysts. The stream on shared cognition has highlighted that cross-boundary team members should make their assumptions explicit, discuss their respective areas of expertise, and agree on the minimal requirements for their joint tasks. Given their emphasis on discussions, this stream can gain in being complemented with research on the role of language in coordination. This stream outlines the linguistic acts through which individuals create common ground and the content of common ground. Research on the role of objects in coordination have analyzed how cross-boundary team members make use of an array of objects, mostly boundary objects, to coordinate their knowledge and contributions.

However, taken separately, these three perspectives fail to provide concrete actionable guidance that practitioners could follow to coordinate effectively. In fact, the literature on shared cognition has mostly focused on analyzing how individuals develop shared cognition in specific contexts. They have, however, come short of producing prescriptive knowledge that is not context-specific and that suggests a concrete course of actions that practitioners should follow to coordinate effectively. The research on language has mostly focused on pairs of individuals and rather simple interactions. There are to my knowledge no studies that have analyzed the linguistic acts through which teams of diverse individuals converse to coordinate their knowledge and contributions. Finally, the research on boundary objects has not suggested what makes some boundary objects more or less effective, as such objects can resolve misunderstandings as well as create them (Nicolini et al. 2012). The research on technology has mostly focused on communication technologies and has not detailed the specific functions that allow cross-boundary teams to overcome their knowledge barriers (Gilson et al. 2015).

The contributions of these research streams have unfortunately not yet relieved practitioners from their difficulties of coordinating in practice. The majority of studies have provided detailed and insightful analyses of how individuals develop shared cognition and use objects in specific settings. This poses the difficulty of generalizing knowledge and applying it to different contexts. There is thus some need for prescriptive knowledge that can be used by cross-boundary team members in a variety of contexts. I suggest that this contribution can build on the integration of the three perspectives (shared cognition, language, and objects) into design science research.

As noted by van Aken (2004) and Gregor and Jones (2007), most research in the social sciences has produced theoretical knowledge that translates into little practicality. They argue for a greater use of design sciences in such cases. Design science research is a methodology that has gained considerable interest, especially in the field of information systems. Its main purpose is to design artifacts (e.g. models, tools) that help practitioners solve practical problems. Simply put, the role of design science researchers is to understand the context and problems of practitioners, draw from descriptive literature and these observations to design those artifacts, evaluate the effectiveness of these artifacts, theorize the knowledge about these artifacts and the social phenomena they address (Hevner et al. 2004).

To bridge the three streams on coordination and design tools that support coordination, I follow Fusarolli and Tylén (2012) in their consideration that language is the main medium through which teams create the common ground that is required for coordination, and that other coordination devices such as objects can be used as substitutes, but not the other way around. Common ground is a form of shared cognition that was coined by Clark (1996) and which corresponds to the set of knowledge, beliefs, and suppositions that individuals think they share. Clark's theory provides solid ground to bridge the literature on shared cognition and language, as he describes the cognitive conditions that should be met for people to coordinate and the linguistic acts through which these conditions can be fulfilled. Mastrogiacomo et al. (2014) have instantiated his theory into a conceptual model for coordination in projects (called the Coopilot conceptual model) and have shown how Clark's theory is useful in understanding how project teams coordinate through discussions in team meetings. In brief, Mastrogiacomo and his colleagues advanced that for team members to coordinate effectively, they must have common ground on their joint objectives (what the team members are trying to achieve together), joint commitments (who does what part for whom), joint resources (can be in terms of financial, time, or expertise), and joint risks (obstacles that might impede the team's advancement). They state that common ground is mostly created through discussions during project meetings, and that when teams fail to establish common ground, they experience coordination breakdowns.

I believe that their conceptual model, along with Clark's theory, provide solid ground to address the coordination challenges that cross-boundary teams face. I hypothesize that they could be addressed by designing artifacts that make teams behave in a certain way. More precisely, if cross-boundary teams are provided with material support to evaluate their level of common ground and guidance on how to converse to repair any common ground breakdowns, they may overcome the coordination challenges they face as was suggested by Mastrogiacomo et al. (2014). Therefore, the first research question that I seek to answer in my thesis is: *How can we support cross-boundary teams in measuring and augmenting their common ground to coordinate effectively*?

I will present the answer to this question in Chapter 4 with the instantiation of the Coopilot conceptual model into a mobile application (called Coopilot App) we designed following the design science research methodology. This application allows each team member to voice their understanding of the four requirements for common ground (joint objectives, joint commitments, joint resources, and joint risks) and it aggregates everyone's votes to display the level of common ground within the team. The design process resulted in two versions of the application, the second one including a conversational guide with questions for each of the four requirements that practitioners can use to trigger repair discussions if there is low or no common ground. I will present the design principles that support the evaluation and repair of common ground in cross-boundary teams. I will also present a theoretical process model of team coordination that allowed us to understand how the lack of common ground influences coordination breakdowns. We outline the fundamental linguistic acts that teams perform to coordinate effectively, i.e. establishing common ground and monitoring common ground. We extend the Coopilot conceptual model with this process and the role of common ground measurement in team coordination.

4 Cooperation challenges

In this section I will describe what the cooperation challenges are by outlining their antecedents and consequences for cross-boundary teams if left unmanaged. I will then review the literature on how cooperation challenges can be addressed. One interesting perspective for cross-boundary teams is that of shared leadership which describes cooperative dynamics in which team members influence and support each other toward the achievement of their shared purpose. I use this perspective over others as it provides an umbrella term in which one can easily integrate other research topics for cooperation such as shared intentionality (through the shared purpose) and interpersonal ties (through influence and support). Moreover, shared leadership describes dynamics in which there are little or no cooperation challenges. It can thus be considered as a desirable target for cross-boundary teams. I will provide an overview of the studies that suggest how to fuel and support shared leadership in cross-boundary teams. I will also review the research that has analyzed how objects and technologies support shared leadership. I will conclude by underlining the lack of prescriptive knowledge for making shared leadership emerge within teams. I will outline the research question that emerges from this lack and that I will address in Chapter 5.

4.1 The antecedents and consequences of cooperation challenges

In addition to coordination challenges, cross-boundary team members face cooperation challenges. Whenever individuals are to cooperate to perform complex tasks, they must plan and agree on the joint actions they are to perform to achieve some joint objective, and thus need to agree on the object of the cooperation (Knoblich et al. 2011). In fact, cooperative attitudes are the prerequisite to any joint activity, as individuals commit to the project only if they expect others to reciprocate (Holmes 2002; Kelley and Stahelski 1970). Cooperation is a positive attitude toward engaging with others and a willingness to collaborate with others (McDonough 2000). This thus poses the question of how individuals construe the motivation to cooperate, which can be challenging in cross-boundary teamwork (Carlile 2002; Marks et al. 2001; Peralta et al. 2015).

Cooperation challenges correspond to the competing interests and agendas that individuals with different functions might have. Carlile (2002; 2004) attributes this divergence to the third type of knowledge boundaries: pragmatic boundaries. These boundaries relate to differences in interests and agendas. In fact, what might be deemed worth by one function will not necessarily be interpreted so by another (Stark 2011). Jarzabkowski and Fenton (2006) provide a simple illustration of such differences. They consider the case of professionals and managers who need to work together yet do not have the same interests: professionals value their autonomy and expertise while managers will seek for control. In this sense, cooperation across functions seems difficult to reach. As new knowledge is required to make sense of the novel situation, practitioners must agree on how to go about it and accept to change or transform their current knowledge. However, practitioners may be reluctant to give up their interests, values and beliefs and "thought worlds" (Dougherty 1992; Hall 2005; Homburg and Jensen 2007; Lovelace et al. 2001). In fact, individuals who have gained extensive expertise in one domain or another tend to integrate and embody the culture, traditions, and interests of that function (Black et al. 2004; Gherardi et al. 1998; Reese and Sontag 2001; Schroeder et al. 1999; Sole and Edmondson 2002).

For pragmatic boundaries not to translate into barriers to cooperation, cross-boundary team members must negotiate shared interests (Edmondson and Harvey 2017) and agree to transform their knowledge (Carlile and Rebentisch 2003; Majchrzak et al. 2011). If pragmatic boundaries are not managed, they may lead to intra-group bias in which individuals with differing functions are seen negatively and preference is given to individuals within the same boundary which is detrimental to cross-boundary teamwork (Gaertner and Dovidio 2014; Homan et al. 2008). Pragmatic boundaries will reveal the divergence of interests between team members, and thus decrease the level of trust and cooperativeness (Williams 2001). The lack of trust or psychological safety is detrimental to collaboration as individuals might lower their expectations, commitment, and investment in the joint activity (Bandow 2001; Edmondson 1999; Lee and Pinker 2010). Also, cross-boundary team members will be more reluctant to share knowledge and integrate knowledge from others if they feel there are divergent interests and motives within the team (Barrett and Oborn 2010; Jarvenpaa and Majchrzak 2008; Jones and George 1998). This proves particularly problematic for cross-boundary teamwork as it is for that very reason that they exist – the integration and sharing of knowledge to provide innovative solutions (Kotlarsky et al. 2015). Cooperation challenges may also increase the level of perceived stress by team members and decrease the level of group cohesiveness (Keller 2001). In highly non-cooperative situations, individuals will be less creative and willing to learn from others (De Dreu and Weingart 2003; Tjosvold et al. 2004). While sometimes the differences between cross-boundary practitioners may go unnoticed during interactions, they can lead to crises when they become so disruptive that practitioners cannot find common ground (Gherardi and Nicolini 2002; Hutchins 1995b).

One promising angle to understand how cross-boundary teams can overcome these cooperation challenges is to look at teams who display shared leadership. Shared leadership is a dynamic and interactive process of influences and support within a team through which team members lead one another toward the accomplishment of their joint goals (Pearce and Conger 2002). Shared leadership describes the quality of cooperative interactions within teams. It provides a valuable perspective to understand cooperation challenges as it describes a dynamic of teams who have little or no cooperation challenges. In fact, Daspit et al. (2013) showed that teams fail to interact cooperatively – and thus overcome the pragmatic boundaries – if there is no shared leadership within the team. Also, shared leadership can be easily integrated with other perspectives on cooperation such as shared intentionality (through the joint goals in the definition above) or interpersonal ties (influence and support in the definition above). Shared leadership provides a more comprehensive understanding of cooperation challenges than the other perspectives taken separately. Moreover, it is in line with the trend of flat or horizontal team structures in which individuals with diverse sets of expertise and resources all actively engage in the project (Wang et al. 2014).

Shared leadership implies that the actions and decisions are not made by one appointed leader, rather the responsibilities are shared by all team members (Yammarino et al. 2012). Team members are thus willing to both provide leadership to others and respond to leadership from others (Katz and Kahn 1978). Shared leadership is particularly relevant to cross-boundary teams working on complex and knowledge-intensive tasks (Pearce and Manz 2005; Serban and Roberts 2016; Simsarian Webber 2002). This is due to the positive influence that shared leadership has on the management of knowledge boundaries as team members are engaged in supporting exchanges of knowledge and influence between them (Carson et al. 2007). Moreover, teams who display shared leadership dynamics perform better than those with an appointed individual leader (Avolio et al. 1996; Hoch and Kozlowski 2014).

Carson et al. (2007) identified three antecedent conditions that must be met for shared leadership to emerge: shared purpose (team members have a similar understanding of the team's objectives), social support (team members' effort to provide emotional and psychological support to their peers), and voice (the degree to which team members have a say and input into the joint activity) (see Table 4 on page 55 for an overview and details). Hence, understanding how these three conditions can be met by cross-boundary teams can inform us on how cooperation challenges are overcome. In the remainder, I will first review the literature on the antecedent conditions in the organization, management, and linguistics disciplines. I will then review the objects and tools that can support the emergence of shared leadership. My conclusions from this literature review are similar to the ones for the coordination challenges, i.e. there is yet a lack of design theories for supporting shared leadership and cooperative attitudes. I will make the same call for design science researchers to get interested in the principles of design that can best address these issues.

4.2 Addressing cooperation challenges through the antecedents of shared leadership

There have been extensive studies on the antecedent conditions of shared leadership, even if such studies were not focusing on the emergence of shared leadership per se. I will review here the main studies that provide concrete means to support the three antecedent conditions to shared leadership, i.e. shared purpose, social support, and voice.

Researchers and philosophers have long argued that shared purpose was the most important building block of teamwork (Knoblich et al. 2011). Shared purpose has been analyzed through a variety of similar concepts such as shared intentionality (*e.g.*, Bratman 1992; Gilbert 2009; Gold and Sugden 2007; Searle 1995; Tomasello and Carpenter 2007; Zaibert 2003), team goal commitment (*e.g.*, Aubé and Rousseau 2005; Hoegl and Parboteeah 2006; Locke et al. 1988; Peralta et al. 2015), shared mission (Barry 1991; Dionne et al. 2004; Morgeson et al. 2010), and task cohesion (*e.g.*, Carless and De Paola 2000; Mullen and Copper 1994; Serban and Roberts 2016). Various scholars have identified what makes a shared purpose emerge. Tomasello et al. (2005) suggest that individuals form some shared intentionality if they are mutually responsive to one another and have a shared goal that is conceived as such by all team members. The shared responsiveness (or interdependence) is crucial, as noted by Searle (1990), since individuals may have a common goal but not intend to do something together. He proposes the example of people enjoying a sunny afternoon in a park. If the people are made of strangers, there is no shared intentionality, compared to a group of friends who gather for a celebration. Hardy el al. (2005) suggest that conversations to create shared purpose (or generalized membership types as they frame it) can be diagnostic (define the problem and its causes), prognostic (to create consensus and commitment within the team), and motivational (to drive others into action). This view of shared purpose is similar to Tomasello and colleagues' conception as it includes both the need for a shared goal and the shared responsiveness (or interdependence) toward the shared goal. Identifying and attributing responsibility for the interdependent parts that team members must do is crucial for cooperation, as the diffusion and ambiguity on everyone's role leads to inaction (Buchan et al. 2002). However, their conception includes the motivational call for action toward the achievement of the shared goal. Clark (1996) suggests that individuals will establish and commit to a joint purpose if they both identify it, are able and willing to do their part toward its achievement, and have common ground on these conditions. This definition presupposes the conditions of interdependence and shared goal (joint purpose) but he adds that there is a need for individuals to mutually believe (have common ground) that the others know the joint purpose and are able and willing to do it. Clark also adds that purposes can be accepted, modified, or declined by others. In such cases, individuals might need to negotiate a shared purpose (Schelling 1960; Tenenberg et al. 2016), a conversational activity that is omitted by Hardy et al. (2005). This negotiation will happen until individuals see that the joint purpose is in their self-interest (Mattessich and Monsey 1992) and believe that cooperating has benefits for them (Lawrence and Lorsch 1967; Sicotte et al. 2002).

In sum, a shared purpose will emerge after team members engage in conversations where they (1) define and negotiate a shared interesting goal, (2) establish common ground on the shared goal and the interdependent parts, and (3) plan or call for joint actions.

In general, the definition of the shared purpose should be done collaboratively as individuals develop cooperative attitudes and collaborate effectively when there is collective ownership of goals (Bronstein 2003), members share a stake in both processes and outcome (Mattessich and Monsey 1992) and members have the same perspectives on collaboration (Hojat et al. 2001). These studies suggest that collaboration is enhanced when members collectively determine the purpose and the goals of their collaboration. In fact, several studies on organizations have emphasized that excluding organizational members from the formulation of the strategy leads to dissatisfaction and lack of commitment (Floyd and Lane 2000; Westley 1990; Woolridge and Floyd 1990), poorly developed strategies (Floyd and Wooldridge 2000), and difficulties in implementing the strategy (Mintzberg 1994). On the contrary, involving organizational members in strategy formulation allows for greater learning (Hart 1992), greater planning (Weigand et al. 2014), and enhanced innovative capabilities (De Dreu & West 2001). Lindenberg & Foss (2011) advance that when individuals design the task and team activities in an integrated fashion, their motivation will increase and eventually lead to an increase in performance.

Social support emerges when team members value and encourage each other's contributions (Marks et al. 2001). Most work on social support has focused on group cohesion and team empowerment (Daspit et al. 2013; Mathieu et al. 2008; Tekleab et al. 2009). While most research focuses on the influence of cohesion on team performance rather than on the antecedents of cohesion (Michalisin et al. 2007), several studies suggest that cohesion depends on the level of perceived interdependencies between individuals (Al-Ani et al. 2008; Cataldo et al. 2006; Raposo and Fuks 2002; Rhoades et al. 2001; Schippers et al. 2003; de Souza et al. 2004). When individuals understand that the achievement of the joint purpose – and thus the advantages they might get from it – depends on the contributions of others, they are more likely to provide support to others and act as a cohesive team. This creates a sense of shared responsibility for the joint purpose that drives participants to work cooperatively and help one another (Kirkman and Rosen 1999; Tesluk and Mathieu 1999).

What leads team members to voice their opinions and ideas has been looked through the lens of psychological safety (Baer and Frese 2003; Edmondson 1999). Psychological safety describes a climate in which team members feel that it is safe for them to voice their opinions, report mistakes, and ask challenging questions. Carmeli and Gittell (2009) suggest that psychological safety emerges in teams where members share high-quality relationships. Such relationships exist when team members have shared goals, share their knowledge, and display mutual respect. Hardy et al. (2005) suggest that effective teamwork happens when individuals use both cooperative and assertive styles of talk, given that they have a strong commitment to the shared goals. Cooperative talk arises when the tone, style, and rhythm of conversations emphasize the willingness by team members to engage with and welcome others' opinions and positions, while assertive talk arises when individuals insist on their own opinions and positions. Other scholars have also identified that voice is dependent on the way participants construe their activity, that is the meaning they attach to what they are doing. For example, Edmondson et al. (2004) suggest that simulations or dry-runs allow individuals to try out different alternatives and hypotheses, without the fear of taking real risks. Such activities indicate to the team that they are made for learning in which input from everyone is required. In a similar vein, Tjosvold et al. (2004) suggest that taking a problem solving approach to teamwork helps teams envision their work as an open discussion in which their main purpose is to understand the problems they face, identify the conditions that led to them, and ideate on solutions. In such settings, openness is favored over blaming, which creates a climate in which everyone is welcome to have a say (Cannon and Edmondson 2001; Carter and West 1998). Also, Steen (2013) suggests that when individuals conceive of their work as a process of joint inquiry (or co-design), they are more likely to engage in purposeful and equal interactions. Teamwork is then perceived as a process in which members face a common problem and they actively and collectively discuss and explore the problem, and develop and evaluate possible solutions to them (Dewey 1927, 1929). In fine, these conceptions of teamwork as a problem-solving activity lead to an acceptance of diverging opinions (De Dreu and West 2001) and constructive task-conflict, which allows team members to question what they are doing and potentially find better and creative alternative paths to reach their shared goals (Carnevale and Probst 1998).

In summary, all these studies have provided an extensive list of factors that give rise to shared leadership and, in turn, the effective management of cooperation challenges (Table 4). As I will argue, these findings are particularly insightful to understand the dynamics that practitioners should strive for to cooperate effectively. As I am interested in how such knowledge can be instantiated into tools that drive practitioners to follow those guidelines prescriptively, I will first review the literature on the objects and tools for cooperation, and then argue that there is little design knowledge on the principles of form and function that support shared leadership and cooperative attitudes.

Table 4 – Summary of the antecedents of shared leadership		
Antecedents of shared leadership	Description	Guidance to support the emergence of the antecedents
Shared purpose	Team members' interests converge toward a shared goal and they have the same understanding of it.	For team members to have a shared purpose they must (1) define and negotiate a shared goal, (2) establish common ground on the shared goal, and (3) plan or call for action. Requires active participation by all participants.
Social support	Team members' effort to provide emotional and psychological support to their peers.	Identify and map the interdependencies between individuals.
Voice	Team members have a say and input into the joint activity. They express their personal positions, opinions, ideas, and knowledge.	Ensure a psychologically safe environment for learning by conceiving of the joint activity as a process of joint inquiry and problem-solving.

4.3 Addressing cooperation challenges through objects and technology

Various studies on collaborative objects have produced interesting analyses of potential ways to address the antecedents of shared leadership, without explicitly having the objective of contributing to shared leadership. One notion that is particularly interesting for establishing a shared purpose is that of activity objects. Such objects provide a shared problem space into which cross-boundary team members bring various skills and conceptual tools to negotiate their shared goals and the direction of their joint activity (Nicolini et al. 2012). This negotiation might lead to conflicts of interests, in which case the activity object will evolve until a shared purpose stabilizes (Aggerholm et al. 2012). The most typical example of activity objects is a contractual agreement. Belmondo and Sargis-Roussel (2015) use the example of strategy tools such as SWOT analyses that allow participants to distort then establish a shared purpose regarding the direction of the strategy that managers design. Other examples include argumentation systems (Lonchamp 2000) such as voting mechanisms that allow users to state whether they refute or support elements of their discussions. In general, shared displays allow individuals to negotiate their shared purpose in a more neutral tone as they depersonalize conflict (Conklin et al. 2001; Détienne 2006). Eppler and Platts (2009) reviewed the literature on visual tools and found that visualization not only depersonalizes conflict but it provides additional benefits such as facilitating communication, integrating different perspectives, and creating involvement and engagement.

Objects and tools that foster social support build on two premises. On the one side, tools that provide users with the awareness of the others' actions contribute to greater transparency and access to information that in turn may influence support and trust (Pinjani and Palvia 2013; Tenenberg et al. 2016). On the other side, mapping interdependencies between tasks, individuals, and resources with tools such as process maps (Eppler 2006; Fiore and Schooler 2004), Petri nets (Raposo and Fuks 2002), or Gantt charts and timelines (Whyte et al. 2008) increases the awareness of team members, that for them to successfully undertake the joint project, they depend on each other's contributions and performance. Al-Ani et al. (2008) suggest that knowledge dependencies can also be addressed by collaborative tools to drive support and cooperative behaviors, especially for cross-boundary teaming. They suggest that tools should be based on four principles: identifying *how much* of *what* information needs to be shared with *whom* and *when*. This suggests that the awareness of interdependencies between tasks, resources, and individuals but also of knowledge requirements will allow individuals to understand to what extent they need to rely on each other, and know who needs what. These tools then not only make people aware that they need to support each other but also direct individuals towards who needs support (Okhuysen and Bechky 2009).

Voice has mostly notably been addressed by co-design tools. Such tools are used simultaneously and participatively by individuals not only to augment their "*ability to carry out certain actions, but also augment their cognitive abilities to see and understand certain design opportunities, conceive of and evaluate possible solutions, and bring potential futures into form so that they can be examined and communicated*" (Dalsgaard 2017, p. 21). Examples of such tools include drawing, illustration, and three-dimensional prototyping (Broadley et al. 2016; Buxton 2010; Eriksen 2009). Since these tools are used at the same time by all participants and require their active participation, they signal to participants that their opinions and ideas are welcome, leading to open communication (Hanington and Martin 2012; Sanders and Stappers 2014). Klemmer et al. (2006) suggest that co-design tools support learning and concept development, as participants can cooperatively try out different solutions and prototypes in a tangible format, and visually analyze and confront these alternatives. Dalsgaard (2017) reviewed the reasons that made co-design tools effective and identified five functions they perform: (1) externalization (alternative solutions can be represented into external representations so that participants can visualize, manipulate, and evaluate them in more detail and complexity), (2) perception (objects reveal facets of the problem that would go unnoticed during conversations), (3) conception (objects help users articulate the problems they face and develop hypotheses on how to solve them), (4) knowing-through-action (new knowledge is generated as participants manipulate the tools), and (5) mediation (co-design objects mediate and make the relationships between participants visible).

In summary, the literature on objects and tools provides initial, yet scattered insights, on how to support the emergence of the antecedents of shared leadership. The assumption is that objects, for establishing shared purposes, should provide a problem space in which participants can negotiate their joint intentions, and such objects should make the arguments material rather than purely conversational to depersonalize conflict. This problem space should also make team members aware of their interdependencies so as to foster a cooperative mindset in which all participants value and welcome each other's contributions. Finally, the literature on co-design suggests that tools that make conceptual ideas tangible can support practitioners in defining better solutions. They also add that the participatory nature of such tools creates a climate of involvement from all participants. The integration of these insights thus suggests that to support teams in addressing their cooperation challenges, tangible tools that make use of shared visualization and provide a problem space for negotiation might prove effective (Table 5).

Table 5 – Potential principles for supporting the antecedents of shared leadership		
Antecedents of shared leadership	Description	Potential characteristics that support the antecedents
Shared purpose	Team members' interests converge toward a shared goal and they have have the same understanding of it.	Visual problem space.
Social support	Team members' effort to provide emotional and psychological support to their peers.	Awareness of interdependencies and knowledge requirements.
Voice	Team members have a say and input into the joint activity. They express their personal positions, opinions, ideas, and knowledge.	Tangibility and active collective participation.

4.4 Second research gap: Designing for cooperation across boundaries

Both literatures on the antecedents of shared leadership and the tools that support its emergence provide interesting and valuable insights on how to help teams develop shared leadership and cooperative attitudes. My point is that integrating both literatures can allow design science researchers to develop tools that specifically address the emergence of shared leadership, and theorize on the functions and forms that support it. In fact, to date, there is no prescriptive design knowledge that directly addresses the emergence of the antecedents of shared leadership. Most studies specifically addressing objects and tools for shared leadership have mainly focused on how teams make use of different objects at different points in time to share leadership (Huxham and Vangen 2000; Mailhot et al. 2016; Oborn et al. 2013; Spillane 2009). However, they did not underline what it is in those objects that supported the emergence of shared leadership. I have outlined possible characteristics that might prove useful, but scholars have not specifically analyzed the relations between these characteristics and the antecedents of shared leadership. Moreover, given the variety of functions that collaborative tools can perform (Nicolini et al. 2012), it is crucial to understand what are the characteristics of tools that enable and influence shared leadership. I have underlined potential characteristics that might support shared leadership but these studies have not specifically analyzed their impact on the emergence and support of shared leadership. The influence of these characteristics thus needs to be evaluated. Therefore, I seek to initiate a nascent design theory for supporting shared leadership by asking the following question: *How can we support cross-boundary teams in developing shared leadership to cooperate effectively*?

To answer this question, we designed the Team Alignment Map, a visual inquiry tool in the form of a poster (in face-to-face settings) or shared online problem space (in distributed settings). The Team Alignment Map instantiates the four requirements of the Coopilot conceptual model (i.e. joint objectives, joint commitments, joint resources, and joint risks) as empty problem spaces that participants discuss and fill with sticky notes in a cooperative and participative manner. In this study, I will outline two characteristics of collaborative tools that allow for the emergence of shared leadership: shared visualization and shared problem spaces. These confirm the potential characteristics that were outlined before (Table 5). The design of the Team Alignment Map is based on a co-design approach to teamwork, which I theorized in an additional study. This theorization is in line with studies that suggest that teamwork should be considered as a process of joint inquiry (*e.g.*, Détienne 2006; Steen 2013). Conceptualizing cross-boundary teamwork as a process of joint inquiry may drive the dynamics between team members to be cooperative and share leadership. I will present both the design principles for shared leadership and the theoretical model of joint inquiry in Chapter 5.

5 Wicked problem solving

In this section, I will first describe what wicked problems are by outlining their antecedents and the consequences. I will then review the literature that suggests how to address the challenges of solving wicked problems. There are two dominant perspectives that suggest how wicked problems can be managed in cross-boundary teams. The first guides cross-boundary team members by providing collaborative scripts that should be followed during team meetings. The second perspective considers the role of visual *inquiry* tools. I will elaborate on the second as it addresses both the process and content of discussions that should be held when solving wicked problems. I will conclude that despite the important emergence and adoption of visual inquiry tools, there is no rigorous knowledge that informs how they should be designed. In fact, most tools have been developed through intuition or imitation of existing tools. In Chapter 6, I will present a design theory for visual inquiry tools based on the cases of the Team Alignment Map, the Business Model Canvas, and the Data Excellence Model.

5.1 The antecedents and consequences of wicked problems

In addition to the coordination and cooperation challenges presented before, cross-boundary teams also need to overcome the difficulties of solving wicked problems. Such problems are typically uncertain, intangible, and hard to describe as the requirements are ever-changing (Buchanan 1992). Cross-boundary teams are particularly necessary in situations with great uncertainty, complexity, and ambiguity (Edmondson et al. 2003), yet these characteristics are also the ones that impede team performance (MacCormack and Verganti 2003). Novelty increases the complexity and intensity of the three types of knowledge boundaries, i.e. syntactic, semantic, and pragmatic boundaries identified by Carlile (2002; 2004), but also increases the need for cross-boundary team members to collaborate and integrate their knowledge as individuals cannot rely on standard procedures or best practices (Bell and Kozlowski 2002; Crawford and Lepine 2013). Cross-boundary teams typically work on projects with great ambiguity regarding the actions that need to be performed to accomplish them (Serban and Roberts 2016).

In these situations, practitioners face wicked management problems. Such problems are ill-defined, have unstable or ambiguous requirements, have various potential solutions, and are often intangible (Buchanan 1992; Dorst 2006; Simon 1973). Examples of wicked problems in management include strategic management and business modeling (Bruce and Bessant 2002; Sosna et al. 2010), information systems development (John and Kundisch 2015), and new product development (Steen 2011). These problems are not governed by stable or linear mechanisms such as routines, for which there are procedures and best practices that suggest the course of action that practitioners must follow to solve them (Dunne and Martin 2006; Pentland 2003; Steen et al. 2011).

To proceed through this complexity, various studies suggest that the best strategy for practitioners is to integrate and generate as much knowledge as possible and adapt their course of action accordingly (Crawford 1974; Duncan 1972; Weick et al. 2005). Team members conceive and evaluate alternative courses of action to complete a task, implement these actions, and either adapt their behaviors if they do not prove effective or continue following that course of action if satisfactory (Burke et al. 2006; Cohen et al. 1996; Pirola-Merlo 2010). However, the challenge in such situations is that the problems are not necessarily construed similarly between team members, and there is often disagreement on the appropriate solutions and courses of actions (Lundmark et al. 2017; Weick et al. 2005). In addition to such disagreements, the more wicked a problem is, the more team members must interact and share knowledge (Crawford 1974; Gladstein 1984; Kozlowski et al. 1999). However, as stated by Carlile (2002; 2004), in novel and complex situations, the integration of knowledge is more challenging due to the emergence of the three types of knowledge boundaries. This inability to find the appropriate course of action to solve wicked problems (process uncertainty) has been shown to have detrimental effects on team performance to a greater extent than the uncertainty related to the characteristics of the final deliverable (Tatikonda and Rosenthal 2000).

5.2 Supporting wicked problems through collaborative scripts

Several scholars have channeled their efforts into developing collaboration engineering (Briggs et al. 2003; De Vreede et al. 2006; Kolfschoten et al. 2006). Scholars in this approach design collaborative work practices (scripts) for tasks that are recurrent and of high-value across and within teams, called thinkLets. They split collaboration into manageable and scriptable activities. Scripts can be combined to support practitioners in managing a whole process that can be more or less complex. They are usually in the form of a procedure of actions that practitioners must follow depending on the problem they want to solve. For example, Bittner and Leimeister (2013) elaborated seven scripts (thinkLets) that describe the seven activities that practitioners should undertake to share understanding within the team. Scripts guide practitioners across the seven activities by specifying what actions should be undertaken, by whom, and for what purpose.

ThinkLets can also be used to ideate and define the courses of actions that teams will follow for their project. For example, Bragge et al. (2005) used seven thinkLets to derive a road map for overcoming the barriers to mobile marketing and explore new mobile services. These consisted of identifying the purpose of the marketing system, identifying the barriers that might prevent the development and implementation of the mobile marketing system, and finally defining actions to overcome the ten most important barriers. In another study, Bragge et al. (2005) used various thinkLets for the development of a strategy for the development of student information systems by Finnish universities, and its implementation. They combined thinkLets to assist the ideation by team members on several activities: the analysis of the requirements for the system, the development of ideas to address these requirements, the prioritization and evaluation of these ideas, and the definition of the actions to implement those ideas.

As these examples show, thinkLets are mainly used to facilitate the process of ideation, knowledge exchange, and decision making. They provide guidance on how to effectively conduct these activities. However, they do not suggest what practitioners should do when they face a specific problem as they are rather general. That is, they do not specify the content of what needs to be done. For example, thinkLets do not define the aspects that should be considered when developing a strategy. It is the facilitator's duty to identify the activities and the related thinkLets that the teams should resort to for the development of the strategy. But these only say how to best carry brainstorming and evaluating activities. They do not inform the dimensions that should be considered for developing the strategy.

5.3 Supporting wicked problems with visual inquiry tools

A new type of management tools has emerged to address the issue of the content on which discussions and reflections between cross-boundary team members should focus on for wicked problems. Examples include the Business Model Canvas (Osterwalder and Pigneur 2010), the Project Canvas (Habermann and Schmidt 2014), the Innovation Matrix (Van Der Pijl et al. 2016), the Customer Journey Map (Kalbach 2016), and the Market Opportunity Navigator (Gruber and Tal 2017). Their main advantages are that (1) they define the scope of a wicked problem and what needs to be thought of, discussed and inquired into to develop a solution, and (2) they provide a shared language or a shared frame of reference (Osterwalder and Pigneur 2013), (3) and they provide a physical problem space through which individuals jointly inquire into the problem.

These tools allow teams to approach specific problems in which there are no straightforward answers. They help teams better understand, explore, and make sense of the problem (Dalsgaard 2017). These tools are usually in the form of visual problem spaces (often as printed posters) that define the characteristics of a specific problem that participants should address. The characteristics of each problem are displayed as building blocks or empty problem spaces in which participants can try out alternative options with post-it notes. For example, the Business Model Canvas (Figure 2) consists of nine building blocks that depict all the aspects that must be considered to define the business model of an organization. Participants can define a value proposition (one of the building blocks) by adding post-it notes in the related block, and do so for the eight other blocks. This will provide a solution to the problem of business modeling. Participants can use post-it notes with different color schemes, one for each solution, so that they can develop different solutions to the problem. They can visualize all the solutions to the same problem on one display.

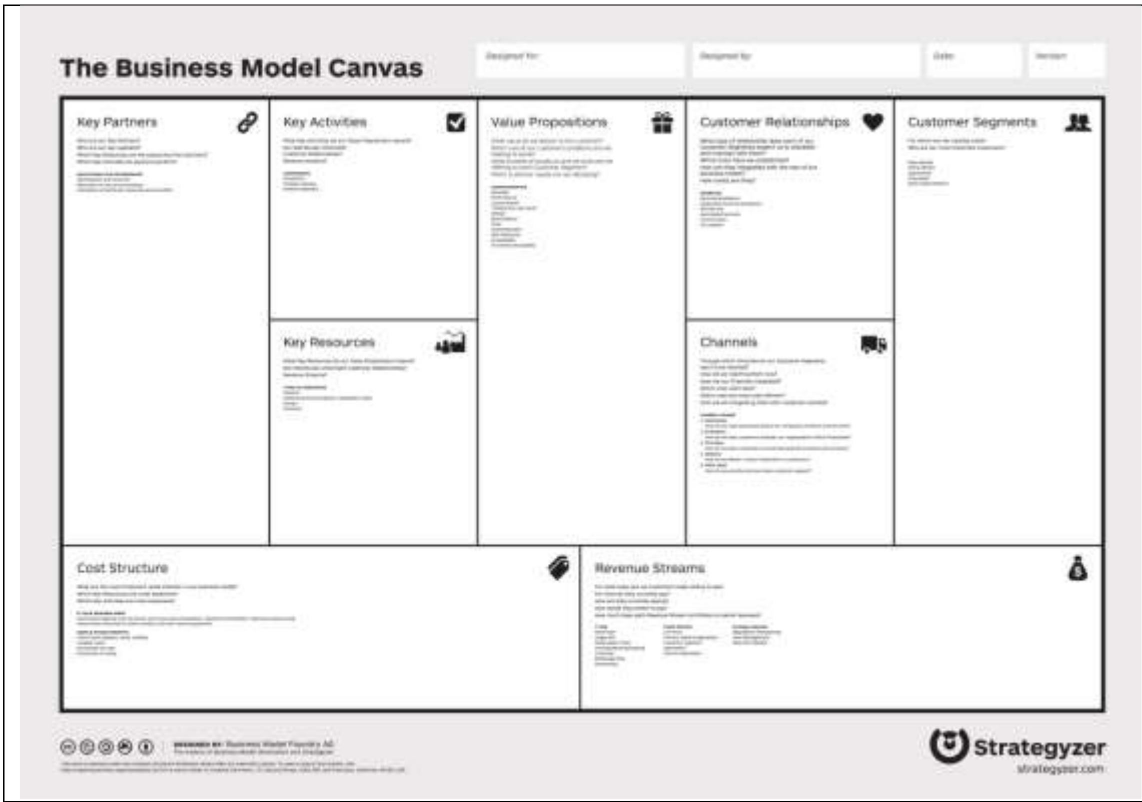

Figure 2 – The Business Model Canvas

This visualization addresses the syntactic boundaries as defined by Carlile (2002). Through visual metaphors such as text, definitions, icons, and the arrangement of the blocks, they provide a common mental model on how to go about the problem. Finally, the third point provides a physical instance of a mental problem space, i.e. the space in which individuals define and encode the main elements of the problem and try out different hypotheses regarding the solution (Newell and Simon 1972). As noted by Fiore and Schooler (2004), what is important is not that individuals construct a problem space, rather that this problem space is shared if the problem solving activity involves multiple people. Visual inquiry tools make use of shared visualization to support the forming of ideas and hypotheses on how to address the problem and experimenting with these ideas in practice (Horn and Weber 2007), which is equivalent to practical joint inquiry.

5.4 Third research gap: theorizing the design of visual inquiry tools

These tools have witnessed wide adoption among management practitioners and entrepreneurs (Trimi and Berbegal-Mirabent 2012). For example, the Business Model Canvas has been used by more than 5 million people worldwide (Strategyzer 2015) and has become a quasi-standard for business modeling (John and Kundisch 2015; Massa et al. 2016). Following the path opened by the Business Model Canvas, other tools dedicated to other specific problems have been extensively developed recently. Given this emergence and the relevance of such tools, it seems crucial to accumulate knowledge on how to design and use them. Currently, there are no theoretical insights on the design principles, which is problematic as most developments so far have been done by imitating the apparent features of existing tools (Piirainen and Briggs 2011), mainly the Business Model Canvas (e.g., Campbell et al. 2017; Chandra-Kruse and Nickerson 2018). The mere imitation of apparent features annihilates the implicit knowledge that these tools embody, such as their ontology of the specific wicked management problem (Osterwalder 2004). Moreover, few studies have been done on the evaluation of such tools. Thus, there is yet no clear understanding on what makes these tools more or less effective in supporting cross-boundary teams' wicked problems. Therefore, the third and last research question I ask in my thesis is: *How can we design visual inquiry tools that guide cross-boundary teams in solving wicked problems?*

To answer this question, I conducted two design science research studies to develop a design theory for visual inquiry tools which I will present in Chapter 6. The design theory was developed based on three cases, i.e. the Team Alignment Map, the Business Model Canvas, and the Data Excellence Model. These three visual inquiry tools were among the few that were developed by following rigorous design science research methods and have been adopted by an extensive number of practitioners. The purpose of the design theory is to support design science researchers and designers in developing visual inquiry tools for other wicked problems than team alignment, business modeling, and data management. The design theory suggests three overarching design principles of form and function that designers must follow: (1) develop an ontology of the elements of the wicked problem, (2) represent the elements of ontology into a shared visual problem space, and (3) define and specify directions for use that allow for joint inquiry. The design theory also includes suggestions regarding how to implement these principles and evaluate them, on top of the overall evaluation of the instantiation. In sum, I suggest that visual inquiry tools are particularly useful for cross-boundary teams' wicked problems due to their foundation on ontology modeling, visualization, and inquiry techniques.

6 Synthesis and conclusion: Towards prescriptive research for cross-boundary teamwork

In this literature review, I have outlined the concerns that scholars have with three cross-boundary team challenges and the related knowledge they propose to address them. The first challenge concerns the difficulty to coordinate knowledge and work between team members with diverse thought worlds and across boundaries. The extensive research that has been done on coordination has flourished in a scattered way, but if accumulated it suggests that cross-boundary members should rely on the power of language and objects to create shared cognition across boundaries. Therefore, the first question that is raised in my thesis is: *How can we support cross-boundary teams in evaluating and augmenting their common ground to coordinate effectively*?

The second challenge relates to the difficulty for cross-boundary team members to create cooperative attitudes and motives. Literature on the subject has suggested that shared leadership is particularly relevant to create a cooperative climate of mutual support and influence. Three antecedents have been identified as giving rise to shared leadership: shared purpose, social support, and voice. To date, no inquiry has been done into how these antecedents might be supported by tools and, hence, allow for shared leadership to emerge. Therefore, the second question I address in my thesis is: *How can we support cross-boundary teams in developing shared leadership to cooperate effectively*?

The third challenge is that of managing the wicked problems that cross-boundary typically face. The recent trend of visual inquiry tools that has emerged in the management practice provides a promising approach to support teams in solving such problems. However, as most developments have remained in the commercial sphere, there is yet no theoretical and design knowledge on how to develop effective visual inquiry tools. Therefore, the last question I address is: *How can we design visual inquiry tools that guide cross-boundary teams in solving wicked problems?*

In general, these research questions echo van Aken's (2004) argument that management research needs to provide more practical and prescription-driven knowledge on top of theoretical accounts, if the field wants to address the lack of relevance and impact that it is often reproached for. I follow his argument and believe that these problems could be addressed by IS scholars with the development and theorization of prescriptive knowledge through design science research. A similar call was made by Osterwalder and Pigneur (2013) for the development of strategic tools and models that address strategic management problems. They also note that the IS field is well-equipped to contribute to this issue by building on its long history and experience with design science research. In fact, the foundational motivation of design science research is to design artifacts (e.g. tools, models, blueprints) that support practitioners in solving issues they face in the field and their daily experiences (Hevner et al. 2004).

In my work, I have decided to focus on how to design tools to address the various challenges that cross-boundary teams face, mainly for four reasons. First, as work is heavily and increasingly mediated by tools (Lee and Amjadi 2014; Orlikowski 2006; Putnam 1994; Stigliani and Ravasi 2012), practitioners are already well-accustomed with material artifacts. Therefore, the costs of changing the work practices is rather low. Secondly, I hypothesize that using simple tools requires less training and can be mobilized rapidly compared to collaboration scripts, collaboration engineering being the only clearly prescriptive approach available for cross-boundary teams. Also, objects allow for the materialization of divergences and convergences (Carlile 2004), which are both necessary for cross-boundary collaboration (Fiol 1994) and not systematically supported by collaborative scripts who mainly rely on communication processes. Thirdly, I believe that the extensive research that has been conducted to identify the antecedents to the major problems faced by cross-boundary teams, as outlined in this literature review, have provided a fine-grained analysis of the dynamics of the challenges that practitioners might face, and this knowledge must gain in practicality. In fact, identifying the antecedents is one strategy to cope with the difficulties of cross-boundary teamwork, but I believe that doing design will prove more effective in practice. Finally and therefore, I seek to build on the recent trend of performative objects (Niedderer 2007, 2013). Such objects are designed in a mindful way so that their characteristics afford specific types of behaviors from the users to follow a predefined and desired behavior.

My contributions consist of six studies that I articulated around three chapters, structured around the challenges they address. In Chapter 4, I will present the Coopilot App, a mobile application that allows cross-boundary teams to evaluate their level of common ground. The design of the application was based on Mastrogiacomo and colleagues' (2014) conceptual model of common ground in project management. The application also includes a conversational guide that helps teams repair any lack of common ground. The application was tested in two contexts, with 18 teams of students and 3 professional cross-boundary teams. Results show that the application is perceived as useful for assessing the team's potential for coordination. Also, it revealed that when common ground breakdowns were noticed, participants automatically engaged in repair discussions. I will derive the design principles that allow designers to develop tools to assess the level of common ground. This chapter also includes a study in which I co-developed theoretical process model of coordination that I co-developed to understand the discursive process through which individuals create common ground and how a lack of common ground impacts coordination. These two studies contribute to both the descriptive and prescriptive knowledge about cross-boundary coordination.

In Chapter 5, I will present the Team Alignment Map, a visual inquiry tool in the form of a physical poster that allows cross-boundary team members to jointly inquire to the requirements of common ground for their joint activity. The Map is based on the same conceptual model as the Coopilot App. Based on the evaluations with two contexts (with 12 teams of students and with 10 professional innovation teams), the Map was considered as supporting effective conversations, guiding these conversations, and supporting shared leadership as it addressed the three antecedents of the latter. One interesting notion that emerged from the findings was that the Map created social contracts, i.e. public commitments to contribute to the project. This chapter also includes a theoretical model that combines Clark's (1996) theory on common ground and Dewey's (1927; 1929) theory on joint inquiry to suggest that collaboration in innovation teams is mainly a process of co-design to create common ground.

In Chapter 7, I will relate a design theory for visual inquiry tools that I co-developed by comparing the Team Alignment Map with the Business Model Canvas and the Data Excellence Model. These three cases represent the few that have been designed through design science research projects compared to the majority of tools that emerged in the business environment. These three cases support the joint inquiry of cross-boundary teams into three different wicked management problems, i.e. coordination, business modeling, and data management, respectively. This design theory provides guidance for designers to develop future tools that address other wicked problems.

To conclude this literature review, I would like to make clear that I do not seek to dismiss other challenges that cross-boundary teams may face. My point in this dissertation is to show how design science research can be an effective strategy or approach to address cross-boundary challenges. As little to nothing has been done in this vein to date, I hope that – in addition to the particular contributions of the studies I conducted – this thesis will serve as an illustration on how to conduct design science research to develop prescriptive knowledge for management problems. I will now turn to the explanation of what design science research is, its methodological and epistemological tenets, and will describe how I used it for the six studies I conducted.

LITERATURE REVIEW SUMMARY

Cross-boundary teams (those whose members have different functions and come from different organizations) are particularly well-equipped to address innovative and complex problems. However, the differences between team members and the nature of the problems they work on present three challenges (among others) that they must overcome to work effectively.

THE 3 CROSS-BOUNDARY CHALLENGES

COORDINATION	COOPERATION	WICKED PROBLEM
Difficulty of creating shared cognition to coordinate team members' contributions due to their knowledge boundaries (syntactic, semantic).	Competing interests and agendas that individuals might have from their knowledge boundaries (syntactic, semantic, pragmatic)..	The tasks on which cross-boundary teams are difficult and wicked. They are uncertain, intangible, and have shifting requirements.
	GUIDANCE FROM LITERATURE	
Three research streams suggest that teams should develop shared cognition (common ground) through language and objects in order to coordinate effectively.	Cross-boundary teams in which there is shared leadership perform better. Shared leadership emerges when three antecedent conditions are met: shared purpose, social support, and voice.	To support the process of joint inquiry, use collaborative scripts from the collaboration engineering stream. Use visual inquiry tools that support joint inquiry into specific management problems.
	RESEARCH OPPORTUNITIES	
The three research streams have developed separately and failed to suggests how objects can support the discussions between team members to create common ground.	Current developments of tools suggest design principles for supporting the antecedents of shared leadership: visual problem space for shared purpose, awareness of interdependencies for social support, tangibility and collective participation for voice. However, no design theory yet.	Visual inquiry tools are mainly developed in the commercial sphere. No rigorous and academic knowledge on how to develop effective visual inquiry tools.
	RESEARCH QUESTIONS	
CHAPTER 4 How can we support cross-boundary teams in measuring and augmenting their common ground to coordinate effectively?	CHAPTER 5 How can we support cross-boundary teams in developing shared leadership to cooperate effectively?	CHAPTER 6 How can we design visual inquiry tools that guide cross-boundary teams in solving wicked problems?

OBJECTIVES OF MY RESEARCH PROJECT

Through design science research, I seek to contribute with design and theoretical knowledge for each cross-boundary challenge. In general, I aim to illustrate how design science research can be used to develop prescriptive knowledge for other cross-boundary challenges, and management research in general.

CHAPTER 3

METHODOLOGY

ABSTRACT OF CHAPTER 3

In this chapter, I will present the core methodology of my doctoral research: design science research. As it lies on different ontological and epistemological foundations from traditional quantitative and qualitative approaches in the social sciences, I will first start this chapter with a section explaining what design science research is and how it compares to other approaches. I will then describe how design science is conducted, how theoretical contributions can be made out of it, and how design science research contributions can be evaluated. Design science research is an overarching methodology that can be complemented with other traditional methodologies (e.g. quantitative analyses, case studies, ethnography), especially for the evaluation of contributions. I will detail the methodology for evaluating the contributions of my studies and the artifacts I designed when I present the studies in Chapters 4 to 6. My goal in this section is to lay the foundations that can help understand the overall rationale behind my doctoral research.

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2. Conducting design science research 79
3. Theorizing design contributions 84
4. Evaluating design contributions 87

1 Designing for prescription

Design science research is a methodology that is different from the traditional paradigms in the social sciences (positivist or interpretivist descriptive research). Initially, its main purpose was to provide prescriptive knowledge embodied in an artifact such as a tool, rather than describing or predicting phenomena. It sought to provide guidance and manipulate the course of actions that practitioners perform to support them in reaching a more desirable future (March and Storey 2008). Various authors have argued that design science research is particularly tailored for helping practitioners solve problems that are complex and for which knowledge is still too descriptive (March and Smith 1995; Nunamaker et al. 1991; Simon 1996; Walls et al. 1992). Over time, scholars have underlined the role of theory as a fundamental motivation in addition to the practical motivation (Baskerville et al. 2015; Gregor and Hevner 2013; Gregor and Jones 2007; Winter 2008). The importance of formalizing and theorizing knowledge about the artificial was increasingly called for to establish design science research as a research paradigm and not mainly a “consulting-like” discipline, especially in the IS discipline (Mandiwalla 2015; Pries-Heje and Baskerville 2010; Venable 2006). This echoes the objectives of my research project which relate to the need to provide, on the one hand, more actionable guidance on how to deal with the three challenges that are faced by cross-boundary teams, and, on the other hand, theorize on how this material or artificial support is brought about to develop prescriptive knowledge on how to overcome the three cross-boundary challenges.

The goal in natural and social sciences is to develop and evaluate theories or hypotheses that describe how and why things are. They provide an explanation and prediction of the realities and phenomena that individuals might face. Such research usually involves the development and definition of constructs that allow one to understand a practical phenomenon. In the management and organization disciplines this translates into post-mortem analyses of the problems that practitioners face, based on situated case analyses or generalized statements. However, as noted by Pries-Heje and Baskerville (2010) and van Aken (2004), what matters to practitioners that face a problem is not historical knowledge on how things were done, but how to address the issues they are currently facing.

The design sciences and especially design science research in information systems address this lack of practicality (Hevner et al. 2004). Design science researchers seek to develop and understand how the environment can be changed with artificial means. Simon (1996) noted that disciplines such as architecture, information systems, computer science, engineering, and management were all concerned with the process of design and the creation of materiality through artifacts. Artifacts can be of four different forms (March and Smith 1995): constructs (concepts that provide a language to communicate and understand phenomena), models (that build on these constructs to describe phenomena), methods (prescriptions on the activities that need to be undertaken to achieve some goal), and instantiations of the above (physical objects such as products and tools). All these artifacts provide concrete solutions to problems of immediate concern and that serve human purpose (Bailey 2008). Prescriptions for addressing the issues that practitioners face are embodied in these artifacts.

It is important to note that design science researchers are not exempt from the natural or social sciences in which their study is inscribed (Hevner et al. 2004; March and Smith 1995; Markus et al. 2002). On the contrary, design science research requires that the environment of the artificial developments be taken into account. Such knowledge is generally referred to as kernel theories – i.e. existing knowledge that informs and constrains the design of the artifact and its evaluation – and allows to explain the sociomaterial dynamics of the environment (Mandviwalla 2015). The knowledge bases in design science research are categorized depending on whether they concern descriptive (or scientific) or prescriptive (design) knowledge (Baskerville et al. 2015; Gregor and Hevner 2013; Hevner et al. 2004). Design scientists can inform the design of their artifact using these two knowledge bases. They must also situate the knowledge they created through their design both compared to the existing descriptive and prescriptive knowledge. Therefore, design scientists usually wear two hats as they must both act as researchers who engage with existing knowledge and as a designer who must create a solution. This duality of designing artificial solutions and creating knowledge at the same time increases the complexity of conducting design science research (Goes 2014). Various seminal frameworks have been proposed to help design science researchers overcome the singular challenges of conducting design science research and creating, accumulating, and presenting knowledge. I describe these frameworks in the next two sections and explain the ones I will rely on in my studies.

2 Doing design science research

In this section, I will present how I applied design science research in the studies of my dissertation. I will structure the methodological presentation around three axes: (1) how design science research is conducted (section 2.1), (2) how design contributions are theorized (section 2.2), and (3) how both the artificial and theoretical contributions are evaluated (section 2.3). As outlined above, design science research is a particular kind of research with its own paradigms that is in its early stages of reaching maturity. The logic of conducting design science research might not be straightforward for those accustomed with the traditional approaches in natural and social sciences. For example, the traditional process of data collection and data analysis is not perfectly reflected in design science research in which the act of conducting research is a simultaneous and iterative process of designing, collecting data, and theorizing (Hevner et al. 2004; Gregor and Jones 2007). It thus seems important to provide an overview and description of the frameworks that are available for the three axes. Therefore, I will present the general rationales of conducting design science research, theorizing design, and evaluating design contributions. I will then anchor the methodology of my research studies by describing in detail the frameworks that I use for each activity and illustrate how I applied them.

2.1 Conducting design science research

To support design science researchers in the process of doing design science research, scholars have defined the steps and activities that must be followed. Initially, design science research was conceived as consisting of building and evaluating the artifacts (*e.g.*, March and Smith 1995). These activities were later refined and expanded into various process models for doing design science research. Among the most widely used and accepted are the frameworks by Hevner et al. (2004), Peffers et al. (2007), and the action design research framework by Sein et al. (2011). While these models rely on the same logic of building and evaluating artifacts in a highly iterative way (Mandviwalla 2015), they differ in the strategy the design science researchers use to solve the problem (Iivari 2015). The first two models are well-suited for designers who seek to address a general class of problems (e.g. supporting cross-boundary team communication) while the latter is intended for solving specific and situated problems that practitioners face (e.g. supporting boundary crossing among the different communities of practice involved in the Human Brain Project).

I will focus on Hevner and colleagues' (2004) framework as it is the one that I used for my research project. I use their framework for several reasons. Firstly, I use the first strategy described above, as I seek to support cross-boundary challenges as a general class of problems, regardless of the specifics of situated contexts, a point I have stressed as lacking in the literature on cross-boundary challenges (see Chapter 2). Secondly, as I will outline in the following chapters, my research project was highly informed by two existing theories in social sciences, i.e. Clark's (1996) theory of joint activities and Dewey's (1927, 1929) theory of joint inquiry. This reliance on kernel theories is well-reflected in Hevner and colleagues' framework, which puts greater emphasis on the addition and grounding in existing knowledge bases than the other frameworks, even if Hevner (2007) later added that kernel theories should not be mandatory.

This issue was subject to considerable debate. To them and March and Smith (1995), some artificial development in the form of an instantiation was enough to warrant valid contributions to design science research (Fischer et al. 2010). This view suggests that in order to avoid the lack of relevance that the IS field was fearing in those days, studies in design should not be rejected for the mere reason that they do not provide rigorous theoretical contributions. On the opposing sides, Pries-Heje and Baskerville (2010) and Gregor and Jones (2007) considered that design science research must be grounded in relevant natural and social sciences, otherwise risking to lead to instrumentalism. Others such as Goldkuhl (2004) lie in between the two sides in that they advise that artificial contributions be grounded, but not necessarily on kernel theories. They suggest four types of grounding, among which empirical grounding through the evaluation of artifacts, using case studies for example. While these views have not yet reached a consensual vision of the role of and contribution to knowledge in design science research, some common ground has been created in the past years with the conjoint paper of Gregor and Hevner (2013). They stipulated that design science contributions should be made to design theories and possibly the kernel theories. In my doctoral research, I have followed their suggestions as I considered that it is important to contribute to both the kernel knowledge and design knowledge. Moreover, my research is highly intertwined with kernel theories, both being grounded in it and contributing to it.

Hevner et al. (2004) suggest that performing design science research consists of three major activities. These activities are defined as three cycles: the design cycle, the relevance cycle, and the rigor cycle (Figure 3). The relevance cycle is a process that links the environment for which the artifact is designed and the design activity itself. Here, researchers need to develop an understanding of the domain in which the artifact will be applied. This domain consists of people, organizations, and technical systems. Design science researchers must then define the requirements of the application domains regarding the problems they face or the opportunities they want to take advantage of. The relevance cycle also includes the definition and evaluation against a set of criteria that will allow to assess whether and how the artifact creates value. Overall, the relevance of design science research can be demonstrated through the utility of the artifact (Venable 2006; Winter 2008). The rigor cycle includes the activities of identifying the descriptive and prescriptive theories that can inform the design of the artifact. Design science researchers may also rely on their own experience and expertise. This cycle also suggests that knowledge resulting from the design science research project should be formalized and added to the existing knowledge base. This reflects the need for design science research not only to produce artifacts but also research contributions, whether theoretical or artificial. One way of formalizing such knowledge is to develop design theories. I will cover the theorization of design science research into greater detail in the next section. Here, design science researchers can also derive methodologies for the evaluation of the artifact from existing knowledge. Finally, the design cycle involves the actual design of the artifact. This process is highly iterative as it may involve the design of prototypes and alternatives that will be evaluated until some satisfactory solution is reached, against the requirements defined in the relevance and rigor cycles. Most often, this evaluation is based on interactions with the individual or organizational end users. Various methods can be used for the evaluation of the artifact such as case studies, field studies, surveys, and experiments (Gregor and Hevner 2013; Nunamaker et al. 1991). The evaluation might be challenging as it is often difficult to define why an artifact works in a certain way (Mandviwalla 2015).

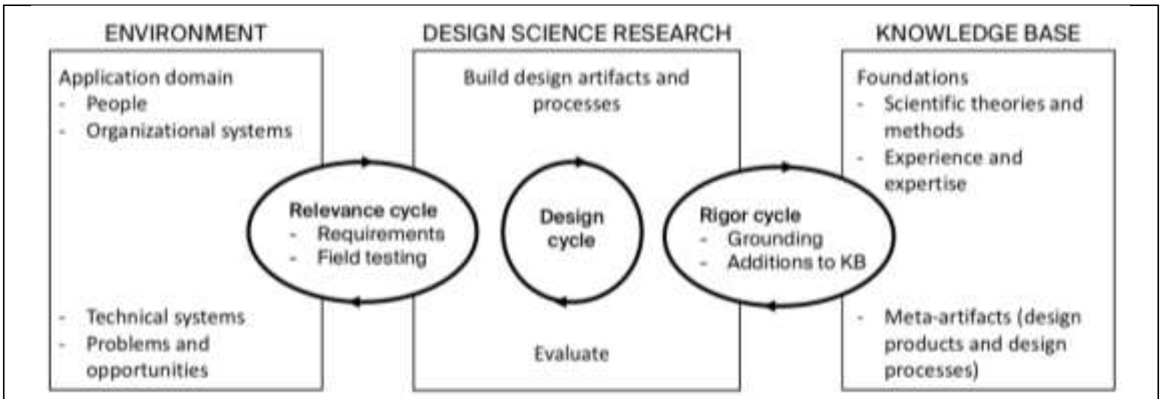

Figure 3 – Three cycle process adapted from Hevner et al. (2004) and Hevner (2007)

My dissertation is inscribed into a design science research project that started with the study by Mastrogiacomo et al. (2014) (cycle 0 in Figure 4). In their study, the authors (two of which have been my co-authors) instantiated Clark's (1996) theory in project management and teamwork as his theory mainly applies to pairs of individuals for day to day activities. Clark describes the requirements of common ground that individuals must establish to commit to a joint purpose or joint activity. Given the explanatory power his theory has for the use of language in coordination, Mastrogiacomo and colleagues developed a conceptual model based on his insights on common ground, but adapted it to teams and more complex projects. They instantiated the conceptual model into a set of cards (the Coopilot Cards) that project managers used as visual support and reminder during team meetings to evaluate through their perception how much common ground their team had. Their longitudinal evaluation with three teams suggested that the Cards helped project managers reduce the number of coordination surprises and communication breakdowns.

Based on the Coopilot conceptual model, I have performed the first two cycles of my thesis, i.e. the design of the Coopilot App and the Team Alignment Map (cycles 1 and 2 in Figure 4). Both developments updated the conceptual model with additional insights we gained from the studies. The Coopilot App helped us develop a process model of team coordination around the conceptual model (Study 2), and the Team Alignment Map informed us on the need to adapt the conceptual model with Dewey's (1927; 1929) concept of joint inquiry to better understand how cooperative cross-boundary teamwork happens (Study 4). Each cycle helped refine and augment the conceptual model incrementally. While it was initially aimed at understanding how coordination was achieved during meetings, it has evolved, as I will show in the second cycle in Chapter 5, into a conceptual model for both coordination and cooperation in cross-boundary teams.

It is important to note that the conceptual model was not used for the third cycle, in which we mainly wanted to provide a design theory for visual inquiry tools. To develop this theory, we theorized the design knowledge from three tools: the Team Alignment Map, the Business Model Canvas, and the Data Excellence Model. The last two visual inquiry tools address problems for which the Coopilot conceptual model is not relevant, i.e. business modeling and data management.

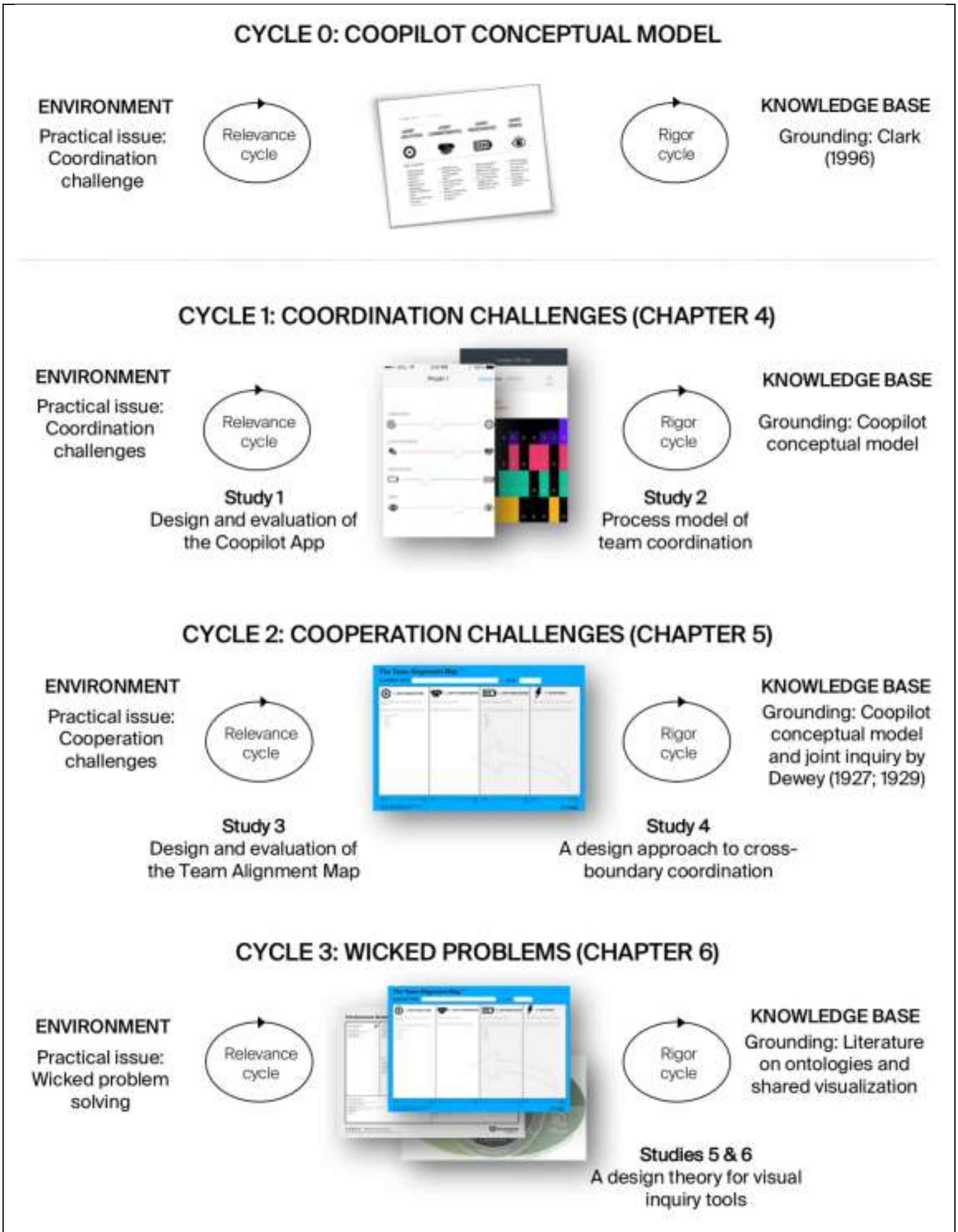

Figure 4 - Overall design science research project of this manuscript

2.2 Theorizing design contributions

One question that is still left is how artificial knowledge can be accumulated and formalized. As stated previously, the design science research scholarship went through a long journey before some consensus emerged on the role of theory and what constitutes a contribution to design science research. It is now commonly accepted that design science researchers should not only design state-of-the-art artifacts, they should also as researchers produce theoretical contributions (Bucher and Winter 2008; Venable 2006). The theoretical contributions are required for design science researchers to differentiate themselves from designers, practitioners or consultants. The role of theory is then to allow for the formalization of the design science contributions and the accumulation of knowledge across design science research studies addressing the same class of problems (Venable 2006). In her paper on the types of theory in the IS discipline, Gregor (2006) considered theories for design and action (theories that say how to do things) as a body of knowledge on its own.

Given this importance, various studies have outlined what constitutes a theory and how it should be represented. Walls et al. (1992) were the first to define what a design theory should include. Building on their work, Gregor and Jones (2007) proposed an anatomy of design theories. Their work is the one I have used to formalize my theoretical contributions (especially in Chapter 6) as it defines exhaustive yet mutually exclusive components for design knowledge that is mature enough to form a theory. Their framework is composed of eight components which make up a design theory (Table 6).

Table 6 – Design theory components (Gregor and Jones 2007)

Component	Description
1. Purpose and scope	What the artifact is for and the meta-requirements or class of problems for the design theory to be applicable.
2. Constructs	Entities or units of interest in the design theory.
3. Principles of form and function	Description of the artifact.
4 Artifact mutability	How the artifact is expected to change over time as artifacts are in constant change.
5. Testable propositions	Truth statements of the design theory that can be tested to evaluate the theory.
6. Justificatory knowledge	The kernel theories whether descriptive or prescriptive on which the design of the artifact is based.
7. Principles of implementation	The process of activities that must be followed to implement the design theory in specific contexts.
6. Expository instantiations	A physical instantiation of the design theory into an artifact that can be used to illustrate and test the theory.

The process of theorizing design is usually deemed difficult and less straightforward than in social sciences (Mandviwalla 2015). To facilitate this process, recent studies have proposed process models (*e.g.*, Gregory and Muntermann 2014; Kuechler and Vaishnavi 2012; Lee et al. 2011; Mandviwalla 2015). In my work, I rely on Lee et al. (2011) who propose a high-level view of the theorization process as abstraction and de-abstraction between the instance (artifact) and abstract domain (Figure 5). It is characterized by four theoretical elements (instance problem, instance solution, abstract problem, and abstract solution) that require four theorizing activities. It takes the form of an ideal process that scholars may follow to theorize their design knowledge regarding one or more of the four domains. The authors distinguish between the abstract and the instance domain. In the instance domain, a particular solution is designed or registered for a specific instance problem. On the other side, the abstract domain denotes a generalized (rather than particular) problem class that is addressed by searching for an abstract solution. The theorizing process is characterized by interplays between problems and solutions in each domain and the transition from one domain to the other (i.e. abstraction and de-abstraction).

Other scholars have addressed how the knowledge should be formulated, especially for the design principles of form and function, sometimes considered as the backbone of design theories (*e.g.*, Chandra et al. 2015; Heinrich and Schwabe 2014; Pries-Heje and Baskerville 2010; Van den Akker 1999). For the three cycles, I follow the guidelines by Chandra et al. (2015) as they provide a precise and consistent way of formulating design principles in terms of action, materiality, and boundary conditions. Action refers to the actions and behaviors that the artifact affords. Materiality relates to the properties of form and function that permit such actions. Boundary conditions describe the conditions under which the design principle is possible, such as implementation settings or the characteristics of the users. They recommend that all design principles be articulated following the template: In order for users to [action], the system should embody [material property] given that [boundary condition].

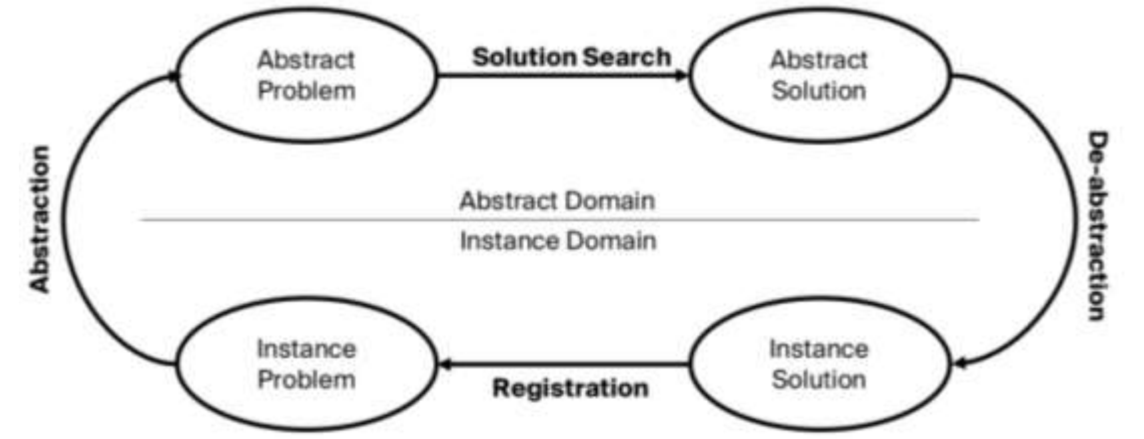

Figure 5 – Design theorizing process adapted from Lee et al. (2011)

2.3 Evaluating design contributions

The evaluation of design theories has received extensive attention to ensure the relevance and rigor of research. March and Smith (1995) were the first to provide a comprehensive list of evaluation criteria. Prat et al. (2015) reviewed studies in design science research and listed 20 criteria that these studies used to evaluate the artifact. They categorized the evaluation criteria according to the artifact dimensions they belong to: the goal of the artifact (e.g. validity, efficacy), the environment in which the artifact is inscribed (e.g., utility, ease of use), the structure of the artifact (e.g., completeness, simplicity), the activity it allows to perform (e.g., efficiency, accuracy), and the evolution of the artifact (e.g., robustness). Aier and Fischer (2011) compared criteria for evaluating design theories with those used in the social sciences. They suggest that artifacts should be evaluated against their utility, their internal and external consistencies, the scope and purpose of the design theory, its simplicity, and the fruitfulness or novelty of its contributions. To perform the evaluation, design scientists can resort to multiple sources (Mandviwalla 2015). Gregor and Hevner (2013) recommend the use of case, studies, experiments, simulations, or experiments. In general, they suggest that the evaluation of artifacts should be looser than in social sciences as it is difficult to evaluate an artifact and single out its influence of social dynamics, and the usefulness of the artifact should be deemed a sufficient criterion for proofs-of-concept and complex artifacts. However, in my dissertation, I have tried to ensure a certain level of evaluation, especially for the usefulness, validity, and efficacy of the artifacts.

I will describe the specific methodologies for the evaluation of each study in their respective chapters (4, 5, and 6). This choice is motivated by several reasons. Firstly, as suggested by Gregor and Hevner (2013), presenting design science research poses particular challenges that are not encountered in the social sciences. This is mainly due to the artifact description, which has no equivalent outside the design science research paradigm. The artifact can be considered as both being part of the methodology and as a result in itself. However, the results of the evaluation then need to be presented separately. Thus, presenting the artifact, the methodology, and the evaluation at the same time can create considerable confusion and impair the intelligibility of the manuscript. Therefore, the strategy they suggest is to present the overall design science research approach as part of the methodology, and decouple the presentation of the artifact and its evaluation.

This is the first reason that motivates me to present only the overall project in this section and present the specifics of the evaluation of each study in their respective chapters. The second reason for which I decided to operate this way is the relatively different approaches I used for each cycle (see Table 7). For example, while the cycles 1 and 2 are both concerned with the design of an artifact, cycle 3 does not involve the development of new solutions as it relies on existing ones. In cycles 1 and 2, I evaluated the Coopilot App and the Team Alignment Map using various evaluation methods. In cycle 1, I evaluated the Coopilot App through case studies with four professional cross-boundary teams and later through questionnaires with thirteen teams of undergraduate students. In cycle 2, I evaluated the Coopilot App through case studies with ten cross-boundary teams working on innovation projects. In cycle 3, I was mainly concerned with the process of theorizing design across the three cases with the framework by Lee et al. (2014). Therefore, to avoid any confusion and cognitive overhead, it seems better to present the methodologies in their respective chapters.

Table 7 - Specific evaluation methodologies in the six studies			
Cycle	Study	Methodology	Reference
1	1: Designing for team coordination	Case studies of four professional cross-boundary teams. Quantitative and open-ended questionnaires with thirteen teams of undergraduate students.	Missonier, M., Avdiji, H., and Mastrogiacomo, S. (2014). "Applying psycholinguistic concepts to IS project management tool design," in *Proceedings of the Twenty Second European Conference on Information Systems* (ECIS). - The evaluations were done after the paper was published (we presented the Coopilot App as a proof of concept).
	2: Process model of team coordination	Theoretical development	Avdiji, H., Missonier, S., and Mastrogiacomo, S. (2015). "Understanding IS team coordination in real time: A process approach to coordination," in *Proceedings of the Thirty Sixth International Conference on Information Systems (ICIS).* - Best Research-in-Progress Runner-up Award
2	3: Designing for cooperation	Case studies of ten cross-boundary teams working on innovation projects.	Avdiji, H., Chandra-Kruse, L., and Missonier, S. (2018). "Sharing leadership through digital collaborative tools," in *Proceedings of the Twenty Sixth European Conference on Information Systems (ECIS).*
	4: Bridging coordination and cooperation challenges through joint inquiry	Case studies of ten cross-boundary teams (Study 3) and twelve teams of undergraduate students working on innovation projects	Avdiji, H. and Missonier, S. (2018). "A design approach to team coordination," *Travaux Neuchâtelois de Linguistique*.
3	5 & 6: Designing for wicked management problems	Ex-post theorization of visual inquiry tools based on three design science research projects.	Avdiji, H., Elikan, D., Missonier, S., and Pigneur, Y. (2018). "Designing tools for collectively solving ill-structured problems," in *Proceedings of the 51st Hawaii International Conference on System Sciences (HICSS),* 400-409. - Nominated for Best Paper Award. Avdiji, H., Elikan, D., Missonier, S., Pigneur, Y., and Legner, C. (under review). "Addressing wicked management problems: A design theory for developing visual inquiry tools," *Journal of the Association for Information Systems (JAIS).*

CHAPTER 4

SUPPORTING CROSS-BOUNDARY COORDINATION CHALLENGES

ABSTRACT OF CHAPTER 4

In this chapter, I relate two studies that I undertook to provide prescriptive guidance for cross-boundary teams to overcome their coordination challenges. The question I seek to answer is: *How can we support cross-boundary teams in measuring and augmenting their common ground effectively?*

In Study 1, which was published in 2014 in the proceedings of the *Twenty Second European Conference on Information Systems (ECIS)* (*reference* Missonier et al. 2014), I present the Coopilot conceptual model which describes how cross-boundary teams establish common ground through discussions to coordinate effectively. I have instantiated the conceptual model in an initial version of Coopilot App, a mobile application which allows cross-boundary team members to measure their level of common ground. The original article presented the Coopilot App as an illustration of how the Coopilot conceptual model could be instantiated to support cross-boundary teams in addressing their coordination challenges. There was, however, no evaluation of the App. Therefore, I complement the original article with evaluations that I performed after the publication of the original article and which informed the design of an improved second version of the App. The second version includes a numerical metric for the level of common ground (in terms of percentage of common ground) and a conversational guide to help cross-boundary teams undertake discussions to repair common ground breakdowns. I related these results in a paper that I plan to submit this year to the journal *Information Technology and People*. Through this study I confirm the validity of the Coopilot conceptual model and contribute with prescriptive knowledge in the form of design principles that support the evaluation of the level of common ground and the guidance for the repair discussions.

In Study 2, which was published in 2015 in the proceedings of the *Thirty Sixth International Conference on Information Systems (ICIS)* (*reference* Avdiji et al. 2015), I sought to understand the process through which the establishment of common ground, its evaluation, and the repair discussions are related. I have developed a process model of team coordination which considers that cross-boundary teams coordinate through two fundamental discursive activities: (1) they interact to establish common ground, and (2) they interact to monitor their level of common ground by identifying any common ground shortages and repairing them. Through this study I contribute with descriptive knowledge on team coordination by providing a more actionable and practical account than traditional studies on team coordination.

With these two studies, I integrate three streams of research on coordination (shared cognition, language, and objects). I illustrate how a tool (object) can support coordination by guiding the conversations between cross-boundary team members (language) to create and maintain common ground (shared cognition).

HIGH-LEVEL CONTENTS OF CHAPTER 4

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2. Study 2: Process model of team coordination 152
3. Synthesis of Studies 1 and 2 and future research 148

1 Study 1: Designing for coordination challenges

In this study, I present the design science research project that I undertook to provide support and guidance to cross-boundary teams for their coordination challenges. I relied on Hevner and colleagues' (2004) framework for conducting design science research (Figure 6). This study is composed of two parts. In part 1, I lay the theoretical foundations that inform the design of an artifact to help cross-boundary teams overcome their coordination challenges, and I present the Coopilot App V1 (steps 1 to 3 in Figure 6). Part 1 is based on a published article. In part 2, I relate the evaluation that I have performed after the publication of this article (steps 4 to 7). I plan to submit the results of this evaluation to a journal this year.

In the first part, I will illustrate how the level of common ground can be measured with a mobile application, i.e. the Coopilot App V1. This part was published in 2014 in the proceedings of the *Twenty Second European Conference on Information Systems (ECIS)* (reference Missonier et al. 2014). The objective of this paper was to illustrate the relevance of adapting Clark's (1996) theory on common ground and coordination between pairs of individuals to understand how coordination concretely happens within cross-boundary teams working on information systems projects. To do this, we relied on the Coopilot conceptual model which was developed by two of my co-authors in a prior study (Mastrogiacomo et al. 2014). We instantiated this conceptual model in a mobile application (Coopilot App V1) which was the first tool – to our knowledge – to measure and materialize the level of common ground between members of cross-boundary teams. The paper was presented as a proof-of-concept of the instantiation of our conceptual model. There was no evaluation of the Coopilot App V1 and the conceptual model.

In this paper, we mainly reviewed the literature on team coordination and how it fell short of providing a practical understanding of how coordination concretely occurs within cross-boundary teams (step 1 in Figure 6). We highlighted that literature on coordination emphasized the role of common ground as crucial for coordination, but that there were no insights on how to make teams aware of how much common ground they have. We proposed Clark's (1996) theory and the Coopilot conceptual model by Mastrogiacomo et al. (2014) as providing an actionable and pragmatic theoretical basis to understand the role of common ground in cross-boundary coordination, how it is established and evaluated (step 2). We built on this conceptual background to design the Coopilot App V1, a basic voting system through which team members could state their individual perceptions of understanding of their joint project (step 3). These perceptions are aggregated by the App to measure and display the level of common ground within the team.

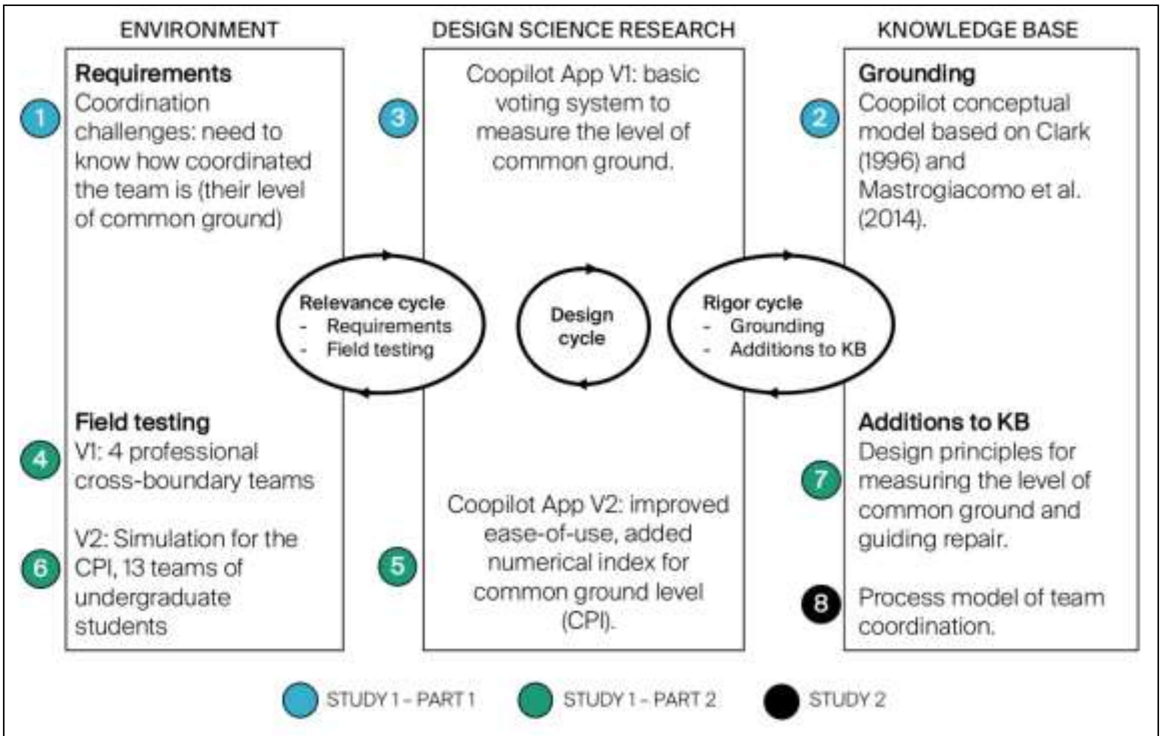

Figure 6 - Design science research process for Study 1, based on Hevner et al. (2004)

The content of the first part of Study 1 departs to some extent from the content of the original paper on which it is based. In the original paper, we reviewed literature on project success/failure and team coordination. We highlighted how team coordination was considered as crucial determinant for the success or failure of IS projects. Hereafter, I have decided to exclude the literature on IS project success and failure for the sake of simplicity. I want to avoid an overload of information by including an additional stream of research in my dissertation. The study was inscribed IS project teamwork, which corresponds to one specific type of teams within the umbrella concept of cross-boundary teams. The literature on IS project team success and failure corresponded to the context of our study, which I extend here to cross-boundary teams. The extension of the context does not change the core of the original article. The research objectives, the research question, the conceptual model, and the instantiation into the Coopilot App V1 remain unchanged.

In the second part of Study 1, I will relate the two rounds of evaluation I made after the publication of the first part above. I plan to submit the results of these rounds of evaluation to the *Information Technology & People* journal later this year. The reason I have not yet published the results is that I did not have the perspective I needed to value the results and understand their contribution. I performed a first round of evaluation with four professional cross-boundary teams (step 4). The results from this round of evaluation confirm the usefulness of the Coopilot App to measure the level of common ground and support cross-boundary coordination for teams with more than 4 members. The App made team members aware of their perception gaps, after which the team engaged in repair actions. Our informants suggested that we improve the ease-of-use of the application and that we provide some more guidance on how to interpret votes. We thus designed the Coopilot App V2 which improved the voting system and provided a numerical measure of the level of common ground (step 5). I evaluated the second version with 13 teams of undergraduate students and collected data on the reactions that team members had whenever they saw their level of common ground (step 6). The results suggested that a high level of common ground created positive feelings of achievement while a low level prompted the team members to repair their perception gaps.

That being said, the presentation of the study will be structured as follows. I will first present the literature on cross-boundary team coordination and language (step 1 in Figure 6). I will then present Clark's theory and the adaptation of his theory to cross-boundary teams through the Coopilot conceptual model (step 2), and how I instantiated this conceptual model in the Coopilot App V1 (step 3). I will then relate the methodology I used for the evaluation of the Coopilot App V1 (step 4) and describe the results (step 5). I will show how these results informed the design of the Coopilot App V2 (step 6), followed by the methodology and the evaluation of this version. Finally, I will conclude with the contributions to the knowledge base we made (step 7). This study confirms the usefulness of the Coopilot conceptual model and the two instantiations in the Coopilot App V1 and V2 to provide practical and actionable support for cross-boundary coordination in practice. I will then outline three design principles that I draw from this study to inform how the level of common ground can be measured and augmented through repair discussions.

1.1 Part 1: Illustrating how the level common ground can be measured

1.1.1 Introduction: coordination challenges in cross-boundary teams

Research focusing on the understanding of IS project success/failure has revealed that effective coordination increases project performance (Hoegl et al. 2004; Hoegl and Gemuenden 2001; Parolia et al. 2007), and that IS project failure often partly results from coordination problems (Espinosa et al. 2007; Kraut and Streeter 1995). Most of these studies are based on the classical perspective of coordination taken from organization literature, such as the coordination theory (Malone and Crowston 1990, 1994), the information processing model (Galbraith 1974) and the fit and contingency model (Lawrence and Lorsch 1967; Thompson 1967). Various studies have complemented and enriched this view of “explicit” coordination mechanisms (used purposely to coordinate) by determining that in addition to explicit components, implicit components of coordination (i.e. those used without a conscious effort to coordinate) are necessary for a project to succeed (Cannon-Bowers and Salas 2001; Espinosa et al. 2004; McChesney and Gallagher 2004). For instance, to manage their dependencies more effectively, team members use cognitive mechanisms (Espinosa et al. 2007; Kotlarsky et al. 2008) such as shared understanding or team awareness of who is available and *who* has previously done *what*, *where* and *for whom*. Shared knowledge about the team or the task helps team members anticipate what others are likely to do and what is required from them (Cannon-Bowers and Salas 2001; Klimoski and Mohammed 1994).

Contemporary studies on coordination do not consider how cooperative work is carried out and pay too little attention to the coordination challenges between team members (Tellioglu 2006). Prior research places coordination at the organizational level of processes and structures; it thus adopts a relatively high-level view of coordination (Faraj and Xiao 2006; Okhuysen and Bechky 2009) and no pragmatic suggestions are made concerning how cross-boundary team members should coordinate (Faraj and Xiao 2006). Although prior research has established that effective coordination implies that team members know that they share knowledge, several questions remain unanswered in this regard. None of these streams suggests how coordination is concretely carried out and how shared understanding is established (Faraj and Xiao 2006; Tellioglu 2006). This proves problematic as coordinating effectively can be especially challenging in cross-boundary teamwork. As outlined by Bruns (2013), coordination requires diverse contributions to be integrated and that may require some extensive effort in cross-boundary teams, due to their differences in perceptions, knowledge, and thought worlds. Carlile (2002; 2004) identified that differences in vocabulary (syntactic boundary) and understanding (semantic boundary) will impede the creation of shared understanding between individuals across boundaries and functions. This difficulty to establish shared understanding raises several questions. For instance, how can team members know that they share enough knowledge to minimize false predictions and coordination surprises? How do we ascertain that team members understand their roles and the project goals? And what we consider the most important question: *How* do we know *who* knows *what*?

We investigate these aspects by considering what we regard as our primary device of coordination: language. Indeed, our main assumption is that *conversation* is the main mediating mechanism between individuals, specifically in terms of how they understand each other's intentions as the project unfolds. We argue that a perspective based on language can fill these two gaps.

Recently, there has been growing interest in language both in organizational theories (Alvesson and Kärreman 2000) and in the IS field (Dreiling 2006), what is referred to as the linguistic turn. Organizational theories regard organization as social constructions in which language plays a constitutive role (Gergen et al. 2004; Putnam and Nicotera 2009; Taylor and Van Every 1999; Weick 1969). McPhee and Zaug (2008) identify four types of messages necessary for an organization's communicative constitution among which coordination. Barnard (1968) defines organizations as cooperative systems and recurring achievements of human coordination, a view shared by Taylor and Van Every (2010, p. 36) who posit that "[f]or there to be organization there must be coordination of action". Moreover, coordination is often a conversational experience (Boden 1994). In fact, the role of language and communication in organizations is often determined by conversations between organizational members (Hardy et al. 2005; Tsoukas 2005). Even if several scholars in the field have recently embraced conversation analysis and other microanalytical approaches to studying workplace interactions (Asmuss and Svennevig 2009), little attention has been paid to real-time coordination per se, *i.e.,* the linguistic acts through which coordination is accomplished during meetings.

The lack of studies examining the role of conversation in real-time coordination in organizational theories and IS studies leads us to another perspective, one that exists outside the organizational and IS fields. That perspective stems from psycholinguist Herbert Clark's (1996) work, which we used as a theoretical foundation and that we will present hereafter. To our knowledge, except a few studies (*e.g.*, Laumann and Rosenkranz 2009), Clark's theory has not been mobilized in the IS field.

1.1.2 A new theoretical approach: Clark's joint activity model

Several researchers including Klein et al. (2005) in the field of psychology, Bechky (2003b) in organization studies, and Dillenbourg and Traum (2006) in computer supported collaborative learning (CSCL) have noted the relevance of Clark's joint activity theory. Clark (1996) described how people use language to coordinate *joint activities*, i.e. activities carried out by an ensemble of people acting in coordination with each other. According to Klein et al. (2005), Clark's ideas bring added value to prior coordination approaches: "*Though previous accounts of team coordination [...] have identified features of effective coordination, Clark's description of joint activity during conversations seems to provide a much stronger basis for understanding team coordination*" (p.143). Hereafter, we specify Clark's concepts we used to adapt his theory to cross-boundary teamwork and design our tool (Table 8).

Table 8 - Clark's main concepts used in our conceptual model

Clarkian concept	Description
Joint activities	Activities that involve more than one person and in which individuals' actions depend on each other to reach a joint purpose.
Joint purpose	What participants want to reach through their joint activities, what they intend to do together.
Conversation and language	Face-to-face dyadic exchange, the basic setting for using language.
Coordination	What people do to align their contributions during their joint activities.
Coordination surprise	Disruption of coordination that happens when participants make wrong predictions about each other.
Common ground	Mutual and recursive knowledge that is created through language and that helps participants coordinate. The set of knowledge, beliefs, and suppositions that people believe they share.
Common ground breakdown	Misbeliefs on what people know about each other. Can result in wrong predictions and lead to coordination surprises.
Interpredictability	What one infers or predicts the other knows or will do.
Grounding	The process through which common ground is established. Includes two phases: presentation of information by a speaker and acceptance by the hearer.
Evidence of understanding	In the acceptance phase, individuals can display their understanding through four types of evidence of understanding: assertions, presuppositions, displays, and exemplifications.

Clark's approach specifies the cognitive conditions necessary for effective coordination and the linguistic acts through which coordination is accomplished. Clark introduces his approaches with a strong statement. Coordination is concerned with what team members do when they solve *coordination problems*, mainly using language. Coordination problems are related to the issue of interpredictability, i.e. when team members – or individuals in general – must infer what actions they can expect from each other in their joint effort to reach the *common goal*. To solve coordination problems, people need to establish and maintain a sufficient level of *common ground*: the set of knowledge, beliefs and suppositions that people believe they share (Clark 1996, p. 93). Put differently, a piece of information, say X, is common ground to persons A and B, if A knows X, B knows X, but also, A knows that B knows X, B knows that A knows X, and so on iteratively. When referring to *common ground*, I mean the subset of the participants' common ground relevant to the project. I do not consider their overall common ground which could include anything from cultural affinities to food preferences. I focus on the knowledge that is related to the project.

Klein et al. (2005) pointed out that people all too often discover a serious loss of common ground. They refer to this as the fundamental *common ground breakdown* (i.e., when there is confusion about who knows what) that creates *coordination surprises*. Such surprises occur when something happens that doesn't make sense in terms of their beliefs. For example, a project team expects one of its members to get a prototype approved by the key users within 10 days but this team member was unaware that he was dedicated to this task, leading to a coordination surprise.

As common ground is the premise for effective coordination and joint activities, it should constantly be updated to avoid such breakdowns and coordination surprises. One of the most efficient ways to construct and maintain a sufficient level of common ground is through language.

Such concepts prove particularly important in the context of cross-boundary teams as they evolve in ever-changing environments whether because new constraints emerge, the specifications of their project need to be modified, unforeseen risks are identified, or new members are integrated in the team. Such cases stress the need for cross-boundary teams to update their common ground with the new information in order to avoid that members perform actions or make decisions based on obsolete information, thus triggering a domino effect that leads to coordination surprises and potential shifts in terms of scope, time, quality, and cost.

Clark has suggested that the process through which common ground is established is the process of grounding. It describes how individuals construe experiences and signals the same way, and thus establish common ground. In general, individuals contribute to common ground, in which the speaker presents a piece of information (signal) to the hearer(s) and the latter accept that piece of information by displaying some evidence of understanding. Clark (1996, p. 228) identified four types of evidence of understanding: (1) assertions of understanding (saying "uh huh" or "I see"), (2) presuppositions of understanding (when the hearer takes up the speaker's contribution, she presupposes she has understood him well enough), (3) displays of understanding (the speaker can understand how the hearer construed his contribution when she answers and displays how she construed what the speaker said), and (4) exemplifications of understanding (the hearer can offer a paraphrase or repetition of what the speaker said, as well as gestures and facial expressions). According to Clark, displays and exemplifications of understanding tend to be the most effective for establishing a contribution as part of their common ground.

Clark and Schaefer (1989) suggest that coordination surprises can be reduced by helping team members "artificially" raise their level of common ground. While it may be sufficient for two spouses to nod, say "okay" or "yes" when discussing the purchase of new curtains, participants in professional settings such as during a project meeting may need more explicit evidence of mutual understanding (*see* Cahn and Brennan 1999; Cherubini et al. 2005). In such a case, if there is any doubt about participants' understanding, cross-boundary team members may need to trigger a discussion or ask questions in real time to decrease the potential discrepancies in common ground between them.

This conception of common ground differs from shared understanding or team mental models which regarded shared cognition as an overlap of knowledge held by different individuals, the overlap making up for the shared in shared cognition (Wilkes-Gibbs and Clark 1992). Common ground includes the recursive beliefs of participants that others also hold a piece of information and this recursive belief is based on shared bases such as the environment, the events that happen in front of people's shared attention. While this difference may seem trivial, it has important implications for the role shared cognition plays in coordination. Compared to traditional accounts, his conception of coordination stresses the importance of interpredictability, i.e. the ability to infer and predict what others know and do. Interpredictability is based on common ground. Therefore, individuals must not only share knowledge or have similar mental models to coordinate, they need to continuously establish common ground to be able to predict what others are to contribute to the joint activity, so that they can adapt their behaviors and attitudes accordingly. Also, common ground is different from shared understanding regarding the level of analysis. Common ground is most often used to describe how people understand each other at the utterance level, which does not necessarily translate into shared understanding (Cherubini et al. 2005). Common ground provides the reference environment that individuals can use to interpret what the others say and as conventional devices for turn-taking and the choreography of conversation (Kecskes and Zhang 2009; Klein et al. 2005). Therefore, the fact that two people undertake a conversation without major breakdowns, does not necessarily mean that they understand each other at the end of the conversation. However, when combined with perspective making and material support, common ground can most effectively lead to shared understanding. Despite the fact that the concept is not specifically tailored for understanding the emergence of shared understanding in team conversations, this perspective allows to bridge the lacking conceptualization of how shared understanding is created and can be supported through conversation (Zackrison et al. 2015).

For that purpose, Mastrogiacomo et al. (2014) decided to design the Coopilot conceptual model initially with the aim of equipping project managers with a way to assess the level of their team's common ground and act accordingly. They based their work on Clark's definitional requirements for *joint projects*. A joint project corresponds to an interaction in which person A proposes something to person B and B responds positively. Clark (1996, p.191) points out that joint projects require joint purposes. For A and B to commit themselves to joint purpose *r*, it is necessary to satisfy four conditions: *(1) Identification*: A and B must identify *r*, *(2) Ability*: It must be possible for A and B to play their part in fulfilling *r*, *(3) Willingness*: A and B must be willing to play their part in fulfilling *r*, *(4) Mutual belief*: A and B must each believe that (1), (2), (3), and (4) are part of their common ground.

1.1.3 Adapting Clark's theory to cross-boundary teams: Coopilot conceptual model

Mastrogiacomo et al. (2014) adapted Clark's theory to project teams in their conceptual model Coopilot. Coopilot is a simple conversational guide to help IS project managers minimize the number of coordination surprises that arise for teams during their project meetings. They translated and adapted the four requirements from Clark's model of joint activity (identification, ability, willingness, and mutual belief) into the four variables that constitute the conceptual model (joint objectives, joint resources, joint risks, and joint commitment). These variables represent the requirements in terms of knowledge, presuppositions and beliefs that participants need to share to act jointly and coordinate effectively during their project (Table 9).

Table 9 - Coopilot conceptual model (Mastrogiacomo et al. 2014)

Clark's requirements for joint purposes	Coopilot constructs	Description
1. Identification: A and B must identify r	Joint objectives	What the participants intend to do together
2. Ability: it must be possible for A and B to play their part in fulfilling r.	Joint resources	What the participants need to do their part
	Joint risks	What could prevent participants from do their part
3. Willingness: A and B must be willing to play their part in fulfilling r	Joint commitments	What participants expect each other to do.
4. Mutual belief: A and B must each believe that 1, 2, 3, and 4 are part of their common ground.	Project meetings	Seek evidence of mutual understanding for joint objectives, joint commitments, joint resources, and joint risks in project meetings or project-related conversations.

They assumed that project managers have to continuously monitor these four variables if they want their participants to act as a team and ensure that their individual contributions will harmoniously converge into a joint outcome through a proper and consistent division of labor. Therefore, they instantiated these four variables in a set of cards called the Coopilot Cards (Figure 7) to support project managers in monitoring their team's level of common ground.

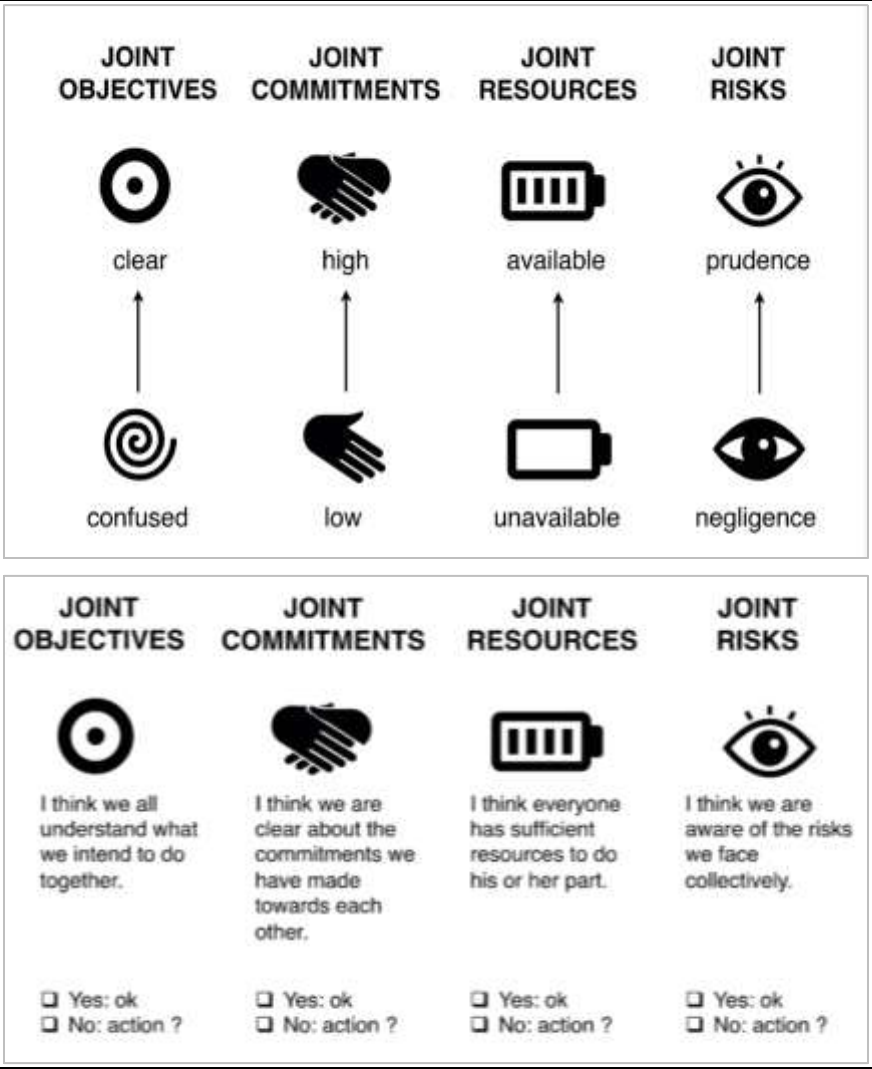

Figure 7 - The Coopilot Cards (Mastrogiacomo et al. 2014)

The Cards described the four requirements of the Coopilot conceptual model using visual iconography and illustrated the amount of common ground using scales with minimum and maximum values. In this research, (only) project managers used the Coopilot Card in every project meeting as visual support to evaluate their team's level of common ground on the four requirements. More precisely, they evaluated their perception of each team member's position on each variable during the meeting based on the proceedings of the aforesaid meeting. This allowed them to appreciate the perception gaps between team members. The project manager used the Coopilot Cards before the closing of the meeting so that they could evaluate whether the proceedings of the meeting related to the four variables were clear for everyone and avoid that participants leave the meeting with misconceptions, wrong perceptions, or biased inferences.

The results of their study demonstrated that frequent use of the Coopilot cards over a period of several months helps managers repair common ground breakdowns, reduces the number of coordination surprises in the project, and thus can increase a project's potential for success as perceived by the project managers. Their study illustrated the value that Clark's theory can bring to the IS field. In order to improve the adaptation of Clark's views to cross-boundary teamwork, I have improved the instantiation of Clark's model by developing an additional tool, i.e. the Coopilot App V1 which aims to measure and provide a real time visualization of the team's common ground.

1.1.4 A new instantiation of Clark's theory: Measuring the level of common ground with the Coopilot App V1

In collaboration with a Swiss firm, we have developed the Coopilot App V1, a mobile application running an instance of the Coopilot conceptual model through a web browser accessible on smartphones and other devices. The aim of this new instantiation is to improve the evaluation of a team's common ground. As mentioned previously, the Coopilot Cards were used by the project managers to assess the team members' perceptions regarding the four values displayed on the cards. The evaluation of the level of common ground was based on the project managers' perceptions, not from the perceptions of all team members. On the contrary, the Coopilot App allows every participant to directly assess their own perception regarding the four requirements. Indeed, for the same reasons as for the Coopilot Cards, the project team uses the application to assess their level of common ground towards the end of a meeting. The process of voting starts with each participant entering a link in the internet browser in their device which directs them to the homepage of the software. They select the appropriate project from the list of all projects rolled out in the company. The browser then directs them to the page on which they can vote on the four variables.

In this new instantiation, the four Coopilot requirements are presented as cursors on which each team member can position their own perception of the ongoing activity (Figure 8). For instance, the team member assesses that: joint objectives are *clear* or *unclear* to them, joint commitments are *implicit* or *explicit* to them, if resources are *available* or *unavailable* to play their part, and if joint risks are perceived as *high* or *low* in terms of risk exposure. After all team members position their cursor and submit their votes, the application displays the votes of the other participants that have already voted and updates automatically as soon as a new vote is submitted (note: this can be a matter of seconds as all participants vote at the same time and the process of voting does not take long). Once everyone has voted, the software displays all participants' votes on everyone's screens anonymously as illustrated on Figure 9. If there is a beamer in the room, it is possible to show all the participants' votes so that they all share the same visualization of the votes. The fully filled points indicate the vote of the user, and the other points show the votes of the other team members. As the votes are anonymous, there is not visual differentiation between the votes of the other team members. Once the votes are aggregated, participants are asked whether they are surprised by the scattering of the votes.

The scattering of the votes represents the level of common ground. The more scattered the votes, the lesser common ground there is. For example, if all the votes were on the right hand side of the sliders, that would mean that the four requirements are clear for everyone, i.e. there is strong common ground. However, if votes are scattered or all on the left hand side of the sliders, there is great confusion within the team. The main difference with the Coopilot Cards is that the evaluation of common ground is made directly by the team members as they state their own perceptions. The Cards served as visual support and reminder for the team leader to evaluate the level of common ground on the four requirements within their team. This was thus based on inferences on inferences, as the team leader had to infer the state of common ground in the team through the conversations. This way of proceeding adds an additional level of potential deviations from reality, thus inaccuracy.

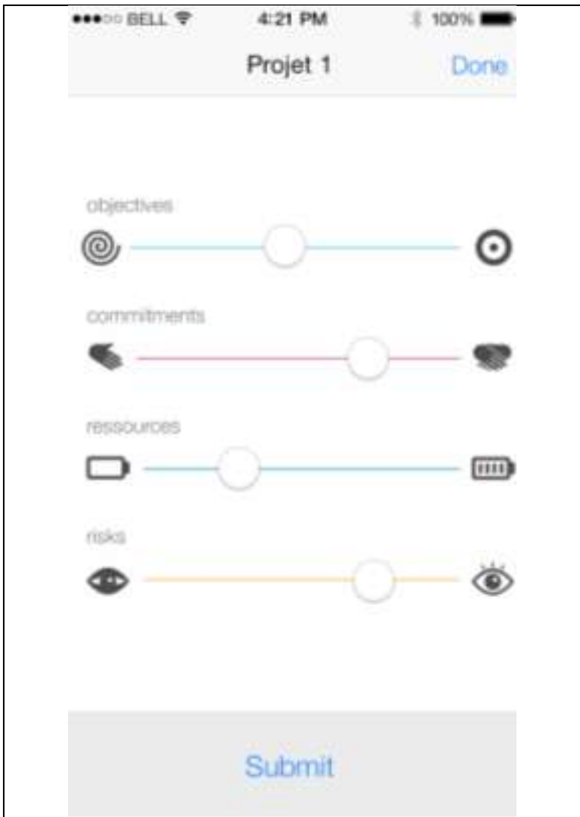

Figure 8 - Coopilot App v1screen for voting

Figure 9 – Coopilot App v1result screen

From this common visualization, participants can start a discussion about the perception gaps they visualize. The scattering of the votes suggests whether the team should engage in repairing conversations, i.e. discuss the requirements for coordination to construe them the same way and establish common ground. For example, if the votes of the joint objectives are all on the right hand side of the slider, while the other three are uniformly scattered, the team could deduct that they need to discuss joint commitments, joint resources, and joint risks. The discussion would allow everyone to state their perception and negotiate a common definition of the four requirements. In general, we hypothesized that the Coopilot App allowed teams to evaluate their level of common ground, and that this would lead to lesser common ground breakdowns and coordination surprises as individuals would engage in repair discussions. I will now outline the evaluation we made of this version and show how our observations support these hypotheses in the next part.

1.1.5 Preliminary discussion

In the first part of Study, I sought to illustrate how the level of common ground can be measured in cross-boundary teams. Using Clark's theory and the Coopilot conceptual model, we first defined the content on which there should be common ground for cross-boundary teamwork: joint objectives, joint commitments, joint resources, and joint risks. In natural settings, as outlined in our conceptual model, the evaluation of common ground would occur during conversations through four types of evidence of understanding (assertions, presuppositions, displays, and exemplifications). The Coopilot Cards by Mastrogiacomo et al. (2014) built on these four types of evidence that project managers would look for during team conversations to infer the level of common ground within the team. The Coopilot App V1 adds a fifth type of evidence, visualization, as common ground is materialized in the result screen of the App. We hypothesized that this way of measuring the level of common ground provides great accuracy, especially when compared to conversational cues with or without the Coopilot Cards. Our motivation to provide material support to measure and visualize the level of common ground builds on the assumption that it would allow to trigger repair discussions if there happen to be common ground breakdowns, which in turn would lead to effective coordination. This is particularly important in cross-boundary teams who experience syntactic and semantic boundaries, which represent obstacles to the establishment of common ground, and consequently, to effective coordination.

In the original paper related in this first part, we had not evaluated the validity and usefulness of the App, as it was presented as a proof-of-concept for the materialization of common ground –

the first ever tool to provide this function to our knowledge. Hereafter, I will relate the second part of the study, during which I undertook two rounds of evaluation.

1.2 Part 2: Evaluating the Coopilot App V1 and designing the V2

In this second part, I will present two rounds of evaluation I performed after the publication of the paper above. I will structure the presentation around these two rounds. I will describe the methodology and the research settings of the evaluation of the Coopilot App V1. I will then relate the results of this evaluation round. These results underlined the need to improve the functionality of the application, especially with guidance on how to interpret the results of the votes and what remedial actions to undertake. Therefore, we designed a second version of the Coopilot App. I will describe this new version and the additional functions we incorporated to facilitate the measurement of common ground: a numerical measure of the level of common ground (the CPI), and the conversational guide to trigger repair discussions. I will then relate the evaluation of this second application. Finally, I will synthesize the two parts of Study 1 and outline its main contributions to cross-boundary coordination challenges.

1.2.1 Methodology for the evaluation of the Coopilot App V1

1.2.1.1 Research method

The evaluation of the Coopilot App V1 calls for a qualitative and exploratory approach as no study had been done before on how to measure the level of common ground, this being the first attempt. Qualitative data is particularly well-suited to analyze complex social processes and phenomena for which we have little knowledge (Eisenhardt and Graebner 2007). Moreover, as noted by Walsham (1995), interview is a good research strategy as it allows the researched to "access the interpretations that participants have regarding the actions and events which have or are taking place, and the views and aspirations of themselves and other participants." (p.78). Therefore, this study consists of four cases in which I conducted six semi-structured interviews with their project leads (Table 10). The goal of the interviews was to understand their issues and have feedback on Coopilot, how they used the app, whether it supported the measurement of common ground, and how it supported them regarding their coordination challenges. The first part of the interviews was dedicated to learning about the context of the use of Coopilot, such as the characteristics of the project, the team setting, and the main challenges the teams were facing. In the second part of the interviews, the project leads were asked to describe and explain the situated practices and uses of the Coopilot App. The interviews were held over the phone and they usually lasted around 1h and were followed by informal ad hoc discussions.

Table 10 - Case descriptions for Study 1

Case	TRANS	WEB	POLITIS	NGO
Organization	Public transportation company in Switzerland with +1000 employees.	Online shopping company in Switzerland with +200 employees.	Canton administration in Switzerland with +15000 employees.	Health NGO headquartered in Switzerland with +30000 employees.
Project	Goal: developing software and algorithms to count the number of passengers hopping on and out of buses. Phase: planning. Duration: 24 months.	Goal: implement a drive-in station for customers to purchase online and pick-up at the station. Phase: execution. Duration: 13 months.	Goal: organization-wide software development program involving multiple departments. Phase: conception. Duration: Initially set for 2 years, cancelled after using Coopilot App.	Goal: implement an organization-wide human resources database Phase: planning Duration: 2 years.
Main project-related issues	Time constraints; managing interdependencies between tasks and related projects; project documents are not shared and accessed by participants.	Difficult to estimate work load and define joint objectives; resources are not available when needed.	Lack of governance; purpose of the project not shared by all participants.	High level of uncertainty; time management and priorities; coordination issues.
Team	8 participants; 5 focusing on the algorithms, 3 on the data management part.	5 IT participants; 2 external suppliers.	66 participants from multiple departments. Project lead in the IS department.	4 participants
Informants	1 introductory workshop with the project lead, 2 semi-structured interviews with the project lead.	1 introductory workshop with the project lead, 2 semi-structured interviews with the project lead.	1 introductory workshop with the program lead, 1 interview with the program lead.	1 semi-structured interview with the project lead.

1.2.1.2 Research setting

The first case is a team of eight participants working for a public transportation company on a 24-month long software development project. The participants were split into two functions, one focusing on the development of algorithms, one for managing the data entries and the database. The main issues that the team was facing and for which we have been reached out are (1) a difficulty to coordinate due to their time constraints, the intense interdependencies between tasks and other related projects, and (2) an inefficient management of knowledge, as some important documents were not read and shared by all team members.

The second case is a team of 7 participants, 5 of which are IT staff from an online shopping company, and 2 are from external supplier companies. The goal of this team was to develop a pilot for a drive-in in which customers could collect their orders made online, so that they do not have to wait extra days for delivery. The main issues that this team was facing are a difficulty to estimate the work load, plan the work accordingly, define the joint objectives and tasks to do, and have access to resources when needed.

The third case consisted of a large software development within the IS department of a Swiss Canton. This represented the largest project among the four cases as it involved around 70 participants from multiple departments. It was also different in its nature as it arouse from a popular decision and had to be approved and sponsored by the responsible politicians. The main challenges here included the lack of governance and understanding due to the number of participants involved. The project lead sensed that participants held different views and had divergent conceptualizations of the project.

The fourth case consisted of the development of an organization-wide human resources database for a large non-governmental organization (NGO) headquartered in Switzerland. The team undertaking this project was made of four members, including the project lead, and sometimes the weekly team meetings were joined by three additional members. The main issues that motivated the project lead to use Coopilot were related to the high uncertainty of the project. The team faced considerable time constraints and had to define and manage their priorities. As they were in a phase where they had to ideate due to the novelty of the project, the team produced an extensive amount of information during the meetings. The Coopilot App was thus regarded as potentially helping avoid communication and coordination breakdowns. This case was also part of the study by Mastrogiacomo et al. (2014). Also, this case is the only one that does not represent a cross-boundary team as members are within the same function and organization, compared to the other cases that involve participants either across functions or organizations.

1.2.2 Results of the evaluation of the Coopilot App V1

The interviews revealed various interesting insights, some confirming our intuition, some being unexpected. Firstly, the interviews confirmed our hypothesis that the Coopilot App is helpful in assessing the level of common ground and supporting cross-boundary coordination. As related by the project lead in the TRANS case, the application showed some divergences in the participants' understanding, especially regarding the joint commitments. The vote triggered "*the discussion on the dependencies between everyone. I had put in place a file that concentrated all the information about the planning, what everyone had to do, and the dependencies with other projects TRANS was related to. The team had not seen the need to refer to these documents and the vote helped me make them aware of the need to check them more often*" (all the quotes in this section are translated from French). After this discussion, the team members regularly accessed the project documents. The project lead also said that in a later meeting, the team members discussed the joint commitments as there was a latent feeling that some people were committed than others. The App also triggered a discussion on joint resources and joint risks, which the team had not necessarily thought of before. This allowed them to "*state the situation [they] were in and deduce actions for the next times to address the lack of resources and the potential risks*" in order to decrease the potential of the emergence of coordination surprises. In the WEB case, the Coopilot App triggered a discussion regarding the joint risks of having the sponsor leave the organization. This raised questions on the joint resources and how the team could develop contingencies and rearrange their commitments and resources in case the sponsor was to leave. This discussion was held with the five participants within the organization, without the two external suppliers. The informant speculated that measuring the level of common ground helped them develop contingencies that were understood by all and prevent potential future coordination surprises.

The interviews also revealed some unexpected insights, especially for the POLITIS and NGO cases. In the POLITIS case, the Coopilot App vote was used during a meeting with all the participants of the program. The program lead sensed that there was a lot of confusion around the project and perhaps some miscommunication on the program, which he thought created some lack of commitment and support for the project. He thus launched a vote with all participants and the results confirmed his impression (Figure 10). The way he handled the results of the vote was a surprise. The vote gave him material proof of his intuitions and feelings about the situation. This gave him stronger evidence that could back up his willingness to cancel the program. He negotiated with the sponsors of the program that the program be stopped given that there is no common ground and that repairing the misunderstandings would require too much effort. This case suggests that the use of the Coopilot App is not only useful to acknowledge and repair misunderstandings, but that when these discrepancies are too great to handle, cancelling the joint activity may be a strategy in itself.

The other finding that we did not expect concerns the NGO case. As the team is small, the project lead considered that the App is "*no more valuable than personally, directly asking those in the meeting the same questions that are on Coopilot*." The idea behind Coopilot seemed interesting to her but there seems to be no need in small teams. Therefore, her approach rather consisted of "*asking the questions instead of using the Coopilot App, at the end of each topic from time to time and at the end of the meeting, like: Have you understood? Do you need any clarifications? What are the risks that you see? Do you see what you have to do? Do you think you* *have the means to do that?*'. She thus preferred to ask the questions related to the four requirements in Coopilot, rather than using the application. According to her, the principles behind the application (i.e. the conceptual model) are easily understood and internalized without the need to use the application. She related that asking questions orally is seen as more expeditious and easier strategy than using the application which would be regarded as an interruption to the discussion.

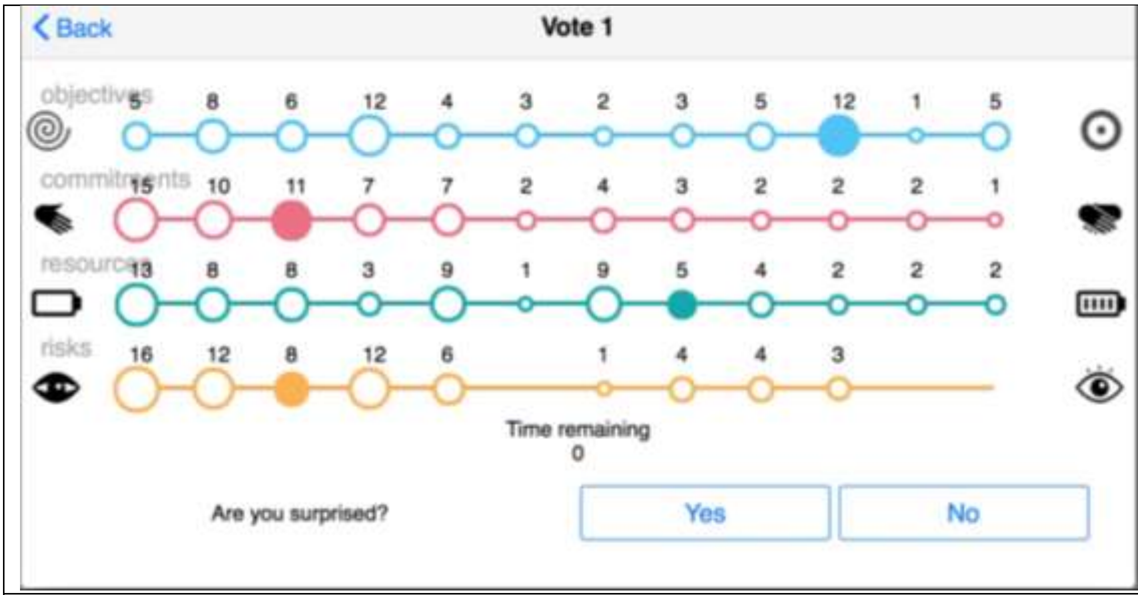

Figure 10 - Coopilot vote in the POLITIS case

In general, all four informants considered that there were usability issues. Their main concerns related to the readability of the results screen and how to interpret the distribution of the votes. Other comments included that the sliders on the voting screens didn't respond well, and that the discussions after the vote should be facilitated. The initiators of the votes were left with their own judgment on how to start the repair discussions. There were also technical issues which I will not detail here. But all these reasons prompted the need to develop the second version of the Coopilot App.

1.2.3 Description of the Coopilot App V2

The second version of the Coopilot App was designed with the help of students in graphic design at écal (Ecole cantonale d'art de Lausanne) and two software engineers from Olympe, a startup that specializes in making software development automatic and easy even for novices. The visual identity of the application was completely modified. The voting screens (Figure 11) were now separated for each variable compared to the first version (Figure 8) on which all sliders were on one screen. We did this to improve the usability for voting. In the new version, the user is presented with two areas representing the two extremes for each variable. For example, the two areas for joint objectives are “confused” or “clear”. The user then could swipe left or right to make the corresponding area greater than the other. Text boxes were added and updated automatically as the areas were moved so that the participants could have a definition of where there vote stands. For example, when the two areas are equal, that means that the vote is neutral, whereas for joint commitments, if the implicit area is increased to three fourths, then that means that the commitments are “somewhat implicit”.

Once the user finishes voting, he is shown with the results screen (Figure 12). We have decided to do a complete reworking of how votes are displayed in order to make the evaluation and mirroring of the level of common ground easier and more straightforward. We first changed the horizontal lines of the previous version to a histogram in order to make the count of votes more intelligible. The previous application displayed the count of votes on the same point by making the related circles larger (Figure 9). Based on the interviews, we noticed it took users much effort and time to deduct the distribution of the votes, especially when several participants were placing their cursors on the same point. In the new application, the height of the bars is proportional to the number of votes on that point (Figure 12). Emphasis is additionally put on the mode (where there are most votes) which is colored with a lighter shade than the other scales. This suggests where the majority of voters lie. Users can swipe right to make the scale appear. We kept the anonymous aggregation and display of the votes as several users had mentioned that it was a crucial feature for them to feel safe enough to state their perceptions.

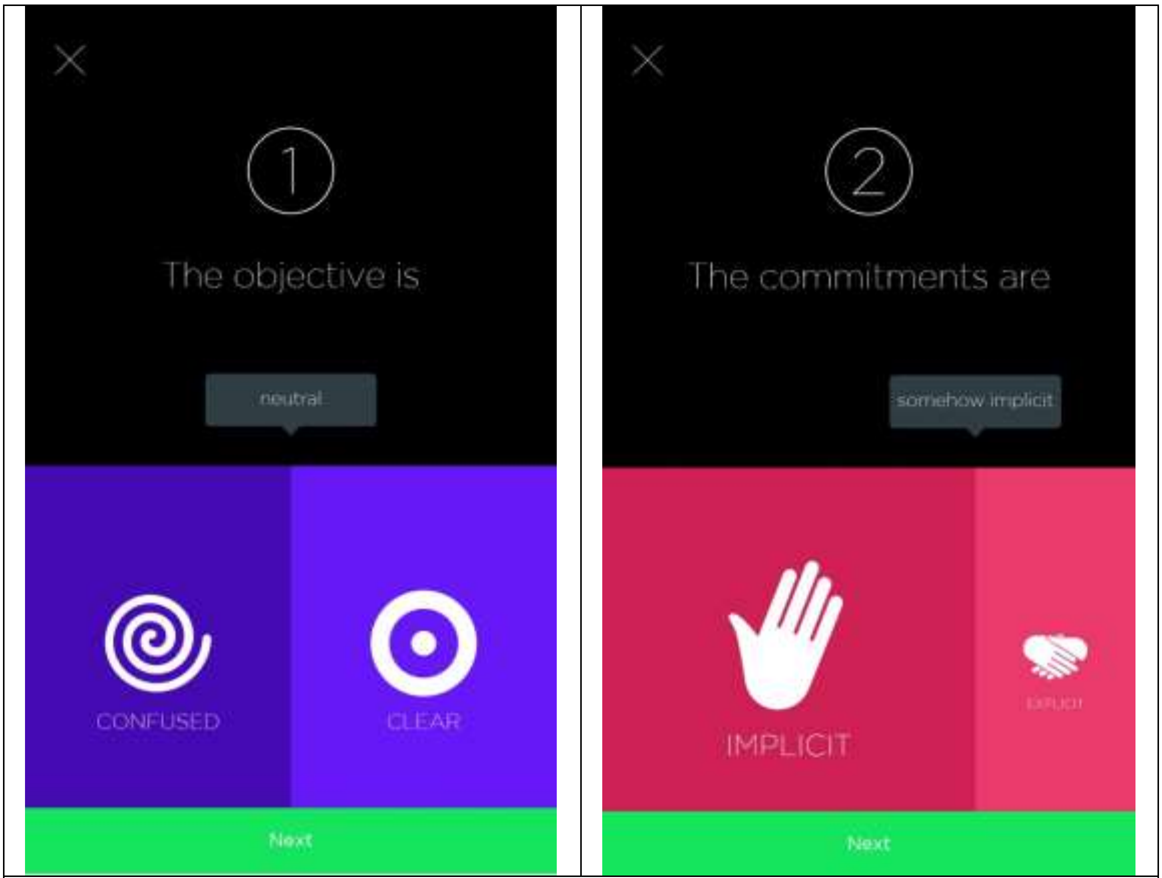

Figure 11 - Voting screens in the Coopilot App V2

Users can swipe right once again to find a conversational guide that includes questions they can ask themselves or the team to trigger a discussion for the domains where there is low common ground (Figure 13). These questions are drawn from Mastrogiacomo et al. (2014). At the top part of the screen, we incorporated an index, called the Coordination Potential Index (CPI), for which I developed an algorithm that computes the level of common ground within the team compares it to a desired level of common ground. It computes the extent to which the votes are scattered and close to the maximum using standard deviations and averages respectively.

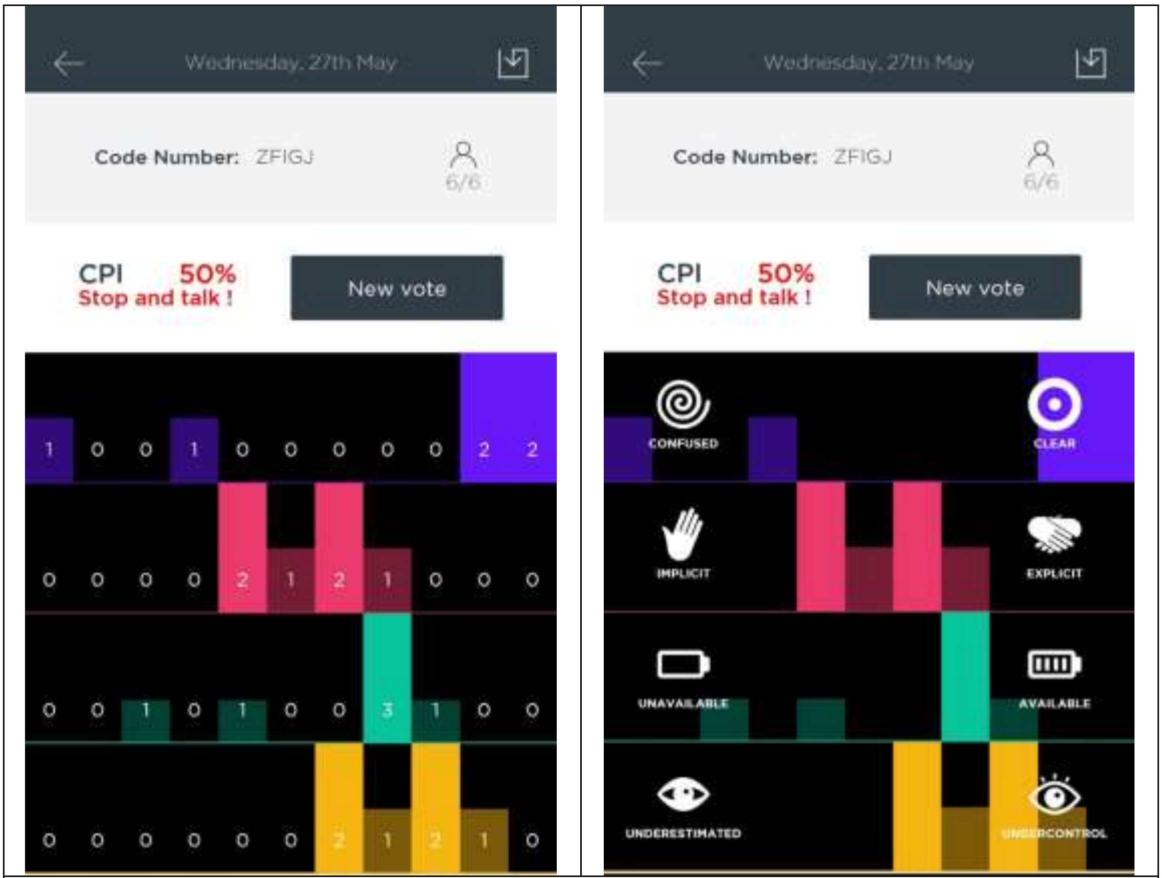

Figure 12 - Result screen in the Coopilot App v2 (with vote count and scale)

The more the votes converge toward the right (or the 10th point), the closer to 100% the value of the index. This means that a desired level of coordination is represented by the convergence of votes toward the right. I also added ranges for the values of the CPI based on hundreds of simulations and the experience we have had with clients on the previous application. When the value of the CPI ranges from 0% to 53% we consider that the level of coordination is too low and suggest that the team stops and talks (Figure 4a and 4b). From 54% to 74% we consider that the level of coordination is medium and that the team should pay attention to the required variables. From 75% to 100% we consider that coordination is effective enough for the team to keep going. The CPI proves to be important for two reasons. First, it enhances the evaluation of common ground as it provides an easily interpreted numerical value that complements the distribution of the votes. In Clark's terms (1996, p.98) it provides greater evidence of quality as a numbers are less subject to interpretation than distributions. Second, it compares the current and desired levels of coordination and accompanies users in the remedial actions and discussions they should undertake. (e.g. “stop and talk”). The CPI is in this sense both a descriptive construct as it mirrors the level of coordination and a prescriptive construct by guiding the remedial actions.

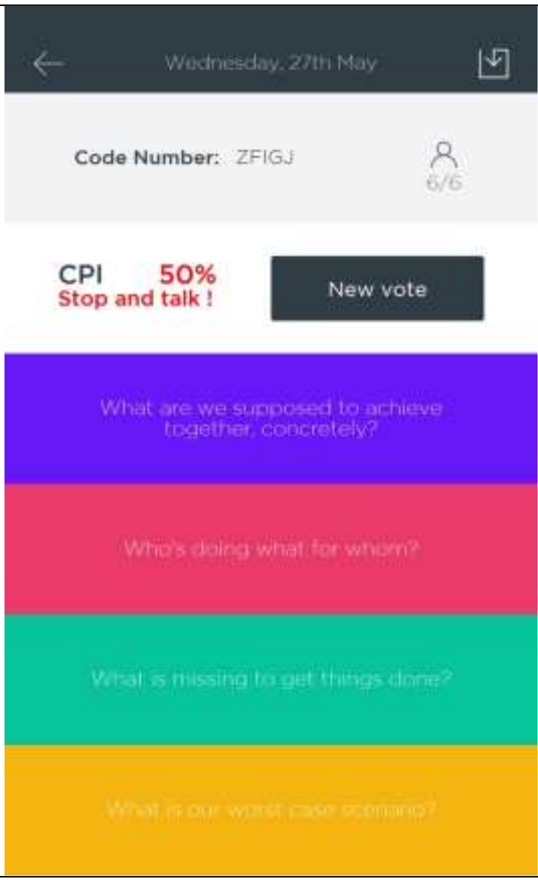

Figure 13 - Conversational guide in Coopilot App v2

1.2.4 Methodology for the evaluation of the Coopilot App V2

1.2.4.1 Research setting

We evaluated the new version with thirteen groups of four to five undergraduate students enrolled in our project management course, for which they use a project management simulation game over the course of four weeks (Bonazzi et al. 2012). The course is given to third-year Bachelor students in management. In the simulation game, students had to manage a project for developing new functionalities for industrial equipment in a company that is specialized in the production and assistance.

I do concur that students are not cross-boundary teams, but this setting was more motivated by opportunistic concerns. In fact, as the utility and validity of the Coopilot App was demonstrated with the previous cases, the purpose of this evaluation was rather to evaluate the new interfaces and the ease-of-use of the version. It was thus based on usability concerns which are rather stable across contexts.

1.2.4.2 Research method

I first tested the CPI and its three different ranges ("Keep going", "Attention needed", and "Stop and talk"). I performed an ex ante artificial evaluation, i.e. before incorporating the CPI in the application (Pries-Heje et al. 2008). I ran simulations as a testing approach (Hevner et al. 2004; Peffers et al. 2007) to produce the samples I needed to perform naturalistic evaluation (Carlsson 2010) of the accuracy and validity of the CPI based on our experience with clients. I randomized 10'000 votes for the four variables for teams with a size of 5, 10, 15, and 50. Together with two practitioners that had been familiar with Coordinator, we drew twenty different simulations for the four different sizes of teams (i.e. we checked 60 simulated votes). We added to these 80 simulations, 12 cases we had encountered with clients. We tested four different formulas for the CPI varying in the weight they gave to the averages and standard deviations. We chose the formula that best described the state of common ground according to our perceptions and long experience. Once the formula was chosen, we defined the three ranges by going through the 10'000 simulations and selecting the respective thresholds.

I was also interested in evaluating the usability of the second version of the App and the actions the voting screen triggered to assess whether teams engaged in repairing the potential common ground breakdowns. Regarding the usability of the tool, as we were more concerned with knowing how the changes to the application influenced the usability of the tool – compared to the exploratory inquiry we undertook for the first version – we performed a quantitative study through questionnaires. We handed out a questionnaire to the thirteen teams of undergraduate students after using the application twice, once at the beginning of the session and once at the closing, 2 hours after approximately. The questionnaire included two quantitative questions on a 5-point Likert scale (1 being "not at all", 3 "neutral", and 5 "totally): (1) compared to other applications you regularly use, do you consider the Coopilot App to be easier to use? (2) do you consider the use of Coopilot App to require too much time and effort? This second question was motivated by the remarks by the project lead in the NGO case as she considered the application to disrupt the flow of the conversations. To evaluate the reactions to the display of the level of common ground, we included two open-ended questions in the questionnaire: (1) What did the Coopilot App provoke in your team when it showed discrepancies between the votes of participants? (2) What did the Coopilot App provoke in your team when it showed no discrepancies between the votes of participants?

1.2.5 Results of the evaluation of the Coopilot App V2

The results from the answers of 60 students to the two questions regarding the usability of the new version suggest that the application was considered easy to use (average of 4.00 with a standard deviation of 1.04). The application was also considered as requiring little effort and time (average of 1.93 with a standard deviation of 1.05). We complemented these questions with one open-ended questions asking students whether they had any comments on the usability of the application. Out of 60 respondents, only 4 reported suggestions for improvement, and they all related to the intelligibility of the result screen.

The results for the reactions when the App displayed common ground breakdowns (i.e. low level of common ground) suggest that the Coopilot App V2 triggered remedial actions in the form of repair discussions. Out of the 60 answers to the first question, 2 were left blank, 29 reported that the Coopilot App did not provoke anything, and 29 reported that the Coopilot App triggered discussions. The answers of the respondents that reported an impact are all displayed in Appendix A. Among those reporting that it did have an impact one person reported that "it created astonishment. We tried to share our own perceptions to understand where the discrepancies came from [...]" (Team 3, respondent 3), another said that "[they] tried to understand the differences and reconsidered the decisions [they had made] and their causes" (Team 5, respondent 2).

The results for the reactions when the Coopilot App V2 showed no perception gaps between team members (i.e. a high level of common ground) suggest that it led to positive feelings of achievement. The response rate to this question was 55 answers out of 60 respondents. The respondents that answered the question related that in general, the lack of discrepancies either triggered nothing (N=13) or produced positive feelings of cohesion, satisfaction, assurance, enthusiasm, and confirmation (N=42). For example, one student said that it brought them "enthusiasm because we knew where we were going" (Team 7, student 2). Another related: "we were satisfied to concretely see that the group was working well. In fact, we did not consider talking about aspects that were going well. This only confirmed what we guessed" (Team 3, respondent 3). All the answers are displayed in Appendix B.

In general, these results suggest that the new version of the Coopilot App is easier to use and does what it is intended to do, i.e. measure the level of common ground and trigger repair discussions when there is a lack of common ground to augment the level of common ground. Also, when the application displayed no discrepancies between team members, it either triggered no special reaction or positive feelings of accomplishment and cohesion, but no concrete remedial actions. As this version proved stable enough, we decided to keep the second version of Coopilot App.

1.2.6 Theorizing the design for measuring the level of common ground

Given that the two rounds of evaluation confirmed the validity of the two versions of the Coopilot App to provide a measure of the level of common ground and support teams in augmenting their common ground through the conversational guide, I have developed three design heuristics that allow to measure the level of common ground and augment it (Table 11). I have formalized the knowledge acquired from this study as design heuristics rather than design principles. The heuristics, compared to design principles, are more generic and founded on less validation evidence (Gregory and Muntermann 2014). They are formalized at a higher level of granularity and are more extensively based on the implicit knowledge that is acquired by the design science researcher rather than on explicit validation. On the other side, they are valuable as they allow future designers to reach a successful solution more easily and rapidly for a problem that is within the same class of problems (Fu et al. 2016). In both cases, however, both forms allow designers to formalize prescriptive knowledge (Kuechler and Vaishnavi 2012).

Therefore, I have captured three design heuristics that should help future design science researchers develop tools for evaluating and augmenting common ground more effectively. The first two design heuristics presented hereafter relate to the evaluation of common ground while the third relates to the augmentation of common ground. In that sense, the three heuristics cover the main concerns that were highlighted in the literature review and that were implicit yet crucial in my design experience both when moving from the Coopilot Cards in Mastrogiacomo et al. (2014) to the Coopilot App V1, and moving from the first to the second version of the Coopilot App. The knowledge that was acquired in the design process but did not appear to be essential is therefore not formalized. For example, one question arose in the design of the second version of the app was whether to display the domains for votes on the same screen (Figure 8, p. 110) or display them separately (Figure 11, p. 119). However, this issue did not appear as crucial for the evaluation and augmentation of common ground and was therefore ruled out. In general, I have voluntarily formalized them in a generic way so that they can be applicable to other contexts in which designers wish to evaluate and augment common ground.

1.2.6.1 Design heuristic 1: define the content of common ground

The first design principle is inspired by Clark's conceptualization of the requirements for common ground and Mastrogiacomo and colleagues' (2014) conclusion that not all common ground is relevant for cross-boundary team coordination. They defined and delimited the relevant content that individuals should agree on and understand similarly to coordinate effectively. This allows me to formulate the first design principle that I draw from this study: *DH 1*

– *In order for cross-boundary team members to create shared understanding for coordination, define the content of the shared understanding they must have to coordinate for their specific joint activity.* In the Coopilot App, we defined the content that is necessary for the specific activity of coordinating, i.e. joint objectives, joint commitments, joint resources, and joint risks. Defining the content of shared understanding directs and frames the team's attention and conversations. It provides a shared vocabulary for the conversations that cross-boundary team members hold for coordinating.

Table 11 - Design heuristics for cross-boundary team coordination

Design heuristic	Illustration in Coopilot App V1 and V2
DH1: In order for cross-boundary team members to create shared understanding for coordination, define the content of the shared understanding they must have to coordinate for their specific joint activity.	Content defined with joint objectives, joint commitments, joint resources, and joint risks.
DH2: In order for cross-boundary team members to have evidence of their (mis)understanding, allow them to state their individual perceptions of understanding through the artifact.	Team members log into a team session and vote on the four requirements individually.
DH3: In order for users to follow a certain set of specific behaviors directed toward coordinating effectively, include a set of remedial actions in the artifact to guide the users' behaviors.	Includes a conversational guide with questions for each of the four requirements that teams can use to trigger a repair discussion.

This addresses the concern with syntactic boundaries that was raised by Carlile (2002). Most (if not all) literature on boundary objects has usually regarded the many functions that these objects can perform without delineating the content of these objects. They often focused on the dynamics and cognitive, as well as discursive, processes that these objects triggered, without establishing the required content that these objects should embody (Scarbrough et al. 2015). Seidel and O'Mahony (2014) suggested that objects should help teams establish a common repertoire and the requirements for their activity to allow for effective coordination. This study concurs with their findings as the first design heuristic typically addresses this need to have a common vocabulary or repertoire on which to rely for interactions.

1.2.6.2 **Design heuristic 2**: Materialize individuals' perceptions of understanding

Clark's second concept, i.e. evidence of understanding during conversations, informs the second design heuristic: *DH 2 – In order for cross-boundary team members to have evidence of their (mis)understanding, allow them to state their individual perceptions of understanding through the artifact.* In both versions of the application, we allowed for individuals to directly state their perceptions of understanding, rather than have the project lead evaluate everyone's perception based on the Coopilot Cards as was done by Mastrogiacomo et al. (2014). Instead of founding the need for a repair discussion on a feeling by the project lead, participants who use the Coopilot can all *see* the need for further discussion. This provides great evidence of understanding or misunderstanding, as individuals can visualize everyone perceptions.

With this, I add to Clark's four types of evidence of understanding that such evidence can rely on visualization on top of the four conversational signals he identified. This is especially relevant in team settings where the conversation does not involve as much turn taking by all members as in dyads. In fact, in teams some members might remain silent or participate only to a little extent to the conversation. Therefore, the four types of evidence of understanding might get tangled up in the layers of team interactions at the level of a whole conversation or throughout multiple conversations. It is thus difficult for team members to find cues of the understanding of all members as they would need to attend to everyone and everyone would have to vocally display their understanding.

Our study suggests that individuals must rely on their overall perceptions of understanding. Our study is thus in line with the findings by Cherubini et al. (2005) that grouding is not sufficient to create common ground between individuals at the level of a whole conversation. In this study, we considered that one way to go about it is to materialize these perceptions. The fact that the Coopilot App asks all team members to state their understanding helps provide solid evidence of understanding of all parties involved. This supporting function might provide the missing link between the micro-level linguistic stream on coordination and the macro-level analyses of collaborative objects.

Also, the comparison of all cases suggests that the number of participants above which evaluating shared cognition within a team might require some material support on top of conversational cues lies around 5. In the NGO case, the team was constituted with four members and the use of the application to evaluate shared cognition was not deemed necessary as they could more easily rely on direct conversations. The other cases involved larger teams and considered that the application was useful in evaluating shared cognition. However, this threshold has not been evaluated against and might require some further investigation, but I do not cover it in this dissertation.

This design heuristic also addresses Nicolini and colleagues' (2012) concern with the ability for boundary objects to resolve as well as create misunderstandings. Asking all participants to state their perceptions of understanding displays such misunderstandings explicitly. In fact, most research has relied on the implicit ability of boundary objects to create or dissolve shared cognition, without investigating the characteristics of what it is that creates shared understanding. We contribute to this inquiry by suggesting that research on boundary objects should further investigate the role of asking participants to state their understanding through boundary objects or technology. Our study suggests that voting systems provide a great basis from which to start this investigation.

1.2.6.3 Design heuristic 3: Guide the remedial actions for common ground breakdowns

The third principle was more informed by the findings and the need for interventions that are specific contrary to the generic nature of guided reflexivity as highlighted in Chapter 2. The evaluations of both versions suggested that team members automatically engage in the repairing of the perception gaps (low common ground) if the application shows scattered votes. They tend not to leave the situation as is without doing anything, they rather undertake a range of actions. I had not expected, however, that the cancellation of the project would be one of these actions. As the intended use of the Coopilot App was to help individuals repair misunderstandings, I was rather surprised by this.

In the second version we included a conversational guide that includes questions that participants can use to trigger repair discussions, in order to make the role of the tool explicit. Since tools and objects can have different uses depending on the intentions of the user, it is important to provide a guide for the remedial actions that the design science researcher should intends for their artifact. Therefore, the third principle can be formulated as such: *DH3 – In order for users to follow a certain set of specific behaviors directed toward coordinating effectively, include a set of remedial actions in the artifact to guide the users' behaviors*. This principle follows the line of arguments made my researchers on affordances, i.e. the range of actions that are made possible by a certain technology (e.g. Faraj and Azad 2012; Niederrer 2013; Zammuto et al. 2007). I should make explicit that I do not consider the cancellation of the project as a strategy to avoid, as it might have been a beneficial decision in the POLITIS context. This case simply informed us on the different uses of the application that can be made and that should better be framed and constrained.

1.2.6.4 Further validation

The insights from this study are to be considered as preliminary. The evaluation of the Coopilot App for both versions should be refined and tested in additional cases. Given the novel approach I applied to coordination in cross-boundary teams, my main motivation was to develop initial insights on the Coopilot conceptual model and how it could be instantiated materially to allow for the management of common ground

In that sense, the usability of the Coopilot App could gain in quality if it were evaluated at a finer detail of analysis. In this study, the evaluation of the usability concerned the overall appreciation of users and their understanding of the main functions. Future analysis of the elements of the App in isolation is needed, mainly regarding the swiping function of the vote through which the user state whether they understand the four requirements, the understanding of the distribution of the votes with the visual iconography (from left to right), and the iconography in general.

Moreover, the evaluation could be complemented with observation data to analyze the long-term dynamics of the use of the App and how it relates to other tools that cross-boundary teams might use. The interrelation or network of tools might also play a role in the efficiency of the tool for coordination. For example, if the App was used with other project management tools such as work breakdown structures and schedules, the joint commitments might be more deeply anchored in the team's common ground, compared to a cross-boundary team that would mainly rely on the App.

Both these rounds of evaluation could strengthen the evidence for the three design heuristics. These should also be evaluated against other tools that allow cross-boundary teams to establish and augment common ground, or should be instantiated into an additional artifact that is developed for managing common ground on other domains. This evaluation should go beyond the validity and usefulness of the solution as suggested by Gregor and Hevner (2013) – i.e. the Coopilot App – but also the usability, validity, and exhaustiveness of the design heuristics *per se*. Also, this cross-analysis will allow to test whether the design heuristics are applicable to other tools or specific to the Coopilot App. The principles have been abstracted at a high level that is not too specific to the application so that they can be applicable to other instantiations. However, their validity and relevance for measuring and augmenting common ground through different means still needs to be confirmed.

1.3 Conclusion and contributions of the two parts of Study 1

The aim of this study was to equip cross-boundary team members with a means to manage their coordination challenges. As outlined in the literature review in Chapter 2, the challenge is to develop shared cognition so that members can have a shared understanding of their situation and predict their peers' contributions in order to coordinate their own contributions accordingly (Cannon-Bowers and Salas 2003; Espinosa et al. 2009). This is particularly challenging in cross-boundary teams which may have different vocabularies and interpretations across functions, i.e. the syntactic and semantic boundaries identified by Carlile (2002; 2004). Given that both objects and language can help create shared cognition, we undertook this study to investigate how objects can support team conversations to create shared cognition in order to allow cross-boundary teams to coordinate effectively. As noted by Nicolini et al. (2012), objects can resolve misunderstandings as well as create them and little is known on what characteristics of objects support the development of shared cognition. Therefore, this study was dedicated to integrating the streams of research on coordination through shared cognition, language, and objects. The research question that emerged is the following: *How can we support cross-boundary teams in evaluating and augmenting their common ground to coordinate effectively?*

To answer this question, we adapted Clark's (1996) theory of joint activities between pairs of individuals to team settings in which there are more than two interacting parties. We specifically attended to his conceptualizations of, on the one hand, the requirements of common ground for coordination and, on the other hand, the evidence of understanding that individuals use to specify how they construe the conversation. The adaptation of his theory into the two versions of the Coopilot App allowed me to develop three design heuristics that design science researchers can rely on to help cross-boundary team members assess their common ground and repair misunderstandings in order to coordinate effectively.

With these design heuristics and the study in general, I sought to contribute the extensive literature on the coordination challenges that cross-boundary teams face. The design heuristics are a nascent design theory in the sense of Gregor and Hevner (2013) that could provide some ground for future research. These design heuristics address Nicolini and colleagues' (2012) concern with the fact that we do not know what makes collaborative objects more or less effective. The three design heuristics define what it is in collaborative objects that creates shared understanding rather than misunderstandings.

With this study, we provided the first tool – to our knowledge – to measure and materialize common ground in real time. This study also illustrates how different descriptive streams of research on the same phenomena (i.e. shared cognition, language, and collaborative objects) can be used as a foundation to create design knowledge through design science research. We thus illustrate van Aken's (2004) and Gregor and Jones' (2007) argument that prescriptive knowledge is much needed and important in organization and management research. The evaluations of the two versions of the Coopilot App have demonstrated that providing simple and rapid guidance can provide meaningful actionable support to practitioners. This study not only contributes to the prescriptive knowledge for coordination challenges, it has also revealed several insights for team coordination. In fact, I have shown how the design heuristics have provided some basis for extending Clark's theory. This study confirms the content of common ground for coordination through the Coopilot conceptual model and has added a fifth type of evidence of understanding to the four already identified by Clark. However, the inclination of individuals to repair common ground breakdowns and perception gaps was a rather unexpected finding which suggests that individuals are prone to trigger a discursive process when aware of their common ground. We have formalized these insights in a second theoretical study through a process model of team coordination that I will present in the remainder of this chapter.

2 Study 2: Process model of team coordination

In the study published as a research-in-progress paper in 2015 at the *Thirty Sixth International Conference on Information Systems (ICIS)* in Fort Worth (TX), we developed a theoretical process model of team coordination which emphasizes the role of conversation. The theoretical model was motivated by three reasons: (1) the findings related in the previous section, (2) the need to define a processual and actionable view of coordination as it is among the three main determinants of IS projects success along trust and knowledge integration (Dongus et al. 2015), and (3) the lack of relevant process models in the literature as all studies on team coordination used a variance approach. Our model is also based on the Coopilot conceptual model and Clark's theory. I will first outline the literature on coordination and language and then present the process model along with the propositions that need to be evaluated to validate the model.

2.1 Introduction: The variance approach in team coordination

There has been an extensive number of studies that address team coordination as outlined in the literature review in Chapter 2. These studies are mainly anchored in the mechanistic ontology laid out by Malone and Crowston (1990; 1994), which considers that certain coordination mechanisms prove more or less effective depending on the situation. That is, they use a variance approach, where the output or dependent variable (coordination effectiveness) varies according to an interdependent variable (coordination mechanism). There are three streams in this mechanistic view of team coordination: explicit, implicit, and integrative mechanisms.

The literature on explicit mechanisms suggests that the type of interdependencies between team members or their tasks acts as a moderator between the output (coordination) and the independent variable (coordination mechanism) (Crowston 1997; Thompson 1967). Some types of interdependencies are better suited for explicit coordination mechanisms. They are called explicit mechanisms because they are explicitly used for the purpose of coordinating. Put differently, their use is mainly and explicitly directed toward coordinating work. Classical coordination research discerns three main categories of explicit coordination mechanisms. The first category refers to the vertical coordination mechanisms, e.g. coordination through authorized entities such as project managers or steering committees (Andres and Zmud 2002; March and Simon 1958; Nidumolu 1995; 1996). The second category refers to horionzal coordination mechanisms, e.g. coordination through mutual adjustment or communication between team members (Thompson 1967) also called feedback processes (March and Simon 1958), or personal coordination (Van de Ven et al. 1976). Finally, the third category refers to task programming mechanisms in which aspects of the task are defined in advance, either through administrative coordination (Faraj and Sproull 2000), or schedules, plans and rules (Crowston 1997; Thompson 1967). Some coordination mechanisms can prove useful for a variety of contingencies (Andres and Zmud 2002; Nidumolu 1995; 1996). For instance, Espinosa et al. (2004) advance that team communication is an effective strategy for complex and intellectual tasks (e.g. ideation) in which the interdependencies between team members are strong and task interdependencies are rather uncertain. On the other hand, they note that team communication may be too costly and require too much effort for predictable and rather certain tasks (e.g. coding), for which stable coordination mechanisms such as plans and rules might be more efficient and effective.

Research on implicit coordination mechanisms has been interested in how individuals coordinate in dynamic, uncertain and complex contexts without using explicit mechanisms (Mohammed et al. 2010). These mechanisms are often considered in the form of cognitive mechanisms such as shared cognition, where individuals share the same understanding of the situation so that they can contribute to the activity in a coordinated manner. These mechanisms are implicit because they happen in the head of the participants without any tangible social or material existence, and they are used without a conscious effort by team members (Cannon-Bowers and Salas 2001; Klimoski and Mohammed 1994). Various notions have been used to describe these implicit cognitive mechanisms. In Chapter 2, we have already reviewed the literature on team mental models (e.g., Cannon-Bowers et al. 1993; Espinosa et al. 2002;

Klimoski and Mohammed 1994; Mathieu et al. 2000; Rouse et al. 1992; Yang et al. 2008; Yu and Petter 2014). Other similar cognitive constructs include transactive memory which describes the memory (or knowledge) that each individual embodies and the knowledge of who knows what so that participants can attend to others (Hsu et al. 2012; Lewis 2003; Liang et al. 1995; Nevo and Wand 2005; Oshri et al. 2008; Wegner 1987). Some scholars rely on mutual knowledge (Cramton 2001; Fussell and Krauss 1992; Kanawattanachai and Yoo 2007; Krauss and Fussell 1990) or collective mind (Crowston and Kammerer 1998; Weick and Roberts 1993). What these studies share is both their interest of the implicit cognitive mechanisms that team members use, and their variance analysis of such mechanisms. In fact, as related by Rico et al. (2008), implicit coordination effectiveness (dependent variable) depends on the sharedness and accuracy of team mental models (interdependent variable). These studies do not explain how such implicit coordination unfolds (or in best cases they cover it at a high-level by identifying moderators. These models consider that coordination is made of input-process-output (IPO), where they try to identify how the implicit coordination mechanisms act as a process toward the output of coordination.

The last stream has developed integrative coordination frameworks they account simultaneously for the role of implicit and explicit coordination mechanisms. They are motivated by the need to accumulate the scattered knowledge on coordination and develop a more holistic account of coordination (Espinosa et al. 2004; Okhuysen and Bechky 2009). They also argue that these mechanisms are interrelated and cannot be analyzed in isolation from one another. For example, Espinosa et al. (2004) suggest that explicit mechanisms both influence (e.g., by interacting or sharing documents) and are influenced by the existing level of implicit team cognition (e.g., members with shared knowledge may communicate less frequently and more efficiently). Okhuysen and Bechky (2009) share the same assumption. They consider that any effective coordination strategy making use of a variety of mechanisms, whether implicit or explicit, needs to fulfill three integrative conditions: accountability, predictability, and common understanding. These are considered the requirements that need to be met for team members to coordinate effectively. In agile software development, Strode et al. (2012) provided a theory for coordination which encompasses both explicit coordination (right thing, right place and right time) and implicit coordination (know why, know what, know what to do, and know who). However, they do not explain how the cognitive state of "knowing why" or "knowing who is doing what" lead to coordination. In general, these integrative studies also use a variance approach in that they define conditions that should be met (moderators) for coordination mechanisms to be effective. Or they consider that the overall dependent variable of coordination should integrate all independent variables of coordination mechanisms, whether explicit or implicit.

2.2 The need for a processual account of team coordination

Due to their structural nature and reliance on correlation, these three streams on coordination do not inform us on how coordination concretely happens. They do not explain the actions that team members perform to coordinate effectively, i.e. what to do and at what point in time. This literature suggests that participants draw from the ever-growing list of coordination mechanisms and attend to the different situations and configurations they are in to coordinate. However, such a conception of team coordination seems to create too much cognitive overload and effort as team members would need to dedicate a lot of conscious effort in implementing the coordination mechanisms, and this is assuming that all they would do is coordinate. Therefore, if we add other team processes and activities such as relationship management and creative tasks, the mechanistic view of coordination seems to impractical and cumbersome to apply in practice. As Newman and Robey (1992) illustrated when comparing variance with process approaches, team members are left with a "puzzle wherein the pieces can be identified but where the [practitioner] is left to his or her own resources to put the puzzle together." This lack of practicality is symptomatic in the way project management methodologies treat coordination as a crucial process to manage and attend to, but with little guidance and insights on how to concretely go about it (Dingsoyr et al. 2010; Strode and Huff 2014). Bruns (2013) also underlined the lack of practicality of implicit coordination mechanisms as she notes that while coordination mechanisms “confirm that coordination occurred, they cannot explain how it was accomplished [...], retrospective and snapshot measures do not provide rich enough data to sufficiently explain how the process unfolds” (p.63).

A process model for team coordination thus seems necessary to overcome this lack of practicality. A process approach to team coordination would not only define the dependent and independent variables, it would also unveil the actions and events that need to occur in coordination (Newman and Robey 1992). The difference between the variance and the process approaches to coordination are summarized in Table 12. I will now turn to the discursive process of team coordination which we designed.

Table 12 - Theoretical nature of coordination approaches		
Perspective	Variance models	Process models
Approach to coordination	Coordination is accomplished through different mechanisms depending on the nature of the joint activity, the context, and team and task configurations.	Coordination is viewed as a continuous process of events and actions to achieve a joint purpose.
Core premise	Coordination is contingent. Fit-alignment between coordination mechanisms and contingencies (e.g. task interdependencies).	Coordination is processual. Activities and events for reaching shared understanding and integrating team members' contributions.
Overarching question	Under what conditions does A or B significantly impact C (coordination)= Which coordination mechanisms are more effective in regard to the different contingencies (activity and team configuration)?	What activities and events are included in C (coordination)? What are the fundamental activities and events involved in team coordination?

2.3 Description of the process model of team coordination

A process approach to coordination can yield various process models, depending on the actions and events that we focus on. In this study, we decided to focus on the discursive process of coordination for two reasons. Firstly, we are interested in what happens when team members gather together during team meetings to coordinate and organize their past, present, and future contributions. Since team meetings are mainly a discursive activity, we decided to investigate what are the linguistic acts that team members need to perform for team coordination. Secondly, we wanted to attend to the lack of practicality of the current coordination models by developing a process model that focuses on the main linguistic activities and that is simple. We aim to avoid the cumbersome nature of most coordination models.

To develop our process model, we rely on Clark's (1996) theory on joint activities for three reasons: (1) it focuses on coordination in and through language, which is our main medium to coordinate (Tomasello 2009), (2) it identifies the fundamental activities for coordinating in and through conversation, and (3) it presents requirements that should be met for two or more people to coordinate on any type of joint activity. Consequently, his theory is a great source for the elaboration of the process (how) through which teams coordinate. The main constructs of our process model are derived from his theory.

The first concept concerns common ground. We use the Coopilot conceptual model which defines the content of common ground for team coordination: joint objectives, joint commitments, joint resources, and joint risks. This will allow us to determine the content of the conversations team members must have.

The second set of concepts is based on the main conversational activities (grounding and monitoring) individuals perform so that they can coordinate on the joint activity. Clark's (1996, p.195) concept of grounding provides great premises for the analysis of how teams coordinate. Grounding is the process through which two or more individuals establish a piece of information as part of their common ground. It relies on conversational contributions in that the speaker presents a contribution to the addressee(s) and the latter accept(s) the contribution. Both parties then engage in the process of ensuring that the contribution was construed correctly, mainly through the four types of evidence of understanding I have already outlined in Study 1: (1) assertions of understanding (saying "uh huh" or "I see"), (2) presuppositions of understanding (when the hearer takes up the speaker's contribution, she presupposes she has understood him well enough), (3) displays of understanding (the speaker can understand how the hearer construed his contribution when she answers and displays how she construed what the speaker said), and (4) exemplifications of understanding (the hearer can offer a paraphrase or repetition of what the speaker said, as well as gestures and facial expressions). If participants manage to establish some evidence of understanding, the information they are discussing is part of the individuals' common ground. Else, the misunderstanding can remain undetected, in which case the information is not part of their common ground. On the other hand, individuals can detect they do not have a consensus on the meaning and repair the misunderstanding. Here, individuals monitor the misunderstanding allowing them to make that information part of their part of common ground.

The last concept relates to performing the joint activity (doing one's part). Clark (1996, p. 203) explained that once individuals have grounded and monitored their knowledge on the joint purpose and their willingness and ability to cooperate, individuals do their part as agreed on closure. That is, they make their individual contributions toward the joint purpose (or project).

Our process model of coordinating in teams is depicted in Figure 14. An overview of our main constructs is summarized in Table 13. Our model depicts team coordination as a continuous and recursive process involving two main activities that team members perform: interacting (grounding, updating, and monitoring) and contributing (making individual contributions). Depending on the results of such activities, either their individual contributions are aligned (thus coordinate effectively) or their individual contributions are misaligned (they coordinate ineffectively). The process is continuous and recursive as it is triggered by the emergence of any new relevant information and as any contributions (either from effective or ineffective coordination) are a source of relevant information.

2.3.1 Grounding and Updating

The trigger of the model is the event of the emergence of a new piece of information relevant for coordination. A piece of information is considered relevant if it belongs to the four domains that constitute the requirements to coordination according to Mastrogiacomo et al. (2014). Hence, we only consider information related to the project. By definition, such information is automatically part of the required common ground (see [1] in Figure 14) as the latter contains all the correct knowledge regarding the four domains. However, new relevant information does not automatically add up to the team's actual common ground. According to Clark (1996), for a piece of information to be part of their actual common ground, teams first need to ground it (see [2;3] in Figure 14). That is, all team members should discuss the information together (mostly during meetings) and make sure that everyone has a correct understanding of it.

In addition, a piece of information that was once established as part of the team's common ground might become obsolete or forgotten over time. Here, teams can update the information to ensure that it is still in their common ground. We expect that team members can compare both states. That is, they have the ability to identify discrepancies in their actual common ground. Clark (1996, p.49) stipulates that individuals have the ability to notice that their common ground falls short of some information [4], even though some discrepancies can go unnoticed. Cherubini et al. (2005) suggest that even though individuals might have grounded all their utterances, this does not necessarily lead to common ground. The creation of common ground might thus need to be mediated by perspective-taking (Boland and Tenkasi 1995), awareness support (Nova et al. 2003), or tools that allow for the assessment of common ground such as the Coopilot App.

Proposition 1: Team members identify the required and actual states of common ground to compare them.

2.3.2 Coordinating Effectively: Making Aligned Individual Contributions

This comparison can lead to three different coordination processes. Should they be equal, we suggest team members have all the required knowledge to perform aligned individual contributions and thus coordinate effectively with each other [5;6]. In fact, by having the required common ground, all team members will know what to do, what to expect from others, what to do for them, and know that everyone is able to perform their contribution. They thus fulfill the requirements for a joint activity as defined by Clark (1996, p. 203).

Proposition 2: In teams whose actual state of common ground is equal to the required state, members will make aligned individual contributions (i.e .coordinate effectively).

Table 13 - Constructs of our process model		
Clark's concepts	**Constructs**	**Definition**
Common ground	Relevant Information	Any information that is related to the basic requirements for coordination (i.e. joint objectives, joint commitments, joint resources, joint risks) (Clark 1996; Mastrogiacomo et al. 2014).
	Required state of common ground	The state when each team member knows the joint objectives, joint commitments, joint resources, and joint risks of the joint purpose and knows that all the other team members they need to coordinate with know them as well. (Clark 1996; Mastrogiacomo et al. 2014)
	Actual state of common ground	The actual state of the team members' recursive knowledge on the basic requirements for coordination on a joint purpose (i.e. joint objectives, joint commitments, joint resources, joint risks) (Mastrogiacomo et al. 2014).
Grounding	Grounding and Updating	The conversational activity through which a team establishes a piece of information as part of their common ground. Information that is in a team's common ground might become obsolete or forgotten over time, in which case teams can update on the information.
Monitoring	Common ground shortage	Difference in terms of knowledge between the required and actual states of common ground (Clark 1996, p.49). Can either originate from missing information (Klein et al. 2005) or erroneous information (Mastrogiacomo et al. 2014).
	Monitoring	The conversational activity in which a team engages to correct a detected shortage between its state of common ground and the required one. Involves the detection and correction of the shortage. The outcome of monitoring leads to corrected common ground (Clark 1996, p.195).
Doing one's part	Making individual contributions	The individual actions made by team members that contribute to the joint purpose (or project) (Clark 1996, p. 203).
-	Coordinating effectively	The state of coordination when there are no common ground shortages. All team members have the required and correct recursive knowledge to make aligned contributions, thus act harmoniously.
-	Coordinating ineffectively	The state of coordination when there are common ground shortages. Members of the team make misaligned contributions based on missing or erroneous information, refraining them from acting harmoniously.

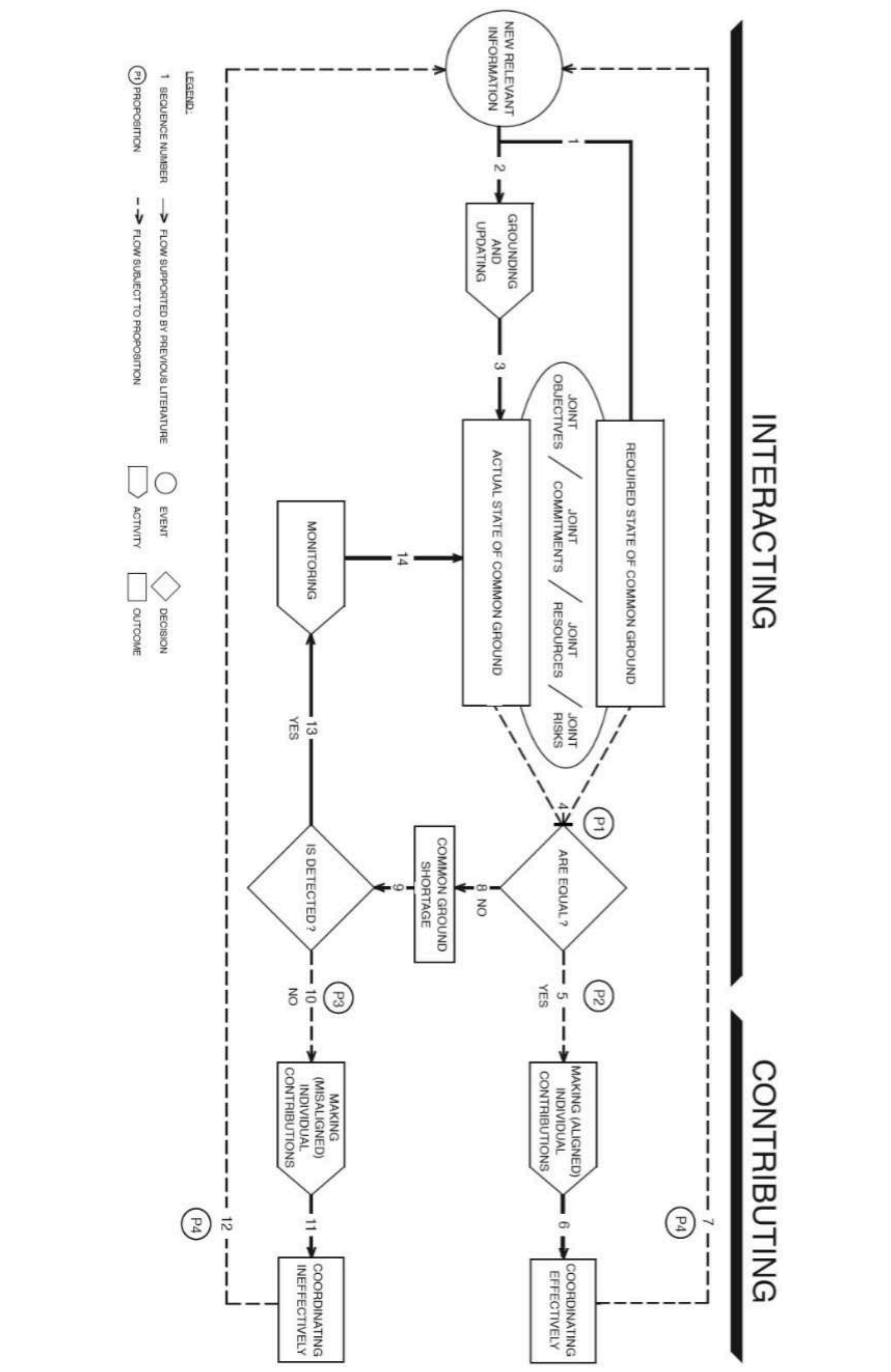

Figure 14 - Discursive process model of team coordination

2.3.3 Coordinating Ineffectively: Making Misaligned Individual Contributions

Conversely, both states (actual and required) can be different due to common ground shortages [8]. Common ground shortages can be of two natures. First, the team might miss some knowledge. Some team members might have individual knowledge that the others don't share or they may consider that others know about some information when in fact they do not. This leads to confusion about who knows what and is what Klein et al. (2005) refer to as "common ground breakdowns". Second, the team might have erroneous knowledge. In this case, team members may have conversed about relevant information but did not attach the same understanding to it and failed to detect the misunderstanding. This is what Clark (1996, p. 195) refers to as "undetected misconstruals" and Mastrogiacomo et al. (2014) as "perception gaps". Misunderstandings can go undetected at the conversation level (rather than at the utterance level) mainly due to the illusion of understanding or the false consensus phenomenon (Cherubini et al. 2005; Ross et al. 1977). If teams fail to detect the common ground shortages [9;10], each team member's actions will be based on erroneous or missing knowledge on the four requirements. If their knowledge is not accurate in one or several of the four requirements, we believe their individual contributions are misaligned and they coordinate ineffectively [10;11].

Proposition 3: Team members who do not detect common ground shortages make misaligned individual contributions (i.e. coordinate ineffectively).

2.3.4 From Effective to Ineffective Coordinating: Monitoring

Nevertheless, teams can detect the gap between the required state and the actual state of common ground, i.e common ground shortages. In that case, they will engage in monitoring the gap [13] either by completing missing information (ground missing information) (Klein et al. 2005, p.19) or repairing misunderstandings (corrected misconstruals) (Clark 1996, p.195). In fact, individuals who detect a discrepancy in their common ground immediately engage in correcting it (Clark 1996, p.49). The correct piece of information will then modify the team's actual state of common ground [14]. Both states are then again compared. Teams who detect such gaps can engage in this loop of comparing and monitoring [4-8-9-13-14] as long as their actual state of common ground does not equal the required state. Team members will then make individual contributions that are aligned and coordinate effectively.

2.3.5 Recursion of the Process: Continuous Interacting and Contributing

Moreover, we do not consider that coordinating is a definite endeavor, done once and for all. Team members should always have recursive knowledge on the right joint objectives, commitments, resources, and risks. But as time project passes, new information emerges (e.g. change of user expectations, reduced staff due to changed budget constraints). Team members then need to engage in the process again [7;12] to ground, update, and (potentially) monitor the new piece of information. In addition to information emerging from the team's environment, the team itself is a source of relevant information. More specifically, we consider that the individual contributions are a source of relevant information. As soon as either aligned or misaligned contributions are made, they need to be grounded [7;12] according to our process model as they impact the joint commitments (what participants expect from each other). On the one side, making aligned contributions informs the team that all members have understood and respect the right joint objectives, commitments, resources, and risks. On the other side, if the contributions that have been made are wrong or incomplete, it informs the team on what the member will be able to contribute in the future.

Proposition 4: When coordinating (whether effectively or ineffectively), team members ground and update their individual contributions and any other new relevant information.

2.4 Scope and boundaries

Our model focuses on coordination at the level of a team of individuals that share a joint purpose (or objective) and does not specify how coordination between different teams occurs (e.g. cross-department coordination). Also, the process model applies to activities for which individuals do not necessarily have stable and clear joint objectives, commitments, resources, and risks.

Moreover, our process model addresses only cooperative settings, that is team members have clear cooperative intentions and are committed to the joint purpose (or project) (Clark 1996, p.203). Our model does not frame how teams coordinate in uncooperative settings. I will cover this aspect in Chapter 5, when showing how the Coopilot conceptual model can be used to design a tool for the emergence of shared leadership and shared intentions, both being indicative of cooperative settings.

2.5 Roadmap for validating the model

To test our propositions and validate the model empirically, we must perform conversation analysis in order to account for the fundamental linguistic activities involved in coordination. As it has proven very difficult to record conversations of IS project team meetings, we will turn to the AMI Meeting Corpus, an open-source database of meeting recordings (Carletta et al. 2005; McCowan et al. 2005). The AMI Meeting Corpus was developed with the initial aim of coping with the methodological problem of analyzing a great enough range of corpuses occurring in the same set of conditions, so that results can easily be compared and generalized. The corpus is made of 100 hours of meeting recordings comprising naturally occurring and scenario-based meetings. The latter consist of four-member teams holding four meetings in one day with the goal of designing a new remote. Each member is assigned a different role: project manager, industrial designer, user interface designer, and marketing expert. All members are provided with role-specific information by a virtual coach during their individual times between meetings. For example, after the kick-off, the marketing expert is provided with a market report while the industrial designer is provided with a list of the basic components of a remote and their layout.

This corpus proves very valuable for several reasons. Firstly, it contains recordings of 25x4 meetings (4 meetings for 25 teams) within the scenario-based projects. Therefore, it allows for greater rigor in the qualitative analysis as cross-case and within-case analysis can be performed extensively. Secondly, the four members are provided with different individual knowledge which proves particularly interesting for our analysis of how teams coordinate around common ground.

Moreover, the corpus has already been transcribed. Finally, the corpus has been used in hundreds of studies thus far. Even though they are mostly in the fields of signal processing, language analysis, and computational language, this large set of studies confirms the robustness and the rigor of the dataset. Our unit of analysis will be the exchange, focusing on the broader scope of chunks of sentences – relating to one piece of information on the four requirements for common ground – rather than utterances (Cherubini et al. 2005). Table 14 hereafter describes the level of the analysis and the propositions that need to be tested for the model to be validated.

2.6 Conclusion and contributions of Study 2

The model we have presented serves as a basis for developing appropriate analyses of team coordination related to common ground. The reliable and valid analysis of these concepts is essential not only to test the four propositions we have developed but also advance our understanding of team coordination.

Currently, the model offers three main advantages to researchers and practitioners interested in team coordination. Firstly, one of the main contributions of our process model on team coordination is that it explains how coordination concretely occurs, while previous theoretical studies have missed or ignored such explanations. Our model stipulates that teams perform two main activities to coordinate: interacting (which implies: grounding, updating, and monitoring) and contributing (making individual contributions). While the purpose of our process model is mostly explanatory in that it explains how different streams of actions lead to effective or ineffective coordinating, it is easy to see and further to test its prescriptive power. In fact, to coordinate, team members must converse to a great extent. The purpose of conversation is to prepare team members to coordinate. Therefore, we hypothesize that the more and the better team members converse about the joint objectives, commitments, resources, and risks, the more likely they are to coordinate effectively. This suggests that designing artifacts that, on the one hand, direct team conversations toward the four domains and, on the other hand, support the monitoring of common ground and identification of common ground breakdowns will help cross-boundary teams coordinate more effectively.

Table 14 – Projected data and validation methodology for each proposition	
Proposition	Data analysis and validation
Proposition 1: Team members identify the required and actual states of common ground to compare them.	1. Identification of speech acts that evaluate common ground (e.g. "Does anybody require any further information?", "I fear I lack some knowledge on matter XYZ"). 2. Proposition is validated if such speech acts are performed as they show that individuals incorporate the ability to assess the level of common ground or how much information is needed.
Proposition 2: In teams whose actual state of common ground is equal to the required state, members will make aligned individual contributions (i.e .coordinate effectively).	1. Computation of the required level of common ground: analysis of all the information that members receive individually and the points that are grounded (agreed on) during the meetings. 2. Identification of coordination surprises. 3. Correlation between the two levels of common ground (required and actual) and the coordination surprises. 4. Proposition is validated when the two levels are equal and there is no coordination surprise.
Proposition 3: Team members who do not detect common ground shortages make misaligned individual contributions (i.e. coordinate ineffectively).	1. Identification of undetected common ground shortages by comparing the required level of common ground with what is actually grounded during the meeting. 2. Identification of coordination surprises and correlation with the common ground shortages. 3. Proposition is validated if undetected common ground shortages lead to misaligned coordination.
Proposition 4: When coordinating (whether effectively or ineffectively), team members ground and update their individual contributions and any other new relevant information.	1. Identification of speech acts related to what members have done individually. 2. Identification of speech acts related to any information the member might be aware of individually. 3. Proposition is validated if members present their individual contributions or individual knowledge to the team.

Secondly, we complement Clark's theory with two main additions. The first addition is that Clark's work does not provide a process for coordination in the likes of our model. Secondly, Clark's work does not include the notion of effectiveness, a key concern in management. Our process model differentiates between effective and ineffective coordination by stipulating that in the former there are no common ground shortages unlike the latter. That is, the effectiveness of coordination is greatly determined by the conversations (i.e. grounding, updating, and monitoring) that occur before individuals make their contributions. This allows to situate how the effectiveness of coordination can be supported and mediated by the team's material environment, as ensuring that there are no common ground shortages might be more difficult than in Clark's account (Cherubini et al. 2005). Moreover, we augment Mastrogiacomo and colleagues' (2014) study that initially instantiated Clark's (1996) concepts to project management. As such, their study used a variance perspective as it revealed that the state of a team's common ground is positively correlated with coordination effectiveness. Our study adds the activities that lead to and stem from common ground.

Most importantly, our process model could prove useful for practitioners if validated as they can focus on a few fundamental activities to ensure that their teams are coordinating effectively: interacting (grounding, updating, and monitoring) and contributing (making their individual contributions). In fact, we have previously noted that contributions from current literature leaves practitioners too puzzled with an increasing amount and variety of coordination mechanisms. Using our process model, cross-boundary team members can simply focus on making sure they effectively ground and monitor common ground so that they can perform aligned contributions. We thus frame the content of meetings and conversational activities.

3 Synthesis of Studies 1 and 2 and future research

This chapter was motivated by the need to know how to support cross-boundary coordination challenges. As a reminder, coordination challenges stem from the difficulty of creating shared cognition due to the knowledge boundaries that cross-boundary team members have. They face differences in vocabulary (syntactic boundaries) and interpretations (semantic boundaries) due to their different thought worlds. Literature has suggested that two ways to create such shared cognition is through language and objects, but neither of both streams has been able to provide effective guidance to cross-boundary teams. Studies on language, although providing pragmatic insights into how to use language for creating shared cognition, mostly focused on pairs of individuals and at the level of utterances. Creating shared understanding at such a micro-level is very different from a macro-level involving multiple individuals and over the course of a whole conversation. Studies on boundary objects have highlighted that they allow individuals with different thought worlds to construe the information they embody in the same way across boundaries. Technologies improve communication across time and space, and some provide awareness of other team members, which allows them to coordinate better. However, objects and technologies can resolve misunderstandings as well as create them. Therefore, in this chapter I sought to shed light on the overall research question: *How can we support cross-boundary teams in measuring and augmenting common ground to coordinate effectively?*

To answer this question, I have bridged the three streams of research on coordination, i.e. shared cognition, language, and objects. I have combined design science research with Clark's theory on joint activities and common ground to design the Coopilot App and develop a theoretical model of discursive coordination in teams. His conceptualization of common ground binds shared cognition with language as it describes the linguistic acts through which individuals create common ground. We have instantiated his theory into two versions of the Coopilot App which allows team members to state their individual perceptions on the four requirements of common ground for coordination, i.e. joint objectives, joint commitments, joint resources, and joint risks.

3.1.1 Contributions to prescriptive knowledge

The Coopilot App is the first – to our knowledge – to materialize the common ground of teams in real time. Overall, the evaluations have shown that the App improves coordination between cross-boundary team members as it allows them to *see* their level of common ground. I have provided three design heuristics that design science researchers can build on to develop tools for supporting discursive coordination and to address Nicolini and colleagues' (2012) concern with the lack of knowledge on what makes collaborative objects more or less effective in supporting the creation of shared cognition. These principles guide the design of tools for supporting cross-boundary teams in evaluating their common ground and triggering repair discussions. The first study suggests that when the number of participants is greater than 5, teams might need some material support to evaluate their level of common ground, on top of the evidence of understanding they construe through conversations. I have also suggested that collaborative objects should incorporate some guidance to users on the actions to undertake as tools might be used for different purposes. I have illustrated this with the conversational guide in the Coopilot App. Overall, the first study shows how the stream of research on objects can be linked with those on language and shared cognition to address cross-boundary coordination challenges.

3.1.2 Contributions to descriptive knowledge

In the second study, I have related the development of a theoretical process of discursive coordination within teams. I have addressed the lack of practicality and actionability that traditional accounts of coordination have. Our process suggests that discursive coordination involves mainly two activities: that of interacting – by grounding the four requirements for coordination and continuously monitoring the level of common ground – and contributing to the joint activity. Our study highlights both the content of the discussions that are necessary for coordination, and their form with the aforementioned activities. It also suggests that one of the most critical activities for effective coordination is that of having common ground and being able to identify common ground shortages on the four requirements.

This leads me to the overall and general contribution of this chapter. Both studies suggest that what is important for cross-boundary team members to coordinate effectively is to discuss to establish common ground on the four requirements (joint objectives, joint commitments, joint resources, and joint risks) and continuously monitor potential common ground breakdowns. As it is difficult and cumbersome for team members to solely rely on their conversations to do so, material support proves useful and important. These insights have allowed me to extend the Coopilot conceptual model with several additions (Table 15, *grey-shaded cells indicate the content that was in the initial version of the Coopilot conceptual model*). Initially, the conceptual model by Mastrogiacomo et al. (2014) contained the content of coordination by outlining that team members must have common ground on the four requirements to coordinate effectively. With the two studies in this Chapter, I have added the process through which coordination occurs and have identified the causes of the challenges of cross-boundary coordination: avoiding common ground breakdowns, and managing the syntactic and semantic knowledge boundaries (Carlile 2002; 2004).

This chapter also contributes to the literature on shared cognition by suggesting the activities and events that allow cross-boundary teams to create common ground. It contributes to the literature on language by identifying how conversations contribute to establishing common ground in team settings. It contributes to the literature on collaborative objects by specifying the characteristics that such objects should have to allow for effective cross-boundary understanding and coordination. In sum, I have suggested that a discursive and material conception of common ground and coordination might provide solid basis for the development of tools that can support cross-boundary coordination challenges. Building on these observations, I define that cross-boundary coordination is a triangle in which language, common ground, and objects play crucial and interrelated roles (Figure 15).

Table 15 - Extension of the Coopilot conceptual model		
Construct	Sub-constructs	Definition
Content of coordination	The four requirements: joint objectives, joint commitments, joint resources, joint risks	The content for which team members must have common ground to coordinate effectively.
Process of coordination	Establishing common ground	The conversational activity through which individuals make a piece of information part of their common ground.
	Monitoring common ground	Information might not be understood the same way by all team members (common ground breakdown) or it might become obsolete, so the team must continuously monitor its level of common ground. In conversations, individuals can rely on the four types of evidence of understanding outlined by Clark (1996): assertions, presuppositions, displays, and exemplifications. Material support provides a fifth type of evidence: visualization.
	Contributing	Doing one's part. The individual actions made by team members to contribute to the joint project. Coordination if effective if the parts are aligned, which is warranted by high levels of common ground and no common ground breakdowns.
Challenges of coordination	Avoiding common ground breakdowns	Misbeliefs on what people know about each other. Can result in wrong predictions and lead to ineffective coordination.
	Managing syntactic and semantic knowledge boundaries	Differences in vocabulary and interpretations that are characteristic of cross-boundary teams in situations with novelty.

3.1.3 Limits and future research

The conclusions in this Chapter are preliminary and need further refinement and validation. In Study 1, I provided initial insights for the design heuristics that can support the evaluation of common ground and effective coordination. It is important to replicate these results in additional cases of cross-boundary teams. Future analysis should not only include additional cases, it should also collect data from a greater variety of sources. Our analyses in Study 1 were limited to interviews and questionnaires as a source of information about the practices of innovation teams. Situated analyses of how the Coopilot App is used is needed to complement the self-reported dynamics by the undergraduate students (when asked how they reacted to the results screen). This could provide insightful data on how individuals interact with the application and the linguistic strategies they use to trigger repair discussions. These strategies should be compared against their efficiency and effectiveness in repairing common ground breakdowns while maintaining a cooperative climate within the team. I believe that pointing to misunderstandings and perception gaps might in some cases be a difficult conversation to have. Defining effective conversational strategies to guide the outcome of the vote seems necessary and important. This would also inform the process model of coordination as to the possible actions that team members have when they monitor their common ground. So far, I have assumed that they repair common ground breakdowns or not. Further and more detailed analysis of the types (or strategies) of repair may enrich the model.

Figure 15 - Visual metaphor of the triangle of cross-boundary coordination

In relation to that, there is one major limit to these studies. Throughout the whole chapter, I have implicitly assumed that cross-boundary team members have cooperative intentions and attitudes. But as highlighted in the literature review in Chapter 2, cross-boundary teams are also prone to the difficulty of establishing a cooperative setting. In the next chapter, I will investigate how cooperation can be supported through the emergence of shared leadership and with another artifact I have designed based on the Coopilot conceptual model: the Team Alignment Map.

SUMMARY OF CHAPTER 4

Due to their syntactic and semantic **knowledge boundaries**, cross-boundary teams have difficulties coordinating effectively. The literature on coordination suggests **three different perspectives** that can inform how effective coordination happens: through language, through the development of shared understanding, and through objects and tools. The motivation of this chapter was to integrate these three perspectives which have evolved in isolation from one another, and develop prescriptive and actionable knowledge for coordinating. To do so, I rely on **Clark's theory on common ground and language use** for coordination. The question I sought to address with the two studies in this chapter is: *How can we support cross-boundary teams in measuring and augmenting common ground to coordinate effectively?*

STUDY 1	STUDY 2
This study was motivated by the need to provide **prescriptive and actionable knowledge** for cross-boundary teams to coordinate effectively, through the development of a conceptual model based on Clark's theory and the instantiation into a mobile application.	This study was motivated by the need to theorize **how coordination is concretely carried out** through discussions in cross-boundary teams, as most accounts use a variance and impractical approach. We developed a processual model of team coordination based on Clark's theory.
CONCEPTUAL MODEL	**CONCEPTUAL MODEL**
The Coopilot conceptual model bridges the streams of research on shared cognition and language by suggesting that cross-boundary team coordination is about establishing **common ground** on four requirements (joint objectives, commitments, resources, and risks). It serves as the theoretical basis to address coordination challenges.	We used the Coopilot conceptual model as a basis for the development of the **process model**. We extended it by adding the interactional and cognitive activities that happen during coordination, based on Clark's concepts of grounding and evidence of understanding.
INSTANTIATION INTO THE COOPILOT APP	**PROCESS MODEL OF TEAM COORDINATION**
The Coopilot App allows team members to **measure** their level of common ground. This allows them to engage in repair discussions that **augment** common ground for the purpose of coordinating effectively.	In the process model, we define team coordination as a process of (1) **interacting** to establish common ground on the four requirements, and (2) **monitoring** the level of common ground.
EVALUATION OF THE COOPILOT APP	**FUTURE EVALUATION**
The evaluation with 17 teams suggests that the Coopilot App allows for a measure of the level of common ground and triggers repair discussions.	The evaluation procedure is provided along with the propositions that should be tested to validate the model.
CONTRIBUTIONS	**CONTRIBUTIONS**
We provide the first tool to allow for the materialization and **visualization** of the level of common ground, and provide **design principles**. We show that visualizing the perception gaps triggers repair discussions to coordinate effectively.	Through the extension of the conceptual model with the fundamental activities for coordinating, we suggest that coordination challenges may arise from the **difficulty of interacting and measuring** the level of common ground.

KEY TAKE-AWAYS OF THE TWO STUDIES

These studies suggest that cross-boundary coordination is a **triangle** between shared cognition (common ground), language, and objects. Effective coordination is achieved through interactions (language) to establish common ground (shared cognition). Since monitoring common ground may be challenging in cross-boundary teams, we prescribe that for team coordination to be effective, it should be supported with tools that help measure the level of common ground.

CHAPTER 5

SUPPORTING CROSS-BOUNDARY COOPERATION CHALLENGES

ABSTRACT OF CHAPTER 5

This chapter is informed by two studies that I co-authored to address cooperation challenges and answer the research question that emerged from the literature review: *How can we support cross-boundary teams in developing shared leadership to cooperate effectively?*

Study 3 is being published at the *Twenty Sixth European Conference on Information Systems (ECIS)* (*reference* Avdiji et al. 2018a). In this study, I sought to understand how the emergence of shared leadership can be supported materially so that cross-boundary teams can cooperate effectively. To do so, I have co-designed the Team Alignment Map, a visual tool that allows team members to jointly inquire into the four requirements for common ground. Results from the evaluation with 10 cross-boundary teams working on innovation projects suggest that the Team Alignment Map addresses the three antecedent conditions of shared leadership: shared purpose (extended to team alignment), social support, and voice. Social contract is identified as an additional condition that allows for the emergence of shared leadership. The process of joint inquiry is introduced as a promising lens to describe the dynamics through which cross-boundary teams cooperate effectively.

In Study 4, which is being published in 2018 in the journal *Travaux Neuchâtelois de Linguistique* (*reference* Avdiji and Missonier 2018), I sought to zoom in the first antecedent condition that is addressed by the Map – i.e. team alignment – as it equates to coordination in the Coopilot conceptual model. My motivation was to understand whether the process of joint inquiry is also relevant to cross-boundary coordination as it appeared as an interesting lens to understand the emergence of shared leadership. I thus updated the Coopilot conceptual model with joint inquiry to be more adequate with the Team Alignment Map. The evaluation was done with the 10 innovation teams of Study 3 and 12 teams of undergraduate students working on innovation projects. Results confirm the relevance of the process of joint inquiry in explaining how coordination occurs in settings with great novelty and uncertainty.

The conclusion I draw from the studies in this chapter is that the process of joint inquiry is relevant to overcome both the cooperation challenges and the coordination challenges in situations characterized by novelty and uncertainty. I thus reconceptualize cross-boundary teamwork through the concept of joint inquiry. I argue that cooperation and coordination are linked through the notion of social contracts. Social contracts bind team members to each other (cooperation) and result in common ground on the future course of action (coordination). Adding the notion of joint inquiry to the Coopilot conceptual model allows to address one of the main limits of Chapter 4, which was that we assumed that the cross-boundary members were in cooperative settings in our account of team coordination. The addition of joint inquiry provides a more comprehensive account on how cross-boundary teamwork occurs.

HIGH-LEVEL CONTENTS OF CHAPTER 5

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2. Study 4: Bridging coordination and cooperation challenges through joint inquiry 190
3. Synthesis of Studies 3 and 4 and future research 204

1 Study 3: Designing for cooperation challenges

In this study, I present the research project that led to the design of the Team Alignment Map. I will relate an extended version of the original article that is being published in 2018 in the Proceedings of the *Twenty Sixth European Conference on Information Systems (ECIS)* (Avdiji et al. 2018a). The two main differences with the original article are that (1) I extend the literature review on the objects and tools to support the emergence of shared leadership, and (2) I provide here a more detailed description of the design research process that we followed to design the Team Alignment Map. I did not include these in the original paper due to space constraints, yet they provide valuable insights for the research question I seek to address in this chapter. In the original article, the Map is presented without the background of the design process. The motivation, the evaluation, the results, and the contributions reflect those in the original article.

The presentation of this study will be structured as follows: I will first describe the cooperation challenges that cross-boundary teams face (step 1 in Figure 16). I will then review the literature on shared leadership, its antecedents, and how various studies suggest to support these antecedents (step 2). I will also present how I complemented the Coopilot conceptual model with Dewey's (1927; 1929) process of joint inquiry which proves solid ground to understand the dynamics that allow for shared leadership to emerge. I will then describe the Team Alignment Map and how we designed it based on the Coopilot conceptual model and the process of joint inquiry to address the cooperation challenges (step 3). I will present the evaluation we made with 10 professional cross-boundary teams in different organizations (step 4). I will conclude with the contributions this study allowed me to make, in the form of design heuristics for shared leadership (step 5).

1.1 Introduction: cooperation challenges in cross-boundary teams

The challenges that I address in this study are the ones related to the cooperation challenges I underlined in the literature review in Chapter 2. Any cross-boundary team project requires a cooperative attitude from all members. The prerequisite to any joint activity is that individuals must agree on the object of their cooperation and know that others are willing to commit to it and reciprocate (Holmes 2002; Knoblich et al. 2011). Cooperation is thus a positive attitude toward engaging with others in a joint activity and committing to the activity (McDonough 2000). However, cooperative attitudes are difficult to develop in cross-boundary teams due to the pragmatic boundaries identified by (Carlile 2002; 2004). Pragmatic boundaries refer to the competing interests and agendas that cross-boundary team members might have. Managing these cooperative barriers is essential as they may translate into lower expectations and commitment in the joint activity (Bandow 2001; Edmondson 1999), a decrease in the level of trust between team members (Williams 2001), and a reluctance to share knowledge with others (Barret and Oborn 2010; Jarvenpaa and Majchrzak 2008). However, managing such cooperation challenges is difficult as individuals must negotiate shared interests and agree to transform their knowledge (Carlile 2002; Edmondson and Harvey 2017).

As I argued in Chapter 2, one promising angle to address these cooperation challenges is to develop shared leadership (Daspit et al. 2013), a dynamic and interactive process of mutual influences within a team through which team members lead one another toward the accomplishment of their joint goals (Pearce and Conger 2002). Given that teams in which leadership is shared display cooperative attitudes, understanding how shared leadership emerges within cross-boundary teams might provide useful insights in understanding how to overcome cooperation challenges (Hill and Bartol 2016). Shared leadership describes the quality of cooperative interactions.

1.2 Literature review on shared leadership

The idea of shared leadership stands in contrast to what Pearce and Manz (2005, p. 139) called “the top-heavy, heroic model of leadership in order to extract work-product from their employees”. The notion of shared leadership was conceived by Pearce and Sims (2000; 2002) in the quest of giving voice to the followers while keeping the leading figures in the limelight. To them, leadership is shared when it emanates from members of the team, and not simply from the appointed leader. Shared leadership is defined as “a dynamic, interactive influence process among individuals in groups for which the objective is to lead one another to the achievement of group or organizational goals or both” (Pearce and Conger 2003, p. 1). Based on this definition, the main characteristics of shared leadership can be summarized as follows: (1) multi-direction of influence and (2) ownership of joint goals; and (3) the interchange of the assumed leadership role without necessarily distributing or stretching it among several team members. This is different from distributed leadership in which influence is distributed across several individuals working on different sub-tasks of the overall project through mechanisms, structures, and processes, without these individuals necessarily working together. The substitution of the role of vertical leaders is manifested in new forms of leadership. Among them are self-leadership, emergent leadership, and shared leadership (Hoch and Dulebohn 2017). Table 16 provides a comparison among the three constructs.

Table 16 - Comparing self-leadership, emergent leadership, and shared leadership

Construct	Definition	Reference
Self-leadership	Self-influence process through which people achieve the self-direction and self-motivation necessary to perform	Neck and Houghton (2006, p. 271)
Emergent leadership	Individual's completion of leader-like work duties and occupying positions of leadership or authority either within or outside of the work domain	Cogliser et al. (2012, p. 753)
Shared leadership	A dynamic, interactive influence process among individuals in groups for which the objective is to lead one another to the achievement of group or organizational goals or both	Pearce and Conger (2003, p. 1)

Several studies have investigated the relationship between shared leadership and the performance of innovation teams (*e.g.*, Ensley et al. 2006; Hoch 2014; Hoch and Kozlowski 2014; Hoegl and Muethel 2007). They conclude that teams in which leadership is shared generate more creative ideas in terms of quantity and quality, display greater willingness to share their ideas and unique information with each other, and implement these ideas more effectively. Compared to vertical leadership, shared leadership has been found to enhance team potency and cooperation, and the number and quality of product ideas in the context of new product development (Cox et al. 2013). Moreover, shared leadership allows teams to inquire and solve complex problems more effectively (Cox et al. 2003; Huelsheger et al. 2009; Morgeson et al. 2010). Also, studies on virtual collaboration found that shared leadership leads to better team dynamics and higher team performance (i.e., innovation) than vertical leadership (Hoch 2014; Hoch and Dulebohn 2017).

Given the effectiveness of shared leadership for innovation and collaboration, several scholars were interested in identifying its antecedent conditions and the types of environments that enable it (*e.g.*, DeRue and Ashford 2010; Dinh et al. 2014; Lord and Shondrick 2011; Serban and Roberts 2016). Shared leadership emerges when both the team's internal and external environments are supportive of it (Avolio et al. 1996; Carson et al. 2007). Carson et al. (2007) identified four antecedent conditions of shared leadership that relate to these environments. An internal team environment that supports shared leadership is determined by three dimensions: (1) *shared purpose* that is manifested in similar understandings of team's primary objectives and focus on collective goals; (2) *voice* that is exhibited through interaction facilitation and participative behaviours in teams; and (3) *social support* in encouraging and recognizing individual and team contributions and accomplishments. When the team's internal environment enables shared leadership, it encourages team members to assume leadership roles and rely on the leadership of their peers. In addition to these dimensions, (4) supportive external environment (e.g., coaching from an external leader) helps team members make coordinated and task-appropriate use of their collective resources in accomplishing their tasks.

Other scholars have noted the importance of analyzing shared leadership not only as a purely social phenomenon but as a practice that both influences and is influenced by the material objects and technologies (Spillane et al. 2004; Spillane 2009). Studies on the roles of technology in shared leadership and virtual teams can be summarized in the following themes (see Avolio et al. 2014 for a complete review). Scholars have observed increased use of technologies, such as instant messaging (*e.g.*, Cameron and Webster 2005) and 3D collaborative virtual environment (*e.g.*, Montoya et al. 2011) that reduce the transmission of nonverbal cues. Therefore, research in affective, haptic, and robotic devices to enrich virtual communication is flourishing to address the challenge (*see* Pentland and Choudhury 2000; Smith and MacLean 2007). Technologies indeed contribute to greater transparency and access to information that in turn may influence team perception, support, and trust (Kahai 2012). Leaders-followers' relationship and team dynamics are also influenced by the rise of social networks through social media (Kahai 2012), the increasing use of tracking devices (Silverman 2011), and constant availability (MacLean 2008). Several studies regarded technology as a mediator between shared leadership and performance (Al-Ani et al. 2011; Avolio et al. 2014; Hoch and Dulebohn 2017; Powell et al. 2004) and have noted how information technologies can be a mediator between shared leadership and performance. Other studies regarded technologies and objects as enablers or antecedents of shared leadership, that in turn influence performance (e.g., Balthazard et al. 2004; Mailhot et al. 2016; Oborn et al. 2013).

The last decades have seen a shift from the leader-centric view towards a more relational view of leadership practices. Scholars have applied the relational perspective in different contexts, such as school leadership (*e.g.*, Coldren and Spillane 2007; Halverson 2007) and policy making (*e.g.*, Oborn et al. 2013). The relational perspective sees leadership as mechanisms that enable collaboration and that are enacted through the interaction between leaders, followers, and the material and symbolic artefacts in the situation (Huxham and Vangen 2000; Spillane et al. 2004; Spillane 2009). Several authors have thus considered the role of collaborative tools in the practice of sharing leadership as an assemblage of actors and objects building on Latour's (2005) actor-network theory. Oborn et al. (2013) examined how policy makers constitute leadership through a socio-technical entanglement of polls, statistics, technologies, and coalitions. They found that technologies (e.g., clinical tools and computer animations) play important roles in supporting sensemaking and democratization in the policy process. Mailhot et al. (2016) conceptualized leadership to involve actor-object couplings and delved into how it empowered collaborative ventures across disparate thought worlds. What these studies have in common is that: (1) they exhibited how and why a certain leadership practice takes place by considering material entities as its defining components, (2) they confirmed the nature of leadership practices as emergent and fluid (Gronn 2000; 2002), and (3) they have demonstrated how leadership roles are transmitted among multiple individuals over time through objects and technologies.

In IS, leadership has been studied with regards to the technologies used by teams (Dennis and Garfield 2003; Li et al. 2016; Sharma and Rai 2015) and in the context of virtual collaboration (Boughzala et al. 2012; Faraj et al. 2015; Malhotra et al. 2007). Several authors argue that the digital age requires that the approach to innovation and collaborative work be undertaken by a more horizontal way of leading, as opposed to the vertical way (Carson et al. 2007; Pearce and Manz 2005).

However, little is yet known on what it is in the technologies and tools that supports shared leadership. Most of the above studies viewed the general material reality of shared leadership without clearly analyzing the characteristics that enable or constrain its emergence. In this study, we built on the recent works on the performativity of collaborative tools on group dynamics, i.e. the tools that are used to communicate, promote shared understanding and negotiation (Nicolini et al. 2012). We sought to open the black box of the interaction between collaborative tools and shared leadership by analyzing the features of the tools that support or enable shared leadership. Therefore, the question I will address hereafter is: *How can we support cross-boundary teams in developing shared leadership to cooperate effectively*?

I will summarize how both descriptive and prescriptive literatures suggest to address these antecedents, and thus support the emergence of shared leadership. These will provide suggestions for the design of the Team Alignment Map, which I will combine with the Coopilot conceptual model.

1.3 Conceptual background

As stated before, despite the growing yet recent interest in understanding how shared leadership is shaped by material conditions, the literature on the characteristics of collaborative objects that support shared leadership is still scarce. Therefore, in the development of the conceptual model that informed the development of the Team Alignment Map, I have broadened the scope of the literature to other studies on collaborative objects and tools that do not directly address shared leadership but are related to its antecedent conditions. I will first review these studies and underline the hypothesized characteristics that might influence the emergence of shared leadership before explaining how these can be complemented with the Coopilot conceptual model to design the Team Alignment Map.

Regarding the shared purpose antecedent, as reviewed in the literature in Chapter 2, teams will develop a shared purpose if they engage in conversations in which they (1) define and negotiate a shared goal, (2) establish common ground on this shared goal, and (3) plan for the joint actions that stem from the shared goal. This definition should be done collaboratively to ensure that everyone has ownership of the shared goal (Bronstein 2003). Activity objects seem to be good candidates for supporting the emergence of a shared purpose, as they are shared problem spaces in which team members negotiate their shared goals and the direction of their joint activity (Nicolini et al. 2012).

The notion of a shared problem space echoes one suggested avenue for addressing the second antecedent condition for shared leadership: voice. Tjosvold et al. (2004) suggest that when teams consider their collaboration as consisting of a problem solving activity, they regard their collaboration as an open discussion in which all input and skills from all team members are welcome. Such a conceptualization of teamwork prefers open communication to blaming (Cannon and Edmondson 2001; Carter and West 1998), which I assume will support the antecedent condition of voice. The material condition that seems best aligned with this assumption is that of co-design tools. These tools support the process of co-design in various ways. Co-design is the joint inquiry into a problem by participants who face a common problem. They do so by discussing, exploring and defining the problem and explore, develop, and evaluate possible solutions to the problem (Steen 2013). According to Dalsgaard (2017), co-design tools allow team members to approach and transform uncertain situations in which there are no straightforward answers by helping them better understand a problem, explore and make sense of the problem. They can take on different forms such as prototypes, shared problem spaces, or virtual representations of parts of the problem. No matter what their form is, these tools converge around a central function: they make ideas and perspectives tangible. This tangibility supports the forming of ideas and hypotheses on how to address the problem and experimenting with these ideas in practice (Horn and Weber 2007).

For the social support antecedent condition, several studies seem to suggest that making individuals aware of the interdependencies between them creates some sense of cohesion and shared responsibility (Al-Ani et al. 2008; Cataldo et al. 2006; Raposo and Fuks 2002; Rhoades et al. 2001; Schippers et al. 2003; de Souza et al. 2004). This line of research has mostly been inscribed in Computer-Supported Cooperative Work (CSCW) and has analyzed how awareness systems not only provide information on what others are doing and what they need in terms of knowledge requirements, they have also analyzed how a team consciousness emerges. In that sense, individuals then understand that their ability to carry on their joint project depends on everyone's contributions, which underlines the need to provide support for each other.

These studies seem to suggest that tools that provide a shared problem space and tangible means for individuals jointly inquire into their shared purpose and their interdependencies are good candidates for supporting the emergence of shared leadership (Table 17).

1.4 Methodology: Design science research

To understand how we can support the emergence of shared leadership in cross-boundary teams, we have performed design science research following the framework by Hevner et al. (2004) (Figure 16). We first analyzed the requirements of the cooperation challenges that cross-boundary teams face both based on the literature review I have just outlined above (1, in Figure 16). I grounded the design of the Team Alignment Map in the Coopilot conceptual model to which we added the process of joint inquiry, in order to define the process through which cross-boundary team members could define the elements of the four requirements for coordination and establish cooperation (2). Of the Coopilot conceptual model, we particularly rely on the four domains of common ground for joint projects: joint objectives, joint commitments, joint resources, and joint risks. I also conceived that the main medium for cross-boundary teams to establish common ground is through conversations during team meetings.

Table 17 – Potential characteristics of tools for supporting the antecedents of shared leadership		
Antecedents of shared leadership	Description	Potential characteristics that support the antecedents
Shared purpose	Team members' interests converge toward a shared goal and they have have the same understanding of it.	Visual problem space.
Social support	Team members' effort to provide emotional and psychological support to their peers.	Awareness of interdependencies and knowledge requirements.
Voice	Team members have a say and input into the joint activity. They express their personal positions, opinions, ideas, and knowledge.	Tangibility and active collective participation.

Therefore, we sought to develop a tool that would be used during such team meetings (3). I will present the characteristics of the Team Alignment Map and describe how we implemented these initial insights and the Coopilot conceptual model in hereafter. We then evaluated the Team Alignment Map with 10 professional cross-boundary teams working on innovation projects using a qualitative methodology (4). The results informed us the addition of social contracts as an antecedent condition to shared leadership, and the need to incorporate the notion of joint inquiry into our conceptual model to understand how to overcome cooperation challenges in cross-boundary teams operating in novel and uncertain situations (5). I will now describe the artifact and the qualitative methods we used to evaluate the artifact and the conceptual model it incorporates.

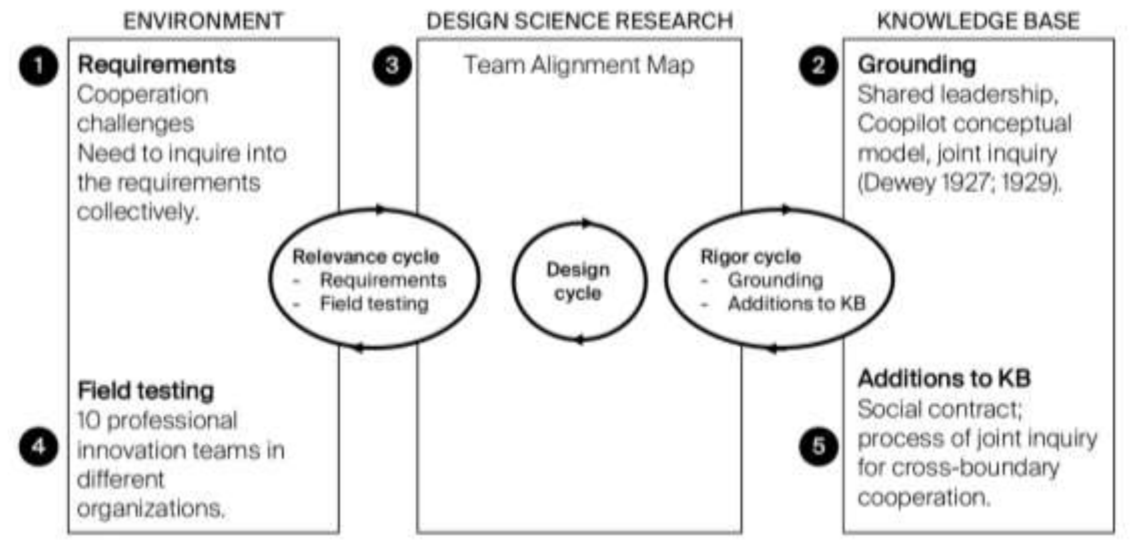

Figure 16 - Design science research process for Study 3, based on Hevner et al. (2004)

1.4.1 Description of the artifact

The Team Alignment Map (TAM) is a collective tool that helps team members co-design common ground on the four requirements. The Team Alignment Map provides teams with a tangible and visual shared problem space. It is in the form of a F4 World format print poster that is placed against a wall of the project meeting room (Figure 17 and Figure 18). The standard and promoted use of the Map recommends that all participants to the joint project be present and actively participate in a three-step procedure: forward pass, backward pass, alignment pass.

The forward pass is the definition step. Participants fill the four columns (joint objectives, commitments, resources, and risks) of the map from the left to the right to define each requirement. Using sticky notes, participants write down what they consider the joint objectives of the joint project to be answering the question: what are we supposed to achieve together? They then aggregate all their answers by presenting each sticky note. They negotiate the joint objectives and remove, amend, or add sticky notes as they see fit. They can thus proceed through trial-and-error and prototyping until they find a solution they all agree on and are satisfied with. Once they agree on the joint objectives, they define the joint commitments answering the question: who is doing what for whom? Participants write what joint objectives they commit to individually. Every joint objective should correspond with at least one commitment. Again, participants discuss and negotiate the commitments as they see fit. They do so iteratively for the joint resources (what resources are we missing?) and the joint risks (what might prevent us from succeeding?).

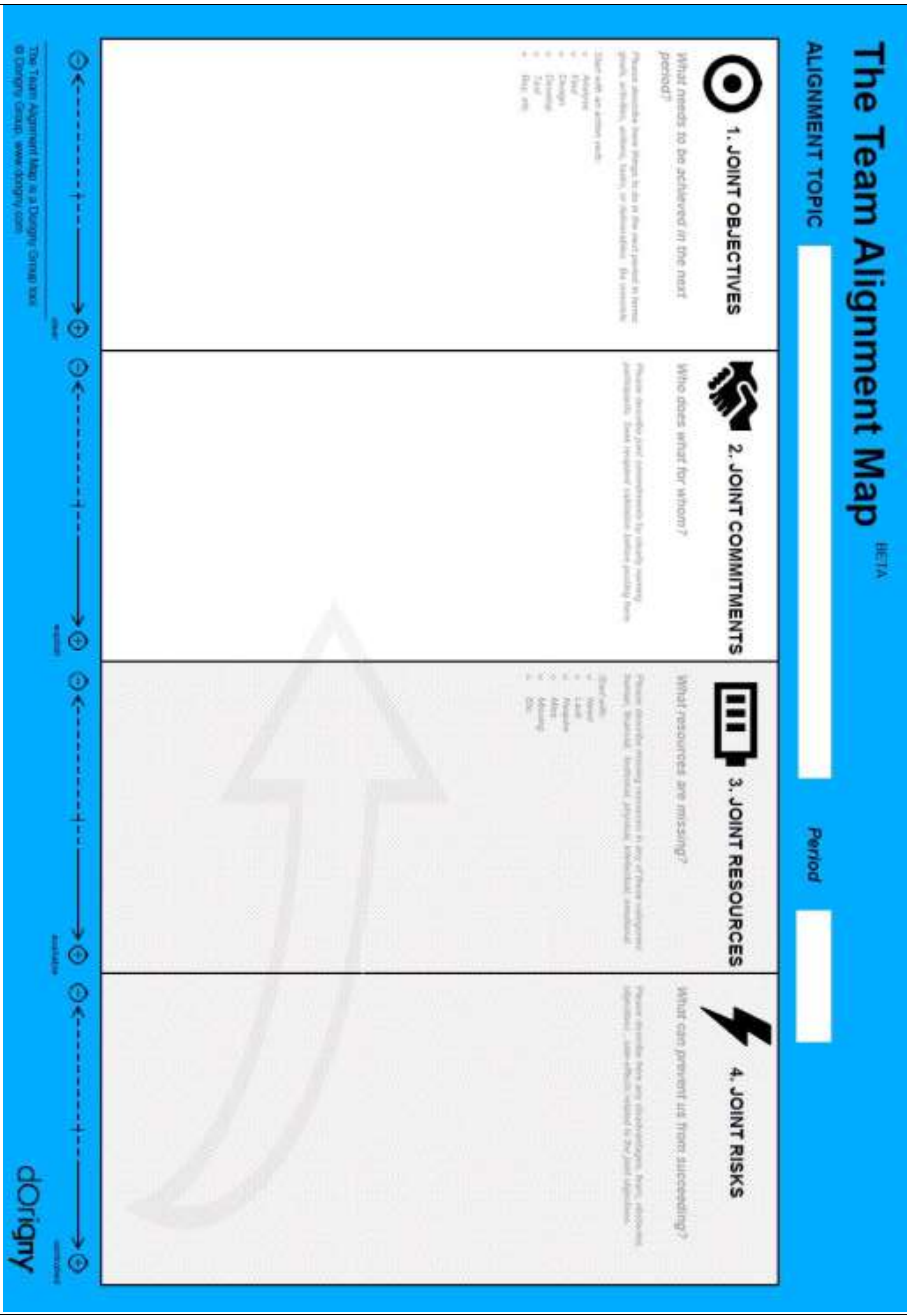

Figure 17 - The Team Alignment Map

Figure 18 - The Team Alignment Map in use

The backward pass is the refinement step. As risks and missing resources can impede on the project, participants collectively reduce the number of sticky notes in the related columns as much as possible. To do so, they can define a new joint objective for acquiring the missing resources of mitigating the risks. Participants then negotiate a commitment to the new objectives. Participants negotiate the reduction of resources and risks through conversation and proceed through trial-and-error until they all agree and are satisfied with the content of the TAM.

The alignment pass is the evaluation of the team's level of agreement. Participants use small sticky notes to voice their perception of the four requirements using horizontal scales at the bottom of each column. When their votes are scattered, the team's agreement is low. The team members discuss and *negotiate* the elements that they do not agree or are not clear on until they are satisfied. This step also helps reduce any misunderstandings and perception gaps as team members can voice when they are not clear on any of the four requirements.

The alignment pass has a similar function to the Coopilot App, in that it allows teams to evaluate their level of common ground, although without ensuring anonymity. Therefore, in some settings we recommended the use of the Coopilot App to state their perception of the elements that are in the Team Alignment Map. The main difference between the two tools is that the Team Alignment Map allows individuals to establish the elements of the four requirements for common ground. While the Coopilot App triggered discussions to define the elements of these four requirements, the Team Alignment Map directly supports this process of defining the elements. This function addresses a comment we had often heard by users of the Coopilot App which is that the app allowed them to know whether they had common ground on the four requirements, but that it did not support users in knowing whether all members within the team were conceiving of the four requirements the same way. For example, how does one know that the joint objectives I have in mind are the same ones as those that the others think of? The Map addresses this question by supporting users directly in the definition of the four requirements through a visual problem space in which they map their shared purpose and the interdependencies between their contributions, resources, and risks.

1.4.2 Research setting for the evaluation

We evaluated the Team Alignment Map with case studies. The cases we chose are cross-boundary teams working on innovation projects (Table 18). Our informants are external coaches within an innovation support company based in Switzerland with employees operating remotely in Europe and the United States. The innovation company is specialized in supporting innovation ventures and they have developed a methodology specifically tailored for this purpose. Their offer consists of two types of supports. On the one hand, they provide three-week long learning sprints to external innovation teams in which they train them on the tools and the innovation methodology. The external coaches help the external teams understand the tool and train them on how to apply their methodology for the specific innovation challenges these teams face. On the other hand, the company proposes ten-week long innovation sprints during which they support and guide the external innovation teams. This is done through workshops during the first two weeks of the innovation sprints and weekly calls in the remaining weeks, with a wrap-up and synthesis session at the end. The goal of these innovation sprints is to come up with a deliverable, whether a marketing plan, a prototype, or a feasibility assessment. The company also provides support for longer innovation projects which can span over years. These long innovation sprints are designed to support external innovation teams more intensively and over the entire lifespan of the innovation project.

Table 18 - Description of innovation themes, teams, and our informants			
Innovation Theme	Innovation goal	Duration	Informants
TEX 1 team of 7 individuals	Testing and validating a new product for a competitive advantage.	10-week Innovation sprint	Methodology expert External coach
R&D 4 teams of 5 individuals	Developing a common language among cross-functional research and development teams.	4-week Learning sprint	Methodology expert
PHARM 2 teams of 5 and 6 individuals	Developing new products.	1.5-year Innovation project	External coach 1 External coach 2
TDC 3 teams of 5 to 10 individuals	Developing new product.	10-week Innovation sprint	Methodology expert External coach

The cases we investigate in this paper involve a total of ten teams that worked on four innovation themes (e.g., new pharmaceutical product development, new methods of product evaluation). It means that two or more teams can be involved in one innovation theme. These innovation teams were indeed formed for the purpose of identifying, developing, and evaluating new ideas. These teams are cross-boundary teams as they involve individuals with diverse roles, functions, and expertise who collaborated during a given time period with a dedicated external coach. Consequently, each team is expected to have its own project with distinct deliverables/ outcomes, even though it may share an innovation theme with other teams. Teams are composed of an external coach and an innovation methodology expert from the innovation consulting company, and a project sponsor and specialized team members from the client organization. Members of these teams collaborated in both collocated and distributed settings.

All innovation teams used the Team Alignment Map, as it had been by the innovation company in their methodology, for the purpose of coordinating the different stakeholders: their clients' innovation teams, the external coaches, and the methodology experts from the innovation consulting company. The latter organization decided to use the Team Alignment Map on their own initiative. This suggests that Team Alignment Map has practical relevance to the teams and is appropriate to their contexts.

1.4.3 Data collection

The research question calls for a qualitative and exploratory approach as little is known about the role of collaborative tools and objects in the emergence of shared leadership. The purpose of our paper is to develop initial theoretical insights on this role. In fact, qualitative data is well-suited to analyze complex social processes and phenomena (Eisenhardt and Graebner 2007). Interview remained the chief source of first-hand data in this study, in agreement with Walsham's (1995, p. 78) observation that "it is through this method that the researcher can best access the interpretations that participants have regarding the actions and events which have or are taking place, and the views and aspirations of themselves and other participants". We review the data resulting from 7 semi-structured interviews with 3 experts in an innovation methodology and 4 external coaches. This study was conducted as a part of a larger research project on the material practices of innovation ventures.

We chose external coaches and innovation methodology experts as our informants for three reasons: (1) they have worked intensively with each innovation team, (2) they can use both insider's and outsider's perspective in observing the teams' collaboration dynamics, (3) they have been sensitized with the features of the Team Alignment Map and are therefore able to articulate specific features in use when narrating their story.

The aim of the interviews for this paper was to gather initial insights on how the teams made use of and were influenced by the Team Alignment Map, even though multiple instances of collaborative tools were used within the teams. In the first part of the interviews, informants were asked to provide general and contextual information about their teams and projects, their roles and responsibilities within the project, the dynamics of the interactions between team members, and the main collaborative challenges they faced. The second part of the interviews was dedicated to understanding the impact of the use of the Team Alignment Map. Thereby, informants were asked to describe and explain the situated practices and uses of the Team Alignment Map within each context. More importantly, each informant was explicitly asked to think of a specific team when narrating a story. The interviews were transcribed verbatim and resulted in 51 single-spaced pages.

1.4.4 Data analysis

The data was analyzed using qualitative methods (Flick 2007; Yin 2013). As previous studies have identified three internal environment antecedent conditions of shared leadership (shared purpose, social support, voice), an initial framework consisting of these three general categories was used to facilitate the first fragmentation of the data. These three categories served only as a foundation for the iterative process which involved going back and forth between the data and the categories.

Given that previous research on shared leadership had been quite silent on the role of collaborative tools, we relied on emergent coding in which we undertook a second round of coding, this time with the open coding approach (Miles and Huberman 1994). Two emerging categories emerged from data (shared problem space and shared visualization), and this process allows also to identify a new category related to antecedent conditions of shared leadership (social contract). We then conducted axial coding to explore links between those emerging categories and also comparing these categories with what has been described in the literature as the roles of collaborative tools. Therefore, theory and evidence informed each other in our analysis. This open coding process and the creation of categories and the subsequent division, combination, or abolishment of the same, were maintained in successive examinations of the transcription.

During the course of our research, we have undertaken several measures to demonstrate five quality criteria as proposed by Lincoln and Guba (1985) and Marton (2013) in the following ways: (1) justifying how the methods of data collection and analysis are suitable for the characteristics of our cases and informants; (2) providing thick description in our analysis; (3) following Yin's (2013) guidelines to conducting and analyzing case study; (4) conducting confirmability audit with our informants; (5) ensuring agreement between the authors' interpretations.

1.5 Findings: supporting shared leadership

Our findings reveal in all teams that the use of the tool facilitates the emergence of 4 major categories that relate to the antecedent conditions of shared leadership: shared purpose (extended to team alignment based on the findings), voice, social support, and social contract. The first three categories have already been identified by previous literature (Carson et al. 2007). Our analysis adds that social contracts (i.e. when team members agree on their commitments and feel they are bound to them collectively) are supported by the Team Alignment Map and prove important as an antecedent condition for shared leadership. We also identified two emerging categories that are related to the facilitating features that enable and direct the shared leadership dynamics within the team: shared problem space and shared visualization. Hereafter, we will describe in greater detail how voice, social support, team alignment, and social contracts were enabled by the features of the Team Alignment Map. We present the major categories in Table 19. Before elaborating on each category, we will outline the emergence of shared leadership with the teams.

1.5.1 Emergence of shared leadership

All projects included stakeholders from different organizations and with different roles and functions (innovation teams, project sponsors, methodology expert, and external coach) and there were no pre-established structures, rules, functions, and responsibilities. In all cases except the PHARM project, the innovation projects were undertaken by ad hoc teams consisting of individuals from different functions in the client organization. Therefore, the methodology experts and external coaches decided to use the Team Alignment Map on their own initiative, to create alignment between the different stakeholders at the beginning of the projects. In fact, it was important for all respondents to start the project in a well-aligned way and have everyone on the same page. Interestingly, the external coach of the TEX project regarded the Team Alignment Map as "*a good sanity check on [...] the things that we need to be aware of and mindful of*".

Our informants narrated dynamics in their teams that display three characteristics of shared leadership as defined in Section 2: (1) multi-direction of influence, (2) ownership of goals, and (3) the interchange of the assumed leadership role.

Table 19 - Definition of the categories			
High-level category	Subordinate category	Source	Definition
Antecedent conditions	Shared purpose extended to Team alignment	Carson et al. (2007) Extended in the findings	Team alignment defined as: Shared purpose and knowledge on the elements of the joint activity (i.e., joint objectives, commitments, resources, and risks.
	Voice	Carson et al. (2007) Confirmed in the findings	The degree to which a team's members have input into how the team carries out its joint activity.
	Social support	Carson et al. (2007) Confirmed in the findings	Supporting and encouraging each other's contributions.
	Social contract	Emerged in the findings	Mutual agreement and commitment by the participants on their contributions to the joint activity.
Facilitating features	Shared problem space	Emerged in the findings	Collaborative physical or virtual space in which individuals must jointly encode the elements of their shared problem.
	Shared visualization	Emerged in the findings	Quality of an object allowing all participants to see the object and its evolution simultaneously.

Regarding the multi-direction of influence, one informant described the dynamic in his team as a safe environment in which anyone within the team could state their needs, expectations, and obstacles. The external coach of the TDC project related his own experience this way: "*I can share stories. I can share a heavy need for utilization and where not so much [...] It's not a negotiation about a contractual thing. It's more a negotiation about what kind of... for example* *resources, what kind of commitments I need.*" This illustration implies the multi-directionality of influence among team members, in which each member can ask the team for support, resources, and commitments. The multi-directionality becomes more apparent in the explanation of the Team Alignment Map by the external coach in the TEX project when they "*would come back to [the tool] as a placeholder: 'Hey remember when we said we were going to do this and this? You know, if this changes, it makes it more difficult for us*".

The ownership of goals is reflected in the stories where, once the conversation with the Team Alignment Map is initiated, team members influence each other towards their joint goals. Team members would go as far as reminding themselves about their own commitments as well as those of their colleagues in order to ensure that everyone is advancing towards the goal. What is meant by joint goals is captured by "*Do we all understand what we're trying to march towards?" Because if we don't, you know, it's easy to get side trapped in innovation sprints and chase something that is shiny and that doesn't fit to your goals. It's good to kind of bring people back.*" (external coach, PHARM).

Moreover, the teams displayed an interchange of leadership role, as is obvious in the following stories about the Team Alignment Map related by the external coach of the TDC project "*[The team] uses it to practically look at 'what is the next thing? Who is going to do that?' and we use it as a way to look at tasks and resources allocation*". In the same vein, he also stated that with the Team Alignment Map "*you get to the very meaningful discussion of 'who needs to do what?', everybody takes a step back and crosses their arms because now they have to do something*".

These examples illustrate how the Team Alignment Map helped shared leadership emerge within the teams by addressing its three characteristics. The remainder of the findings is dedicated to outlining the categories that emerged in our findings relating to the antecedent conditions of shared leadership and how these were supported by the features of the Team Alignment Map.

1.5.2 Team alignment (shared purpose)

Team alignment was perceived as the result of making the four elements of the activity explicit and on which everybody agrees. Team alignment then not only includes sharing the purpose of the activity, but also the commitments, resources, and risks. This suggests that shared leadership does not only depend on the extent to which people manage to negotiate their divergent interests in a shared objective as has been outlined by previous literature, but that individuals should be aware and agree on the four elements. The external coach of the TEX project described this need as follows: "*My fear there and that's happened to me in the past: if you're not aligned on the goals, on what you're trying to achieve, what the level of commitment is and then talk about who's involved and what's involved and the risks… then you risk coming out of any hands-on session and everybody going in different directions that they think they agreed because they didn't explicitly visualize or ever talk about it*". This also suggests that team alignment is supported by the facilitating feature of **shared visualization** that The Team Alignment Map provides. In fact, it is facilitated by the fact that team members "*have that all explicit on the tool*" (external coach, TDC) which makes "*[the discussion] more tangible*" (methodology expert, TEX).

1.5.3 Voice

Voice is the degree to which a team's members have input into how the team carries out its joint activity. In each project, team members related that the Team Alignment Map was useful in facilitating interaction among them and that they felt a collective sense of contribution and responsibility. Voice is more than just interaction or communication - it is about the feeling of being heard and listened to, and therefore being empowered through communicative participation in a project discourse, including critical events such as sense making and decision making. In what follows, the rise of voice in team collaboration with The Team Alignment Map is elaborated.

The methodology expert of the TEX project described that using the Team Alignment Map "*is not so much filling it out and assigning roles and responsibilities to people. It's more 'okay here are the main points we need to make sure that we cover'*". Team members interpreted the empty columns of the the Team Alignment Map as a problem space that was shared and was to be used by all parties. This feature of the tool made participants perceive the conversation as an exercise in which everyone had to fill the parts of the empty spaces. As the external coach of the TEX project underlined, "*it becomes more about the structured conversation and the tool, and less an emotionally charged thing where people are just free-*form building other's fears. *And it's okay, you know, 'now we're just trying to fill this out, we're just talking about it'. You can really redirect it back to the [tool]*". This objectification of the conversation made conversations less personal, in which individuals felt welcome to share their opinions and views and where criticism and disagreement were welcome. The external coach of the TDC project regarded the tool as "*a good way for [others] to challenge me and my thinking*". Furthermore, each member could notify any inconsistencies between the elements in the four columns or any missing elements they had noticed, and they did so on their own initiative. "*I find that it also helps you come up with more. Be able to look at it and say 'there's something missing here' or 'we forgot to discuss about the objectives, we didn't talk about the resources'. Visually, it just helps prompt, it becomes a prompt to make sure that it's as complete as possible*" (external coach, PHARM).

Based on these accounts, we can distinguish two ways in which **shared problem space** was perceived to be a facilitating feature in the emergence of voice: Firstly, it facilitated a collective dynamic during the conversation in which everyone was involved and asked for their input. Secondly, the shared problem space provided a visual overview of the elements of the activity that team members put on the Team Alignment Map, allowing them to refine the alternatives that they agreed on.

The **shared visualization** made team members more engaged during the conversation as the conversation became visual and easier to follow. The methodology expert of the R&D project compared a virtual conversation with the Team Alignment Map to a voice-only and concluded "i*f someone had to do this over the phone with me and the client, I might just daze out and then I'd be like 'hey what were we talking about?'. This is just an easy way to keep track on what point we're on. Or what are we working on. I'm super visual.*" The methodology expert of the TEX project even related shared visualization to the binding impact of putting a sticky note that everyone can see: "*The Team Alignment Map makes them pay attention more because they want to make sure 'ok what did I commit to? What did I say I would do?'. I think it makes them a little bit more engaged than kind of designing the agreement [alone].*"

1.5.4 Social support

All respondents perceived that the Team Alignment Map supported their conversation and allowed them to point to topics of discussion that they consider as difficult to address. As the tool was perceived as a **shared problem space** in which the goal was to come up with a mutually satisfying solution, it allowed team members to prompt conversations about topics which they may have left unnoticed but which might have caused harm to the team in the long run. Team members were able to support each other in designing the elements of their activity in a way that might be beneficial to everybody. The external coach of the TEX project related: "*One of the teams I worked with, there weren't any design skills in the team and that was a risk because we needed them. Because I knew this from experience, from our past running experiments that we were going to need some design built. So the Team Alignment Map kind of facilitated the conversation of 'how do we get design skills?' or 'how do we have somebody even host on the team that we can rely on?'*"'.

1.5.5 Social contract

Our analysis identified an additional element that proved important to shared leadership and team alignment, in the form of social contracts. When alignment is reached, it resulted into a social contract between all team members according to six out of seven respondents. This social contract consisted of an "*agreement on what everybody committed to doing*" (external coach, PHARM). It was a social contract "*between what [the team] needs and what we need from each other*" (external coach, TEX). The social contract was in all cases considered as binding. The Team Alignment Map acts a liability that individuals can refer to if commitments are amended unilaterally or not fulfilled. The social contract is what makes team alignment binding and lasting over time. The respondents stressed two critical dimensions of social contracts: (1) they relied on the participation and agreement of all parties, and (2) the social contract must be in a tangible form to avoid any deviations in the future. These dimensions are supported by two features of the Team Alignment Map. The first dimension is supported by the **shared problem space** which calls for the participation and input of all individuals. The second dimension is supported by the **shared visualization**. The methodology expert of project TEX defined the Team Alignment Map as "*some sort of contract where everyone is saying 'Okay, I commit to this'. It's in writing, it's in front of us. Everyone can see that this is something I agree to [...] It's all laid out.*"

1.5.6 Features supporting shared leadership

The results from our analysis show that collaborative tools can through the features of shared visualization and shared problem spaces support the antecedents of shared leadership. While both features are highly interrelated and interdependent in the Team Alignment Map (i.e., the shared problem spaces are represented visually on a shared visual display), our analysis suggests that it is important to consider them separately as they each support a different set of the antecedent conditions of shared leadership (Table 20).

The antecedent conditions of shared leadership that shared visualization supports are team alignment, voice, and social contract. Team alignment is facilitated as the elements that team members agree on are made explicit through tangible marks that are visible by all. This suggests that collaborative tools can support alignment by providing shared tangible points of references. These marks also support the antecedent condition of voice by helping team members follow and understand the conversation. Team members thus have a greater awareness of the conversation. Results suggest that this makes them more comfortable to contribute to the conversation and voice their opinions and suggestions. Finally, shared visualization has a binding impact on team members. When visible by all, the tangible marks cannot be ignored by team members. Whenever an element of the conversation is agreed on and written on sticky notes, team members automatically consider that they all commit to it. This thus creates a social contract between participants for which they feel they all have shared responsibility.

Table 20 - Description of the dynamics between the facilitating features of collaborative tools and the antecedent conditions of shared leadership

Feature of the collaborative tool	Antecedent condition	Description of the relationship
Shared visualization	Team alignment	Tangible marks (e.g., sticky notes in The Team Alignment Map) of the team conversation that are visible by all team members provide explicit points of reference to team members. This facilitates the alignment of the members' understanding of the conversation.
	Voice	Shared visualization allows team members to follow the conversation more easily which makes them more engaged and active in the conversation. It also allows team members to see and voice any inconsistencies or missing elements.
	Social contract	The tangible marks of the elements that the team members agree on have a biding impact as they cannot be ignored or denied.
Shared problem space	Voice	A shared problem space suggests that all team members are to play an active role in the conversation and the solution of the problem. Team members consider that the empty problem spaces are to be used by all parties.
	Social support	With shared problem spaces, team members perceive the conversation as a problem-solving activity in which they feel more comfortable to voice any inconsistencies or missing elements.
	Social contract	As the shared problem space calls for the input and participation of all team members, it creates a binding sense of ownership between them.

The antecedent conditions of shared leadership supported by shared problem spaces are voice, social support, and social contract. In general, shared problem spaces promote a sense of joint inquiry in which everyone is involved and play an active role. Joint inquiry is a process through which individuals jointly explore and define a shared problem, and jointly explore and evaluate alternative solutions to the problem (Figure 19). With shared problem spaces, team members feel that it is appropriate for them to voice their opinions and suggestions throughout the whole process of joint inquiry. They thus feel comfortable enough to share their insights for both the definition of the problem and the solutions. Team members can also collectively assess whether they cover all the elements that are essential to their project and detect any inconsistencies in the way they defined their alignment problem and the solutions. Relatedly, the shared problem space supports social support by making it easier for teams to prompt conversations on elements that might harm the team in the long run. Finally, as the shared problem space calls for the participation of all team members, it creates a sense of collective ownership between them, which translates into a social contract.

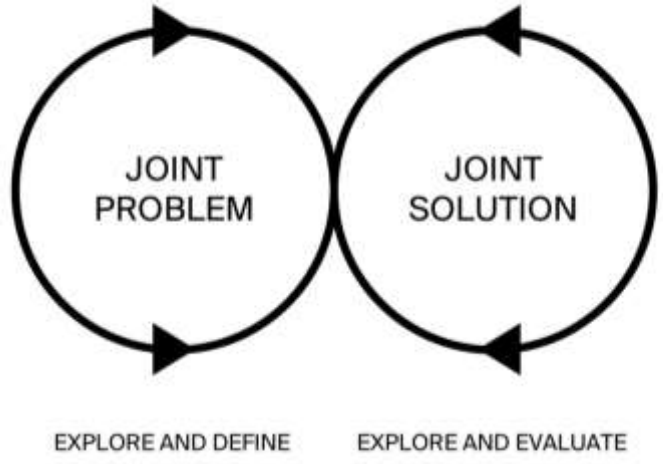

Figure 19 - Visualization of the process of joint inquiry

1.6 Limitations

Given the novelty of the study and the little insights previous literature had provided on the material characteristics that support the emergence of shared leadership, the motivation of this study was exploratory. This explains the reliance on interviews as a method for data collection (Eisenhardt and Graebner 2007; Yin 1994). Further analysis is required to provide more extensive support for the results of this study, which are to be regarded as preliminary and emerging. On the one hand, the findings should be replicated across other cases. One of the limitations of this study is that, despite the findings emerging from ten different cases, they were all related to the innovation consulting company as clients. The effect of the company should be singled out as there might be some organization factors that might impact the results. For example, the company culture may have some impact on the way its employees interact with the clients and the teams they work for and with. Although some differences in the use of the Team Alignment Map were noticed across the informants, this does not totally rule out the impact of a potential shared vision and approach to teamwork that might be more sensitive to the emergence of shared leadership. Also, the innovation consulting company included the Team Alignment Map in its innovation methodology. While this proved valuable in that the use of the Map was rather homogenous – thus excluding the potential effects of different use cases on the results – it could also reflect a similar conception of teamwork that reflects shared leadership. They might, for example, all value the need for everyone to feel safe to voice their opinion or deem that social support is crucial in teamwork. Therefore, other cases are needed to single out for the potential impact of similar conceptions of teamwork. Such cases could include teams in which shared leadership does not seem natural or counterintuitive, so that the validity of the results of this study can be strengthened.

Also, the findings and main conclusion of this study should be refined with additional methods for data collection such as observation, descriptive evaluations, or experiments. Through (non-participant) observation, further light could be shed on how the Team Alignment Map is used *in situ* and how the emergence of shared leadership is practically supported. This could be done through the analysis of the conversational acts that team members use to attend to the three antecedent conditions of shared leadership. Also, the findings could be complemented with descriptive data as soon as the exploratory knowledge on the material characteristics for shared leadership reaches some saturation. This would account for the strength of the relationships between the constructs that are at play, both regarding the social dynamics and the material environment. For example, we might analyze to what extent the shared visualization supports the three antecedent conditions, and for which it is the most relevant. Regarding this, future research should also analyze different forms of shared visualization and shared problem space to identify the most effective means to support shared leadership. In this study, I have mainly outlined that these two characteristics play a significant role, however it would be interesting to identify the effectiveness of different configurations of these aspects.

Also, as noted by Mailhot et al. (2014), leadership is a sociomaterial phenomenon that relies on a variety of tools. Therefore, future analysis should also account for the role that other tools play in supporting, strengthening, or hampering the emergence of shared leadership. In this study, I have mainly focused on the Team Alignment Map due to the exploratory nature of the research project. To provide a more comprehensive account, further work is needed to identify additional material characteristics that support shared leadership and the process of joint inquiry, and how these are related to shared visualization and shared problem space. Such an analysis could also set the boundaries or meta-requirements for the relevance of the process of joint inquiry for shared leadership. Other dynamics and processes may also support the antecedent conditions but through different means. Identifying these could allow for the development of a framework or taxonomy for the sociomateriality of shared leadership.

1.7 Synthesis of Study 3 and additions to the knowledge base

Our results inform us on the role of collaborative tools in the emergence of shared leadership through the case of the Team Alignment Map. It is, to my knowledge, the first study to provide prescriptive insights for all three antecedent conditions. I have identified that there are two features of collaborative tools – shared visualization and shared problem space – which contribute to the emergence of shared leadership. The results indicate that these two features support the emergence of the three antecedents of shared leadership: shared purpose (extended to team alignment), social support, and voice.

Our results are in line with the studies that were not directly linked to shared leadership but appeared to address the antecedent conditions of shared leadership (Table 17). These studies implied that shared purpose could be supported with a visual problem space, social support with making individuals aware of their interdependencies and knowledge requirements, and voice through collaborative tools that make tangible the need for everyone to participate actively. Our study corroborates these hypothesized characteristics. The visual problem space is reflected in our construct of shared problem space, while the awareness of interdependencies and tangibility are addressed by the shared visualization in our findings. Our study thus consolidates the scattered conclusions of prior studies on the material support that allows for shared leadership to emerge.

In addition to these findings, social contract emerged in the findings as an important condition.. The results suggest that the shared nature of the collaborative tool through the combination of the shared visualization and the shared problem space creates a sense of collective commitment. In fact, the combination of these two features makes it evident to everyone that they are all aware of the four elements of the activity and that they agree on them. It is team members themselves who agreed on their own commitments. This indicates that the influence on everyone's actions comes from team members themselves, which is in line with the definition of shared leadership as a mutual influence that comes from team members themselves.

However, these dynamics are not only representative of coordination. In fact, as argued in Chapter 4, our Coopilot conceptual model of team coordination suggests that coordination is mainly a process of conversational interactions to establish common ground on the four requirements, and the monitoring of the level of common ground. The findings of this study encompass these insights through the antecedent condition of team alignment. However, the other conditions, and social contract especially, suggest that the teams engaged in activities and processes in addition to coordination.

Previous research had not identified social contracts as an antecedent condition of shared leadership and we believe this is one key aspect in the role that collaborative tools can play. In fact, our study suggests that when a tool is used collectively for exploring solutions and making decisions on these solutions, it creates a moral commitment between all individuals. Thus, our study suggests that the “sharedness” of a tool through features that promote a spirit of joint inquiry can support dynamics of shared leadership. Not only is this spirit of joint inquiry considered as crucial to the performance of innovation teams, it is also difficult to achieve due to the boundaries that might impede their collaboration (Carlile 2004; Edmondson and Harvey 2017). Our study suggests that one way to go around such challenges is to improve the material conditions of innovation teams through collaborative tools that incorporate features of sharedness and allow for joint inquiry.

In the next section, I will relate the fourth study of my thesis in which we combined this notion of joint inquiry with the Coopilot conceptual model to redefine how cross-boundary teams coordinate and cooperate. In fact, Study 3 suggests that the Coopilot conceptual model is not sufficient, in its current state, to account for the dynamics and activities that the teams displayed. The dynamics that were prompted by the Team Alignment Map were not only related to coordination (as is the case with the Coopilot conceptual model), but also to cooperation through the emergence of shared leadership and the spirit of joint inquiry it promoted. Therefore, in Study 4, I aim to extend the Coopilot conceptual model by including Dewey's (1927; 1929) conceptualization of joint inquiry, which describes how individuals cooperate when they face a shared problem. My goal is to evaluate whether the concept of joint inquiry is compatible with the Coopilot conceptual model, thus cross-boundary team coordination. Study 4 constitutes an addition to the knowledge base on cooperation challenges that emerged from the findings of Study 3 (step 5 in Figure 16, p. 170).

2 Study 4: Bridging coordination and cooperation challenges through joint inquiry

In this section I will relate an extended version of the fourth study I undertook and which is published in *Travaux Neuchâtelois de Linguistique* (*reference* Avdiji and Missonier 2018). Before, I explain how this study is extended in this thesis, I will first outline the reasons that drove me to undertake it.

In this study, I sought to zoom in the first antecedent of shared leadership, i.e. team alignment. Since this antecedent condition equates to cross-boundary condition as defined in the Coopilot conceptual model in Chapter 4, my motivation is to understand whether the process of joint inquiry is also a promising lens for coordination or only for the description of the overall concept of shared leadership in its entirety. In Study 3, the three antecedent conditions were treated as a bundle that would allow for the emergence of shared leadership.

I seek to understand whether and how coordination and joint inquiry are linked, and consequently assess whether the Coopilot conceptual model should be updated to include joint inquiry. In its current state, the Coopilot conceptual model defines cross-boundary coordination as a discursive process through which individuals preform two conversational activities: (1) establish common ground and (2) monitor it to maintain a high level of common ground and avoid misunderstandings. These activities are not in line with those in the process of joint inquiry: (1) explore and define the shared problem, and (2) explore and evaluate alternative solutions. The results in Study 3 hint that the process of joint inquiry may nevertheless be applicable to coordination, as mentioned before. In fact, the Team Alignment Map prompted the cross-boundary teams to enter in a process of joint inquiry into the four requirements for coordination (joint objectives, joint commitments, joint resources, and joint risks). Therefore, in the current study, I am concerned with analyzing how the process of joint inquiry and coordination interact.

Given that the cross-boundary teams in Study 3 worked on innovation projects, I hypothesized that the notion of joint inquiry may become relevant to coordination in situations where there is novelty and uncertainty. This hypothesis is also in line with the emphasis that Carlile (2002; 2004) put on novelty when explaining the challenges that cross-boundary teams face for coordination and cooperation. That is, I seek to understand whether the Coopilot conceptual model for coordination can gain from incorporating the process of joint inquiry for situations with great novelty and uncertainty.

As I will show, the process of joint inquiry is relevant for cross-boundary coordination in settings with great novelty and uncertainty. It allows individuals to have better visibility over their future course of action and establish common ground in fast-paced environments. These findings provide a crucial contribution to my dissertation: it allows me to outline that team coordination and cooperation challenges that cross-boundary teams face in novel and uncertain situations are interrelated and can be overcome if team members engage in joint inquiry.

In this section, I will first review how the literature addresses team coordination in situations characterized by great novelty and uncertainty. The literature review suggests that the current approaches to team coordination do not account for these characteristics. They fail to translate into descriptions of coordination that reflect accurately the reality of team coordination in situations with great novelty. I will propose to augment the Coopilot conceptual model with the notion of joint inquiry. As the process of joint inquiry is highly iterative and continuous, it provides solid basis for explaining how team coordination occurs in dynamic environments. Given the importance of the notion of joint inquiry, I will make some additions to the original article in the section on the conceptual model. Due to the space constraints of the original article, I could not provide a detailed description of the concept of joint inquiry and the new conceptual model. As in the original article, I will then evaluate the relevance of the new conceptual model through the Team Alignment Map and relate how the results should be subject to further validation. Finally, I will provide an extended conclusion including insights that I did not relate in the original paper due to space constraints.

2.1 Literature review: Coordination in novel and uncertain settings

Academic developments on coordination have had two distinct units of analysis: real-time coordination in the here-and-now of face-to-face encounters (e.g. when two or more people coordinate to move a desk outside a room), coordination across time and space especially in organizational settings (e.g. when work teams hold a meeting for a web development project to coordinate everyone's individual contributions). In this paper, we focus on team coordination across space and time.

In such settings, team coordination is the process through which a group of individuals form action plans to integrate and align their contributions, knowledge, and objectives (Rico et al. 2008). Team coordination is one of the main and enduring issues in innovation projects such as the development of new products or software (Espinosa et al. 2002). Such projects stress the need for effective coordination as they are characterized by novelty, shifting or uncertain requirements, low visibility over the future course of action, and partial knowledge being spread across participants (Edmondson and Harvey 2017). The complexity of innovation projects cannot be addressed by single individuals. Therefore, they require the collaboration of multiple individuals with diverse roles, resources, and domains of expertise.

As innovation projects usually last from several weeks to several years, they are structured around an extensive number of recurrent project meetings during which team members integrate everyone's previous contributions (i.e. what actions everyone has performed until the meeting), monitor the situation, and plan the actions that everyone must perform until the next meeting. Team members can also rely on additional coordination devices such as objects (e.g. PowerPoint presentations or contracts) or conventions (e.g. organizational hierarchies) to align their interdependent individual contributions (Klein et al. 2005; Tylén et al. 2009).

Scholars have produced an extensive number of studies to analyze what makes team coordination effective in such settings, producing two dominant theoretical perspectives (Avdiji et al. 2015; Zackrison et al. 2015).

The first is the contingency approach which is concerned with finding the coordination devices for individuals to manage specific types of interdependencies (Espinosa et al. 2004; Okhuysen and Bechky 2009). This approach was initiated by Malone and Crowston (1990) who considered that coordination is effective when there is a match between the situation individuals face and the coordination devices they use. For example, when the activity of one participant depends on the output of the activity of another, the authors suggest that ordering activities sequentially will allow for effective coordination. However, as projects are prone to emerging requirements, continuous change and low visibility (Henderson and Clark 1990), it is difficult for individuals to identify and manage interdependencies between participants and use the right coordination devices (Sosa et al. 2004). In sum, this approach fails to address the complexity and the need for flexible interpredictions during innovation projects.

The second theoretical perspective is the discursive approach. This approach stresses that managing innovation projects is about performing non-recurrent activities, i.e. activities that have very little or no routine aspects or in which routines change. In such cases, teams need to resort to discursive coordination because dependencies between participants can no longer be managed in a predictable and programmed way (Bechky and Okhuysen 2011). Most studies on the coordinative power of language have focused on the here-and-now of simple interactions between (often) two individuals (*e.g.*, Clark and Brennan 1991; Gardner and Levy 2010). Other studies have underlined the importance of communication for high-level team coordination (Bechky and Okhuysen 2011; Minssen 2006; Wittenbaum and Stasser 1998), but they do not explain what makes communication in teams effective. In fact, discursive coordination is not innate and is difficult to ensure for activities involving multiple participants across time and space (Minssen 2006; Sewell 1998). Very often people are not able to create a shared understanding during their conversation because of their different representations, language, and responsibilities (Kleinsmann and Valkenburg 2008). This difficulty increases as the requirements and goals of the joint activity continuously change and are difficult to predict, as is characteristic of innovation projects (Badke-Schaub et al. 2007). Therefore, communication in teams still often leads to ineffective coordination, i.e. participants experience coordination breakdowns, misunderstandings, perception gaps, and wrong predictions mainly due to the team's inability to create shared understanding (Bittner and Leimeister 2014; Mastrogiacomo et al. 2014). As noted by Zackrison and colleagues (2015) most communication researchers have focused on coordinating language, interpersonal interactions, and social ties (*e.g.*, Fusaroli and Tylén 2012; Pearce and Pearce 2000).

We assume that an approach to coordination based on joint inquiry can overcome the limitations (i.e. lack of interpredection flexibility and shared understanding) of both the contingency and the discursive approach in innovation projects. Such an approach would be more effective than traditional accounts to encompass the increasingly important characteristics of innovation projects. For these reasons do we seek in this paper to answer the following question: *How can team coordination through joint inquiry be effective in innovation projects?*

For that, we develop a conceptual model based on Clark's (1996) psycholinguistic theory on joint activities and Dewey's (1927, 1929) concept of joint inquiry which has recently been applied to design thinking (Steen 2013).

2.2 Conceptual model for the design approach to team coordination

To derive our design approach to team discursive coordination, we turn to two theories that have been used in teamwork. We propose to complement Clarks' approach with Dewey's (1927; 1929) process of joint inquiry that is particularly relevant in co-design and design thinking (Steen 2013). Dewey proposed inquiry as a process that starts from a problematic situation in which actors combine doing and thinking to move to the resolution of the problem. When problems have shifting or uncertain requirements and the future course of actions required by individuals is difficult to foresee (low visibility), actors proceed iteratively through exploration and evaluation. They discuss to define the problem and evaluate possible solutions. This process of exploration and evaluation has recently been outlined as important for innovation projects, through the creation of shared and visual problem spaces where individuals can proceed iteratively by prototyping, trying out and selecting alternative solutions (Avdiji et al. 2018; Osterwalder and Pigneur 2013).

Our conceptual model addresses coordination specifically for the challenges of innovation projects: Clark's theory of common ground on the four requirements addresses the distributed and partial knowledge characteristic (shared understanding), while Dewey's iterative process of exploration and evaluation addresses the need to cope with shifting requirements and low visibility over the course of action (need for interprediction flexibility).

Joint inquiry is a democratic process through which individuals who face a shared problem will collaborate to define the shared problem and find potential solutions to it, through a combination of doing and thinking. More precisely, joint inquiry involves the performance of two sets of activities: (1) interactions between individuals to jointly define and explore the shared problem, and (2) interactions to jointly explore, develop, and evaluate alternative solutions to the shared problem. Dewey proposed joint inquiry as a cooperative process through which individuals could improve their situations. His process is prescriptive – or 'melioristic' in Steen's words – in that he wished to empower people with the necessary activities they should perform to improve their conditions and act cooperatively. This emphasis on cooperative attitudes provided an accurate reflection of the nature of the interactions that the cross-boundary teams in Study 3 displayed.

Dewey viewed knowledge as instrumental, in that it is developed through and used for practical experiences. To him, the primary purpose of knowledge is to fuel cooperation and communication between individuals to change their situation. The role of knowledge is not only to describe things and phenomena, it is a tool that individuals use to address problematic situations and engage with their daily experiences. This view of knowledge emphasizes the central role of communication and cooperation, as participants interact with each other to produce knowledge that allows them to explore alternative futures to organize positive change. Knowledge is both a medium for interaction and reflection upon these alternative solutions.

Steen built on the process of joint inquiry to provide a new conceptualization of the process of co-design. Co-design is the process through which individuals from various disciplines share their knowledge and bring various skills to cooperate on the development of an artifact that will address a specific problem. Co-design stresses the cooperative nature of the development of solutions, especially for the users or recipients of the solutions. Steen defines co-design as a three-phase and iterative process during which individuals (1) explore and define the problem they face to have a common understanding and perception of it, (2) simultaneous conceive and refine the problem and possible solutions, and (3) evaluate and try out these possible solutions in practice. Steen's – and by extension Dewey's – conception of co-design reflects the abductive approaches of design thinking. In design thinking, the problem and the solutions are simultaneously and iteratively explored and defined (Dorst 2011). This approach contrasts with the deductive and inductive approaches which describe a more linear process of producing knowledge.

Dewey's consideration of knowledge as instrumental for communication and cooperation reflects the conception of common ground and the use of language by Clark (1996). Both regard information or knowledge as a prerequisite and outcome of activities that interacting individuals perform. However, both operate at different levels of analysis. While the pragmatic account of language by Clark describes the interactional activities between individuals at the level of utterances, Dewey's process of joint inquiry provides a meso-level view of how individuals interact to achieve joint purposes.

I define cross-boundary coordination in novel settings as a process of joint inquiry into the joint objectives, joint commitments, joint resources, and joint risks. Cross-boundary teams thus engage in a process through which they interact to define and explore the four requirements, and explore and evaluate different alternatives to these four requirements. In both these activities, team members must establish common ground on the four requirements. Therefore, team members must agree and share the same understanding of the four requirements both when defining them and exploring the potential combinations of the elements of the four requirements.

This definition is compatible with the actions of presentation and acceptance for grounding. As a reminder, the process of establishing common ground mainly consists of interactions during which the speaker presents a piece of information (signal) to the hearer(s) and the latter accept that piece of information by displaying some evidence of understanding. Cross-boundary coordination in situations with novelty is then conceived as a series of interactions during which team members present and accept potential definitions of four requirements and potential solutions.

2.3 Methodology

Our methodology is based on Hevner and colleagues' (2004) approach to design science research (DSR). We instantiated our conceptual model into the Team Alignment Map. To evaluate the relevance and accuracy of our conceptual model, we evaluate the ability of the Map to support two propositions: (1) The Team Alignment Map supports individuals in creating common ground, (2) The Team Alignment Map increases the team's visibility over their future course of action. The first proposition relates to the

2.3.1 Research setting

We tested the usability and utility of the Team Alignment Map in two settings: a hospitality management school (HMS) and the innovation company of Study 3 (IC). Both contexts were chosen as they had contacted us to help them solve coordination problems for their innovation projects. In the HMS, 12 teams of 6 students, in their last semester of undergraduate studies, were mandated and financially-supported by external clients ranging from local businesses to international companies. Examples of projects include creating a new branding strategy, elaborating proofs of concept for new services, and developing business plans for new ventures. All projects lasted 10 weeks and the curriculum was cleared out during this period so that students could dedicate their full time to the project. The innovation company (IC) is the research setting that I used in Study 3. As a reminder, it was mandated by clients to support them in developing new business opportunities and redesign their organizations and business models. Our analysis includes 10 teams of 5 to 10 individuals working on four different projects. Examples of such projects include developing new products, and testing and validating a new product for a competitive advantage.

2.3.2 Data collection and analysis

Qualitative data analysis is well-suited to analyse complex social processes and phenomena, and perform exploratory research as our research question calls for (Eisenhardt and Graebner 2007). Interview remained the chief source of data collection in agreement with Walsham's (1995, p. 78) observation that "it is through this method that the researcher can best access the interpretations that participants have regarding the actions and events which have or are taking place, and the views and aspirations of themselves and other participants".

We evaluated the Team Alignment Map through semi-structured interviews with users from both cases. In the HMS case, I held semi-structured interviews with members of seven teams at the end of their projects. In total, I interviewed 27 students. We analyzed whether the Team Alignment Map supported teams in coordinating effectively. For that, we inquired on two propositions drawn from the characteristics and challenges of innovation projects, as mentioned earlier: (Proposition 1) to what extent it supported individuals in creating shared understanding, (Proposition 2) increased the team's visibility of their future course of action (flexibility).

The data was analysed using qualitative methods (Flick 2007; Yin 2013). We conducted thematic analysis (Fereday and Muir-Cochrane 2006) in which we both coded the data based on categories relating to the functions of the tool (e.g. support shared understanding, visual support). These categories served only as a foundation for the iterative process which involved going back and forth between the data and the categories. For the purpose of this study, we focused on the codes that pertained to shared understanding and flexibility.

2.4 Findings

In this section, we report excerpts from the main categories that emerged in our data analysis (Table 21). We chose excerpts from both cases but due to space constraints, we cannot outline all supporting claims for our propositions and focus on the quotes that can be understood easily without contextual information.

For 33 out of 34 respondents (the 7 informants from the IC case in Study 3 and 27 students from the HMS case), the Map supported their team in creating common ground on the joint activity (Proposition 1). Common ground was supported by three functions of the tool: its ability to help team members clarify and make explicit the content of the four domains, it made thoughts tangible as they were written on sticky notes so that teams did not merely rely on mental representations, and the creation of shared expectations on the project often through social commitments to what they put on the sticky notes. The shared visualization of the Map improved the team members' ability to reach shared understanding at the end of team meetings. Team members' understanding and intentions for future contributions were aligned, and resulted in social contracts.

Also, 22 out of 34 respondents outlined the prototyping affordance of the tool (Proposition 2). Sticky notes could easily be removed, displaced, added to explore and evaluate alternative solutions. The shared visualization also helped team members monitor the progress they had made since the previous meeting and change their action plans accordingly. The Map thus addressed the need for flexibility on interpredictions that is required during innovation projects, as requirements and contingencies can change rapidly. Thus, in settings characterized by great novelty and uncertainty, engaging in joint inquiry provides a way to coordinate effectively.

Table 21- Propositions and excerpts from interviews in Study 4		
Proposition	Functions of the TAM	Supporting excerpts
P1: The Team Alignment Map supports individuals in creating common ground.	Clarifies and makes explicit the four domains (joint objectives, joint commitments, joint resources, joint risks)	"Basically, the way I looked at [the tool] was "here are our goals, here are our commitments, here are the resources and here are the risks" and just having an open conversation with the company and the team about each of those and making sure that we were all aligned on what those were." IC Team 1 "[The tool] helped us avoid misunderstandings. Without it, we would have had problems communicating effectively." HMS Team 11
	Makes thoughts tangible	"I definitely like using the tool to make my way of thinking and my way of seeing the project explicit." IC Team 6 "It is easier to think about our activity when it is physically there." HMS Team 9
	Creates shared expectations	"[The tool is] really helpful because we can get to a next level of clarity and expectations and, you know, dos and don'ts and what makes sense and what doesn't make sense." IC Team 5 "I found it super helpful [...] for everyone to be on the same page."
P2: The Team Alignment Map increases the team's visibility over their future course of action.	Allows for the team to adapt to changing situations	"Because we might find out later that something I committed to might be pointless or it's just a waste of time for me to even be doing it in the first place. But if I commit to it, I feel like I have to do it, you know? So I think that, that's where going back and revisiting it would be really really helpful." IC Team 2 "It was easy to see the full picture and realize that we needed to add this objective to that and change that one commitment." HMS Team 8
	Facilitates the monitoring of progress	"Because what helps is the visual representation of having that discussion at the end of the workshop and it's a grounding force in order to say "okay where are we now compared to where we were when we started this workshop or when we first started this process? What has changed? What is the team alignment map looking like?" IC Team 3 "And that's cool cause you can go back to it at the end of the project and be like "alright, let's look at this" and you know, do we make it to what we want it to? What we originally set out to do?" IC Team 12

2.5 Limitations

As these findings mainly rely on interviews, there are some limitations to consider when reading the results. The findings should be regarded as preliminary. My main motivation here was to explore whether the Coopilot conceptual model – and the concept of joint inquiry consequently – are applicable and can prove useful for understanding cross-boundary team coordination. Therefore, I have relied on interviews to unveil the cognitive, behavioral, and linguistic dynamics of the usage of the Team Alignment Map regarding coordination. Interviews thus proved the best strategy for accessing these dimensions (Eisenhardt and Graebner 2007; Walsham 1995).

The data from the interviews that I presented here was very concise due to the space constraints of the journal I submitted the original article to. Therefore, the findings do not reflect the data exhaustively as most propositions were supported by additional claims from the cross-boundary teams. I have, however, decided not to change the results sections from the original papers as they represent the most critical part in terms of research. Therefore, this study should be extended, not only with a more extensive set of claims, but also controlled analyses and descriptive data. In fact, I have stated for each proposition how many teams provided responses for each proposition, but these figures should be complemented with more detailed appreciations and some pseudo-quantification strategies in the sense of Yin (1994). One way to tackle this issue would be to use questionnaires, now that the exploratory run is done, to assess the extent to which cross-boundary team members relate to statements regarding the propositions. This would inform the strength of the propositions and the functions of the Team Alignment Map (consequently, the Coopilot conceptual model extended with the process of joint inquiry).

However, the findings need further validation both through case replication and using multiple data collection methods. The latter should include the observation of the coordination dynamics that are at play both when using the Team Alignment Map and after its use. Such an analysis would provide a more rigorous and detailed analysis of the impact of the tool and the process of joint inquiry for coordination. In fact, coordination and the organization of work are sociomaterial practices that involve the use of multiple objects for different purposes (Nicolini et al. 2012; Scarbrough et al. 2015). By using interviews in this study, I have mainly focused on the dynamics related to the Team Alignment Map in use. Therefore, the analysis should be complemented with insights on the support the other tools brought for coordination, and the interplay between the additional tools and the Team Alignment Map. For example, one of the informants of this study (IC Team 4) suggested that he used additional project management tools after the discussions he held with the Team Alignment Map to anchor the commitments they had made and increase the level of detail for the joint objectives until they were translated into tasks. This is an illustration of the dynamics that could be uncovered in an additional study.

2.6 Conclusion

Overall, our findings suggest that the Team Alignment Map supports team coordination during innovation projects by facilitating the creation of common ground between participants and allowing them to define and adapt their future course of action. Our study thus suggests that the design approach derived from Clark (1996) and Dewey's (1927; 1929) process of joint inquiry provides an interesting and valuable approach to team coordination that is particularly well-suited for innovation projects and situations with novelty. The results suggest that the concept of joint inquiry is relevant to team coordination and understanding how teams can overcome their coordination challenges. We conceive team coordination as an activity in which team members jointly inquire into the four requirements for coordination (joint objectives, joint commitments, joint resources, and joint risks). Participants try out and negotiate a variety of combinations of the four requirements and agree on the one they see fit, creating binding social commitments.

This view of cross-boundary coordination provides another perspective on novelty. Carlile (2002; 2004) stated that knowledge boundaries emerge as novelty increases. In situations with little novelty, cross-boundary teams mainly face syntactic boundaries as they need to develop new ways of conceiving and communicating about the new situations they face. As novelty arises, semantic and pragmatic boundaries will emerge and make cross-boundary coordination even more challenging. The conception of cross-boundary teamwork as a process of joint inquiry into the four requirements for common ground provides a theoretical basis that encompasses these three types of knowledge boundaries.

Our approach complements the dominant perspectives on coordination in two ways. Firstly, as outlined before, studies in the discursive approach have failed to provide concrete and actionable guidance on how teams should coordinate. Our approach structures the content (the four columns) and the process (joint inquiry through the forward and backward passes) of coordinative conversations. Secondly, the contingency approach is not suited for innovation projects as requirements and situations change frequently, which leaves practitioners with a difficulty to constantly update the match between new situations and the right coordination devices. Our approach supports flexible interpredictability through one main coordination device in the form of a physical coordination problem space (i.e., Team Alignment Map).

We suggest that further research is required to assess our findings as our approach is nascent. Future studies should make use of direct observation of team meetings as we relied mainly on interviews and thematic coding. Such observations could allow for the identification of conversational strategies and behaviors specific to the design approach of coordination.

3 Synthesis of Studies 3 and 4 and future research

In this chapter, I have presented how the cooperation challenges that cross-boundary team members face can be managed and overcome. These cooperation challenges emerge mainly due to the pragmatic boundaries that cross-boundary teams face. Research has suggested that teams who display shared leadership dynamics are well-equipped to cooperate effectively. Due to the lack of descriptive and prescriptive studies on how shared leadership can be supported, I undertook to answer the question: *How can we support cross-boundary teams in developing shared leadership to cooperative effectively?*

3.1 Contributions to descriptive knowledge

This Chapter has also allowed me to outline several theoretical contributions. Overall, Study 3 illustrates how a collaborative tool can reshape the way cross-boundary cooperation is perceived. Findings suggested that team members conceived of their activity as a process of joint inquiry in which they needed to explore their problem and develop alternative solutions to it. This led me to propose a conceptualization of cross-boundary teamwork as a process of joint inquiry into the four requirements for common ground. I combined Dewey's (1927; 1929) and Clark's (1996) perspectives to show that the cooperation challenges that cross-boundary teamwork can be overcome if they engaged in such a process of joint inquiry. Using the same visual metaphor as I did for the triangle of coordination in Chapter 4, cooperation can then be conceived as a triangle between joint inquiry, shared leadership, and support form collaborative objects (Figure 20).

Study 3 not only informed us on how cooperation challenges can be overcome through joint inquiry, it also suggested that our approach to team coordination could also be conceived as a process of joint inquiry. Therefore, in Study 4, I sought to evaluate whether the process of joint inquiry was also relevant to cross-boundary coordination. Given that teams in Study 3 described the dynamics of their interactions as a process of joint inquiry and that this joint inquiry supported team alignment (which relates to coordination), I undertook to analyze in greater detail the relationship between coordination and joint inquiry. My motivation was to analyze whether the integration of joint inquiry into the Coopilot conceptual model was relevant to coordination, and bridge cross-boundary coordination with cross-boundary cooperation. The evaluation in both cases provided evidence for the relevance of considering cross-boundary coordination as a process of joint inquiry in situations where there is great novelty and uncertainty. Findings seem to confirm that the inquiry into the four requirements for coordination through the Team Alignment Map helped teams create common ground (Proposition 1) and increased their visibility over their future course of action.

Figure 20 - Visual metaphor of the triangle of cooperation

The findings from both studies suggest that the notion of joint inquiry proves relevant to address both the cooperation and coordination challenges that cross-boundary teams face in novel and uncertain settings. This finding reinforces Carlile's (2002; 2004) conceptualization of the three knowledge boundaries that emerge as the novelty of the situation becomes more important. Cross-boundary teams first face syntactic boundaries (differences in vocabulary and lexicon) and semantic boundaries (differences in perception and understanding) which increase the difficulty of coordinating. In situations with great novelty, he suggested that teams will face pragmatic boundaries (divergent interests and agendas) in addition to syntactic and semantic boundaries, thus making cooperation difficult. The integration of the process of joint inquiry into the Coopilot conceptual model provides a comprehensive account of how these boundaries can be addressed in novel and uncertain situations.

These insights allow me to extend the Coopilot conceptual model with two main additions (Table 22, grey-shaded cells were part of the Conceptual model as extended in Chapter 4). Firstly, I add to the process of coordination in the previous version of the conceptual model (Table 15, p. 151) that the process of coordination is not only the management of common ground but also a process of joint inquiry. This underlines the challenge of managing novel and uncertain situations. Secondly, I added insights on cross-boundary cooperation and shared leadership.

Finally, as noted in the limits of Studies 1 and 2 in Chapter 4, I had evaluated the Coopilot conceptual model and the Coopilot App with cross-boundary teams in cooperative settings. Combining these insights with the results of Studies 3 and 4 suggests that cross-boundary team cooperation is a prerequisite to cross-boundary coordination. That is, coordination cannot occur in teams that do not have cooperative attitudes. The current chapter suggests that cooperation is thus a necessary condition for teams to coordinate. I argue that the link between coordination and cooperation is represented by the antecedent condition of social contracts, which I identified in addition to the other three antecedent conditions (team alignment, social support, and voice). The findings suggest that social contracts are the crossing point between cooperative attitudes (or shared leadership) and coordination (team alignment). Social contracts not only fuel cross-boundary cooperation through the emergence of shared leadership (Study 3), they also bind the commitments made by team members on their future course of action (Studies 3 and 4). I conclude from these studies that cross-boundary coordination and cooperation challenges can be overcome if team members manage to jointly inquire into the four requirements and create social contracts between them on these four requirements (Figure 21).

Table 22 - Extension of the Coopilot conceptual model to coordination and cooperation

Dimension	Construct	Construct type	Sub-constructs	Definition
Cross-boundary coordination	Condition: high level of common ground	Content	Four requirements	The content for which team members must have common ground to coordinate effectively (joint objectives, joint commitments, joint resources, and joint risks).
		Process	Managing common ground	Establishing and monitoring common ground. Material support provides the greatest evidence of understanding through visualization.
			Joint inquiry	The process through which individuals solve a common problem. Includes two activities: (1) explore and define the problem, (2) explore and evaluate alternative solutions.
	Challenges	Knowledge	Syntactic and semantic knowledge boundaries	Differences in vocabulary and interpretations that are characteristics of cross-boundary teams.
		Situation	Novelty and uncertainty	Characteristics of projects in innovative contexts that lower the visibility over the project and interdependencies between team members. Can be materially supported through tools that support joint inquiry.
Cross-boundary cooperation	Condition: shared leadership	Content	Four antecedent conditions of shared leadership	Team alignment, social support, voice, and social contract. Allow for shared leadership to emerge so that teams cooperate effectively.
	Challenges	Knowledge	Pragmatic knowledge boundaries	Divergence in interests and agendas that are characteristic of cross-boundary teams.
		Situation	Novelty and uncertainty	Characteristics of project in innovative contexts that increase pragmatic boundaries. Can be materially supported through tools that support joint inquiry.

Figure 21– Visual metaphor of hourglass of social contracts

3.2 Contributions to prescriptive knowledge

In Study 3, I have shown that the Team Alignment Map helps address cooperation challenges by supporting the emergence of shared leadership. I have shown how the Map addresses the three antecedent conditions of shared leadership, i.e. shared purpose (extended to team alignment), social support, and voice. I have also outlined that social contracts allow for the shared leadership to materialize into commitments that bound team members and secured shared leadership. These antecedent conditions are supported by two main characteristics of the tool: shared visualization and shared problem space. Shared visualization supported team alignment by providing visual points of references of team discussions (team alignment), made them more engaged in the conversation as they could follow the conversation more easily (voice), and made them be more committed to the joint activity as they visually stated what they would contribute to (social contract). The shared problem space suggested that the input of all team members was required (voice), made teams perceive of their joint activity as a problem solving and joint inquiry process in which individuals felt more comfortable stating their opinions (social support), and created a binding sense of ownership of the joint activity as it suggested that the input and participation of all was required (social contract).

In Study 4, I reported that the Team Alignment Map also supports the process of joint inquiry to address coordination challenges in situations with great novelty and uncertainty. I have identified five supporting functions which fall under two categories. The Map supports the establishment of common ground which is crucial to coordination, through three functions: (1) it clarifies and makes explicit the four requirements of coordination, (2) it makes thoughts tangible, and (3) creates shared expectations. I have also outlined the features that support joint inquiry in novel and uncertain situations for coordination: (4) the Map allows for the team to adapt to changing situations, and (5) it facilitates the monitoring of progress.

Overall, I have shown through the four studies in these last two chapters that material support can be provided to cross-boundary teams to manage the challenges that emerge from the three knowledge boundaries that were outlined by Carlile (2002; 2004). The Coopilot App supported teams in coordinating effectively by allowing team members to evaluate their level of common ground and repair any misunderstandings or perception gaps that might stem from syntactic and semantic boundaries. The Team Alignment Map helps teams manage their pragmatic boundaries in addition to the syntactic and semantic boundaries, as it proved to be useful for both coordination and cooperation challenges, as outlined above. What these tools have in common is the visualization and tangibility they provide on the four requirements. The Coopilot App allowed teams to see their level of common ground on the four requirements, while the Team Alignment Map provided a visual problem space for teams to jointly inquire into the four requirements.

3.3 Limits

As said in both studies, I do concur that these insights need further refinement and validation. In Study 3, I provided initial insights for the analysis of how features of collaborative tools can support the emergence of shared leadership. It is thus important to replicate these results in additional cases of cross-boundary teams. Future analysis should not only include more cases, it should also collect data from a greater variety of sources. Our analysis in Study 3 was limited to interviews as a source of information about the practices of innovation teams. Through additional data collection methods such as non-participant observations, future research could understand the socio-technical dynamics of shared leadership in greater detail and as they unfold. This could overcome the reliance on the ex-post data of our study. It is also necessary to analyze additional collaborative tools to replicate and contrast the findings of our study which was based on the case of the Team Alignment Map only. This could allow future research to confirm our findings and potentially identify other features of collaborative tools that might support the emergence of shared leadership. In general, theoretical advancement and replication is required. I also suggest that further research is required to assess our nascent approach to cross-boundary coordination in Study 4. Future studies should make use of direct observation of team meetings as we relied mainly on interviews and thematic coding. Such observations could allow for the identification of conversational strategies and behaviors specific to the joint inquiry approach to cross-boundary coordination. Studies in design science research that instantiate the process of joint inquiry into artifacts can also contribute to the empirical confirmation of the prescriptive power of this conception of cross-boundary coordination.

In the next chapter, I will further analyze the notion of visualization that proved to be important in both the Coopilot App and the Team Alignment Map. I have instantiated the concept of joint inquiry into the notion of visual inquiry tools, which are tools that build on shared visualization to allow cross-boundary teams to address specific wicked management problems, i.e. the third type of challenges that cross-boundary teams face. I have done so with the Team Alignment Map and two other tools that extensively rely on visualization to help team members address specific wicked problems: business modeling with the Business Model Canvas, and data management with the Data Excellence Model. We analyzed the three artifacts and elaborated a design theory that outlines the role of shared visualization, ontologies, and joint inquiry.

SUMMARY OF CHAPTER 5

Cross-boundary teams may experience cooperation challenges due to their pragmatic knowledge boundaries. The difficulty of aligning their divergent interests and intentions may result in a failure to work together. Prior studies suggest that teams who display shared leadership do not experience such cooperation challenges. To allow for shared leadership to emerge, three antecedent conditions should be met: shared purpose, social support, and voice. However, too little is known on how to support these conditions. The question I sought to answer with the two studies in this chapter is: *How can we support cross-boundary teams in developing shared leadership to cooperate effectively?*

STUDY 3	STUDY 4
This study was motivated by the need to provide prescriptive and actionable knowledge for developing shared in cross-boundary team as shared leadership creates cooperative dynamics between team members.	This study was motivated by the dynamics of joint inquiry that the cross-boundary teams in study 3 displayed. With this study we sought to assess whether joint inquiry is compatible with team coordination.
TEAM ALIGNMENT MAP	**CONCEPTUAL MODEL**
Shared leadership can be supported with tools that provide a visual problem space, raise awareness of interdependencies, and call for active participation by all team members. Based on these insights and the Coopilot conceptual model, we design the Team Alignment Map which allows teams to jointly discuss and explore the content for the four requirements (joint objectives, commitments, resources, and risks).	The combination of the Coopilot conceptual model and Dewey's (1927; 1929) prescriptive and democratic process of joint inquiry suggests that cross-boundary team coordination is a process through which members (1) jointly explore and define the four requirements (joint objectives, commitments, resources, and risks) and (2) jointly explore and evaluate alternatives to these requirements.
EVALUATION OF THE TEAM ALIGNMENT MAP	**EVALUATION OF THE TEAM ALIGNMENT MAP**
The evaluation with 10 cross-boundary teams working on innovation projects suggested that the Team Alignment Map addressed the three antecedent conditions of shared leadership. The Map supported a process of joint inquiry, which appears to be related to shared leadership.	The evaluation with 10 cross-boundary teams and 12 teams of undergraduate students suggested that the Team Alignment Map helped (1) create common ground on the four requirements, and (2) increased the visibility over the course of action. This second point is relevant to situations with great novelty.
CONTRIBUTIONS	**CONTRIBUTIONS**
We designed a tool to support the emergence of shared leadership within cross-boundary teams. We provide design principles that support the three antecedents of shared leadership, and identified social contract as an overarching antecedent for shared leadership.	This study confirms the relevance of the concept of joint inquiry to team coordination in novel situations. We outlined the five characteristics of the Map that supported the joint inquiry into coordination.

KEY TAKE-AWAYS OF THE TWO STUDIES

The two studies suggest that the notion of joint inquiry is relevant to overcome both the cooperation challenges and the coordination challenges that cross-boundary teams face. Cooperation and coordination are linked through the notion of social contracts. Social contracts bind team members (cooperation) and result in common ground on the future course of action (coordination). Using the hourglass metaphor, cooperation makes it possible for coordination to occur through social contracts. This chapter also informs us on the need to provide material and prescriptive support for the process of joint inquiry through shared and visual problem spaces, for both coordination and cooperation.

CHAPTER 6

SUPPORTING WICKED PROBLEM SOLVING

ABSTRACT OF CHAPTER 6

Following the value and relevance that the process of joint inquiry has for the coordination and cooperation challenges in cross-boundary teams, I conclude the presentation of the studies of my doctoral research with two studies suggest how to support joint inquiry to address the third challenge that cross-boundary teams face: wicked problem solving. There have been extensive developments of visual inquiry tools in the past decade, following the success of the Business Model Canvas (Osterwalder and Pigneur 2010). Such tools are assumed to support the process of joint inquiry through shared visualization. But since their development has mostly relied on the imitation of the Business Model Canvas without building on rigorous design science research, the following question arises: *How can we design visual inquiry tools that guide cross-boundary teams in solving wicked problems?*

In study 5, which was published in 2018 in the proceedings of the *Hawaii International Conference on System Sciences (HICSS)* (*reference* Avdiji et al. 2018b) in which we related the design principles that allow for teams to inquire into two different wicked management problems, i.e. cross-boundary teamwork with the Team Alignment Map and business modeling with the Business Model Canvas. The two tools represent instantiations of extensive design science research projects. The paper was nominated for Best Paper Award.

This study was later extended in Study 6 which is under review for a special issue on design science research knowledge accumulation in the *Journal of the Association for Information Systems* (JAIS). In this paper, we included an additional case, the Data Excellence Model which is used to inquire into data management strategies. In this study, we refined and extended the findings of Study 6. We expanded the design principles found in Study 5 to a nascent design theory. Therefore, in this chapter I will relate the original article of Study 6 as it encompasses all the findings of Study 5 but with greater detail and useful additions. Study 6 covers all eight components of Gregor and Jones' (2007) framework for design theories in IS, whereas we only outlined design principles in Study 5.

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1 Studies 5 and 6: Designing for wicked management problems

The reality cross-boundary teams face today is increasingly characterized by wicked problems. Such problems are complex, unique, intangible, and difficult to define and ultimately solve. This is for instance the case of strategic management (Camillus 2008; Clegg et al. 2011) or new product development and service design (Dunne and Martin 2006; Steen et al. 2011). As these problems are not governed by stable and linear causal mechanisms (Dunne and Martin 2006; Farjoun 2010), they are often addressed with iterative approaches such as design thinking and joint inquiry (Détienne 2006; Martin 2009; Steen 2013). Joint inquiry is a process through which cross-boundary teams who face an uncertain situation define and explore a problem, and generate and evaluate different hypotheses about how to solve this problem. These approaches are becoming more popular for wicked problems than traditional linear approaches since they allow for iterative and creative processes (Boland et al. 2008).

Practitioners make use of a variety of tools to navigate the complexity of joint inquiry (Dalsgaard 2017). Work is increasingly mediated by objects and tools used for purposes and functions (Nicolini et al. 2012). Among this variety of tools, recent years have seen an emergence of what we call *visual inquiry tools* to support the process of exploration and ideation of the wicked problem. Examples of such tools include the Business Model Canvas (Osterwalder and Pigneur 2010), the Project Canvas (Habermann and Schmidt 2014), the Innovation Matrix (Van der Pijl et al. 2016), or the Customer Journey Map (Kalbach 2016). Such tools are often in the form of shared and visual problem spaces in which teams can collectively explore and evaluate different hypotheses about a wicked problem.

As these tools have gained in popularity and adoption, it is important to know to what extent they support the process of joint inquiry and through which principles of form and function. However, it is not clear how rigorously and theoretically sound these tools are designed. There is a lack of systematic or rigorous prescriptive knowledge for the design of such tools that could inform future developers. Since this visual approach to inquiry tools may prove useful to address wicked management problems, the development of prescription for their design is increasingly called for. The lack of such knowledge leaves room to potential inconsistent developments that are solely based on the imitation or replication of existing tools, without a clear and rigorous conceptualization on the functions and form of the intended design. For these reasons, we seek to answer the following question: *How can we design visual inquiry tools that guide cross-boundary teams in solving wicked problems?*

To answer this question, we propose a design theory based on three independent design science research (DSR) projects. The theory integrates principles and knowledge from three visual inquiry tools, each of which addresses a specific wicked management problem. Our design theory informs us that such tools have three fundamental pillars: (1) an ontology that frames and defines the wicked management problem at hand, (2) a simple and shared visualization of the ontology, and (3) a set of directions for use that users can follow to solve the wicked problem.

Our study makes three major contributions. First, we propose a design theory that provides sound guidelines for future designers to develop visual inquiry tools for additional wicked management problems. Second, our methodology, which is based on the theorizing process by Lee et al. (2011), illustrates the accumulation of knowledge and can therefore inform design science researchers who wish to develop design theories for multiple artifacts and projects. Third, we demonstrate the potential of the information systems (IS) discipline and its extensive DSR tradition for the design of tools that are relevant and appropriate for the realities of management.

2 Literature Review

The practice of management has been strongly mediated by tools supporting and guiding practitioners in a wide range of tasks and problems (Jones et al. 2013; Orlikowski 2010; Putnam 2015; Stigliani and Ravasi 2012). Tools can be any kind of object, concept, framework, method, or model that aid practitioners in analyzing and solving a problem, making decisions, and collaborating with others (Lee and Amjadi 2014; Nicolini et al. 2012). The 1980s were a particular decade which saw the development of an extensive number of management tools that are still widely used today, such as "the Five Forces" (Porter 1979), strategic group maps (McGee and Thomas 1986) or the BCG growth-share matrix (Henderson 1979). Such tools were among the first to target specific management activities and assisted practitioners in analyzing a situation and evaluating strategic choices (Jarzabkowski and Kaplan 2015). These tools were developed based on the assumption that management activities mainly required procedural rationality (Simon 1978), which is the use of rational and causal thought processes to come to a decision or a solution. Therefore, they were primarily developed for the purposes of rational analysis and decision-making processes (Cabantous and Gond 2011; Jarratt and Stiles 2010).

The problems that managers have been facing in the last two decades have increasingly been inscribed in what we call wicked management problems. Such problems are typically uncertain and not governed by stable or linear causal mechanisms (Dunne and Martin 2006; Farjoun 2010) making them less suitable for rational and causal thinking (Buchanan 1992). This is for instance the case in strategic management and business modelling (Camillus 2008; Clegg et al. 2011), information systems development (John and Kundisch 2015), new product development and service design (Dunne and Martin 2006; Steen et al. 2011), and the organization and coordination of work (Okhuysen and Bechky 2009; Minssen 2006). Wicked management problems are complex, unique, intangible and hard to define. They cannot be well-specified or clearly described and requirements are either changing or ambiguous (Buchanan 1992; Dorst 2006; Simon 1978). Moreover, the solution to a wicked problem is usually also based on stakeholders' judgments and mutual satisfaction, since there are no "universal solutions" nor "stopping rules" (Rittel and Weber 1973).

Various scholars have argued that wicked problems are better addressed by designerly inquiry (Boland et al. 2008; Brown and Martin 2015; Détienne 2005; Dunne and Martin 2006). This type of inquiry is an approach to innovation and the resolution of problems that is highly iterative, abductive, collaborative, and creative. It focuses on delivering a solution via prototyping and testing parts of solutions until a satisfactory solution is reached with stakeholders (Brown 2009; Seidel and Fixson 2013). As Dalsgaard (2017) and Steen (2013) argue, designing is a process of *joint inquiry*, building on Dewey's work (1927; 1929). When individuals face an uncertain and complex solutions – as is the case with wicked problems – they jointly explore and define the problem, and jointly develop and evaluate hypotheses about how to solve the problem in an iterative and democratic way. Hence, individuals do not merely analyze a situation and make decisions based on causality, they rather experiment with different understandings and hypothesis of the problem and try out different solutions until a satisfactory one is reached.

As traditional management tools mainly address the description and analysis of the situation and are not intended for a collaborative use (Jarzabkowski and Kaplan 2015; McMillan and Overall 2016; Teece 2010), a new type of management tools has emerged in the last years to guide practitioners throughout joint inquiry, which we term as visual inquiry tools. Examples of such tools include the Project Canvas (Habermann and Schmidt 2014), the Innovation Matrix (Patrick van der Pijl et al. 2016), the Operating Model Canvas (Campbell et al. 2017), the Customer Journey Map (Kalbach 2016), and the Market Opportunity Navigator (Gruber and Tal 2017).

These tools have been developed to aid a less linear and more creative problem-solving process relying on design techniques and the benefit of visualization for collaboration (Comi and Bresciani 2017). According to Dalsgaard (2017), they allow one to approach and transform uncertain situations in which there are no straightforward answers by helping to better understand a problem, explore and make sense of the problem. Also, such tools support the forming of ideas and hypotheses on how to address the problem and experimenting with these ideas in practice (Horn and Weber 2007). Table 23 summarizes and positions the visual inquiry tools in comparison with the traditional management tools.

Table 23 - Comparison of traditional and visual inquiry tools		
Type of tools	Traditional management tools	Visual Inquiry Tools
Management problems addressed	Well-structured problems	Wicked problems
Problem-solving type	Analytical and rational processes of decision making, planning, and optimization.	Joint inquiry: exploring alternative hypothesis, creative and iterative design, design thinking.
Examples	Porter's Five Forces, BCG growth-share Matrix, Strategic group maps.	Project canvas, Innovation Matrix, Business Model Canvas, Operating Model Canvas, Customer Journey Map, Portrait of Design Essence, Market Opportunity Navigator.

Given the increasing amount and use of visual inquiry tools, it seems crucial to accumulate knowledge on how to design and evaluate them. The lack of theoretical insights on the design principles and qualities of such tools has been problematic as the developments have so far relied on intuition or the imitation of existing tools, without a clear and rigorous conceptualization on the functions and form of the intended design. Designers can then only rely on the apparent features and properties of other tools and miss rigorous guidelines on the design process and activities (Piirainen and Briggs 2011). For instance, several design science researchers could only replicate the logics behind the design of existing tools without prescriptive knowledge for their development (Campbell et al. 2017; Chandra-Kruse and Nickerson 2018). Moreover, as noted by Osterwalder and Pigneur (2013), the IS field has the opportunity and potential to contribute to the emergence of visual inquiry tools by building on its long tradition of developing design knowledge via DSR, and the modeling, formalization, and representation of concepts and problems addressed by such tools. These reasons motivate the question that drives this research project: *How can we design visual inquiry tools that guide cross-boundary teams in solving wicked problems?*

3 Method

To answer the question, we develop a design theory for visual inquiry tools by theorizing the knowledge acquired from three design science research cycles following Lee and colleagues' (2011) framework for theorizing design, Kuechler and Vaishnavi's (2012) development process, and presenting the design theory according to Gregor and Jones' (2007) guidelines. A design theory is a set of principles and knowledge that describe and guide the design of an artifact in order to attain a specific goal in the material world. Our design theory seeks to provide prescriptive knowledge, in part in the form of design principles, that applies to the same class of problems (i.e. wicked management problems). It accumulates the experiences from the development of visual inquiry tools pertaining to different contexts (*e.g.*, business model, team collaboration, data management). In Baskerville and Pries-Heje's (2014) terminology, our design theory aims at great projectability, the equivalent of generalizability in descriptive theories (Lee and Baskerville 2003; Nagel 1961). A design theory is said to have great projectability when it can be applied (or projected) to different instances or environments that do not necessarily need to be defined or tested at the time of theorization. In our view, our design theory has high projectability within wicked management problems and we relate three evaluated projections via our three cases. In other words, this study is the result of knowledge accumulation and reuse across these three cases (Majchrzak et al. 2004; Markus 2001). In Gregor and Hevner's (2013) terms, our design theory represents a contribution to knowledge of level 2, since we identify a nascent design theory with its related constructs, models, and design principles. In the remainder of this section, we will present the three DSR cases we used to develop the design theory and then will describe the theorizing process we followed.

3.1 Describing the Cases

We theorize the design of three cases that illustrate the iterative development of visual inquiry tools for wicked management problems based on a design thinking paradigm (Table 24). The cases represent three extensive design science research initiatives that have been undertaken separately. These three cases are critical cases, since they are among the few representative examples of visual inquiry tools that our research questions target and were designed based on both theoretically sound, rigorous academic works as well as being grounded in practice. These artifacts were all developed in close collaboration between academics and practitioners, and were continuously refined based on evaluations in situated contexts. Moreover, these three projects produced artifacts that are extensively used and adopted in practice. For example, the Business Model Canvas is used by more than 5 million people globally (Strategyzer 2015) and is arguably a quasi-standard in the field (Massa et al. 2016). The Team Alignment Map was developed in June 2016 and has since then attracted more than 200 requests for proposals and training, while the Data Excellence Model is used by data specialists in more than 30 companies. Hereafter, I will describe the Business Model Canvas and the Data Excellence Model. The description of the Team Alignment Map is already provided in Chapter 5.

3.1.1 The Business Model Canvas

Motivation. In a business landscape characterized by complexity and uncertainty, in which business models demand the coordination of an increasing number of stakeholders (Teece 2010), there needs to be a tool to understand, map and share a firm's business logic. This was the logic behind the Business Model Canvas when it was designed (Figure 22). Particularly, the idea was to bring a common ground for entrepreneurs from different backgrounds to look at their business model in order to ask themselves the right questions.

Description of the tool. The Business Model Canvas is a collaborative tool for business model development (Osterwalder and Pigneur 2010). The Canvas defines business models as having nine components, and presents these components via a visual template in either the form of a paper-based F1 poster or on a computer-based support to facilitate generating and communicating business model ideas. Because the Business Model Canvas seeks to help users inquire into business models, its designers have instantiated the nine elements of the business model ontology as building blocks (i.e. empty problem spaces) on a shared large print paper-based canvas. As the Canvas is visualized by all participants, the nine building blocks provide a structure for group reflection and discussion in which all participants actively and collaboratively participate. Each block is depicted as an empty space that users discuss and fill with sticky notes on which they write elements of the solution of the organizations' building blocks. The tool supports joint inquiry, since it allows team members to jointly discuss and define the business model problem they face, and to discuss and explore alternative solutions.

Table 24 - Overview of the cases			
Management tool	Business Model Canvas	Team Alignment Map	Data Excellence Model
Wicked management problem	Business modeling	Team coordination	Corporate data management
Adoption and use	Adopted by people worldwide, including startups, SMEs and large organizations for business modeling, strategic management, and competitor analysis.	Adoption by teams to manage collaboration and project kick offs in organizations in different sectors, including healthcare, consulting, education, and manufacturing.	Adoption by more than thirty large European companies to define their corporate data strategy and/or to assess and develop data management for digital scenarios. Used also for maturity assessments and to monitor progress.
Development	2000 to 2004: Design of the business model ontology 2004 to 2007: Creation of a visual representation of the ontology into the Business Model Canvas 2008: Business Model Workshops to test usefulness of the tool 2011 to 2012: I-pad app and web-app along with business model mechanics (adding a function to the canvas: testing of hypothesis based on the lean startup approach).	2012 to 2014: Design and evaluation of the ontology of team coordination in three organizations. 2014: Mobile application 2016: Shared visualization of the ontology into the Team Alignment Map. Evaluation with 12 teams of 6 students working on innovation projects. 2017: Refinement of the shared visualization and evaluation of the directions for use 10 professional teams in innovation projects.	2006 to 2009: Design of the initial reference model; 2009 to 2015: Stable reference model, but ongoing refinement of building blocks 2015 to 2017: Revision of the reference model, shared visualization into the Data Excellence Model.

Development process. The development of the Business Model Canvas started in conversations between Osterwalder and Pigneur, which led to Osterwalder's thesis (2004) and a first article (Osterwalder and Pigneur 2002) in which they tried to understand how business models could be described and represented so that tools and concepts could be developed for business modeling. To tackle this question, they designed a rigorous ontology of business models, which they called the business model ontology (BMO). The goal of this ontology was to define the main components of business models and their relationships. To develop the BMO, Osterwalder and Pigneur (2002), identified the key concepts and relationships in the domain of business models. These were extracted from an extensive literature review for which they produced definitions. Finally, they identified terms to refer to these concepts and relationships using labels. By following this process, they identified nine building blocks, which they represented as a set of boxes that were related by arrows to depict their relationships.

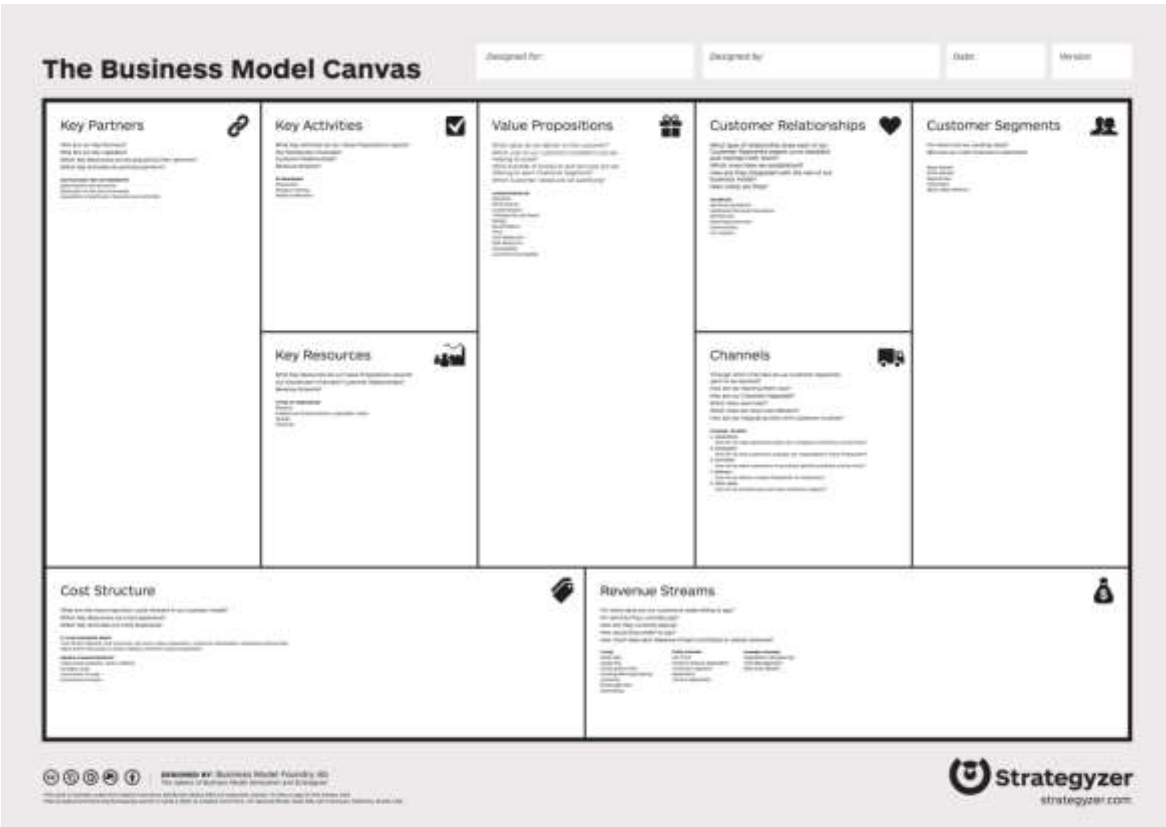

Figure 22 - The Business Model Canvas

The business model ontology was instantiated into a shared visual tool, the Business Model Canvas (Osterwalder and Pigneur 2010). The key components from the ontology development were retained. The relationships were used to set the order of the components. A conceptual map was built upon the ontology, to relate all the concepts. The conceptual map was the basis to the structure of the visual instantiation. Concept maps have an additional level of abstraction compared to ontologies which makes them less complex to understand and use. The Canvas was designed based on this ontology and the intended functions and goals the designers bore in mind. These goals included (1) the business model tool should help business practitioners understand a business model and the relationships behind its elements more quickly, and (2) it should create a common language to improve communication between the stakeholders when addressing business model issues (Osterwalder and Pigneur ,2013). One of the hypotheses behind these goals was that a visualization tool would improve communication quality between stakeholders and would allow them to inquire into business models more easily.

Adoption and use. The Business Model Canvas is seen as essential for entrepreneurs to conceptualize, prototype and test their business model (Trimi and Berbegal-Mirabent 2012). John and Kundisch (2015) go further, stating that the Business Model Canvas is arguably the most important tool for this purpose. In fact, the tool has attracted tremendous interest in practice as the designers of the tool state that more than 5 million downloads of the tool were made globally (Strategyzer 2015). By 2015, the book *Business Model Generation* had sold 1,5 million copies, and more than 400 universities have used the Canvas for at least one course. In practice, the Canvas has become the quasi-standard for describing business models. Moreover, the impact of the Canvas is not limited to practice, since the book describing the tool has been referenced by more than 6,000 academic studies according to Google Scholar.

3.1.2 The Data Excellence Model

Motivation. In the digital and data-driven economy, companies realize that they are increasingly dependent on data, but they hardly manage data as a corporate resource (Redman 2013). One of their key problems consists in the lacking common language and conceptualizations of data strategies between business, data and IT to discuss data's role in business and to identify, align and share data management approaches. Thus, they revisit their existing data management approaches and fundamentally rethink their ways of managing data with an increasing focus on collaborative working and joint inquiry. The work on the Data Excellence Model (Figure 23) was initiated by a consortium of data management experts, comprising practitioners and academics, with the goal of supporting transformation towards data-driven enterprises.

Development. The Data Excellence Model has its roots in 2006, when a group of data management experts decided to launch a research consortium on corporate data quality. They found it very hard to improve data quality in their companies, due to a lack of knowledge and awareness about data. By working on a domain reference model, their goal was to create a shared language and understanding of the problem and the required practices to align stakeholders from different units and backgrounds (business, data, IT) when working on the design of a data strategy. Since then, senior data management professionals from more than 30 European enterprises in various industries and researchers from three academic institutions have contributed to the artifact’s development and its refinement based on user feedback. The initial artifact was designed in 2006, following the consortium research approach (Oesterle and Otto 2010), and is based on a systematic analysis of relevant academic literature and practical experiences in data management. It remained stable for almost 10 years (Otto et al. 2007) and was also adopted by the European Foundation of Quality Management as their Corporate Data Quality Framework (EFQM 2011). In parallel, the different building blocks were further refined by ongoing research activities, resulting in working papers (practitioner guidelines) and more than 10 dissertations (academic results). In 2015, a revision of the reference model was initiated by the companies to address the changes resulting from increasing digitalization and exploding volumes of “Big Data”. The requirements and the emerging reference model were discussed and evaluated at five consortium workshops between February 2016 and February 2017. Besides several additions to the model, visualization was considered as a priority in the revised version in order to communicate and work with stakeholders from business and IT.

Description of the tool. The Data Excellence Model (Pentek et al. 2017) was designed as a reference model that outlines the main design areas that stakeholders of data management practices must inquire into when defining a data strategy. It is also used by companies to effectively manage data as corporate resource. It specifies the generally valid elements of a system that can serve as a reference for designing company-specific models.

Given the understanding of data as a strategic resource for the digital economy, the structure of the reference model builds on existing work from performance management, that measures, controls, and communicates indicators to improve the organizational achievement of objectives (Dahlgaard et al. 2013). The reference model reflects a continuous management cycle and organizes building blocks for data management in three categories – goals, enablers, and results – that are interlinked in a continuous improvement cycle. Goals define the strategic direction for data management, enablers facilitate the goals, and results measure the achievement of the goals. Improvement emphasizes the dynamic nature of the model, indicating a process to adjust the goals and improve the enablers.

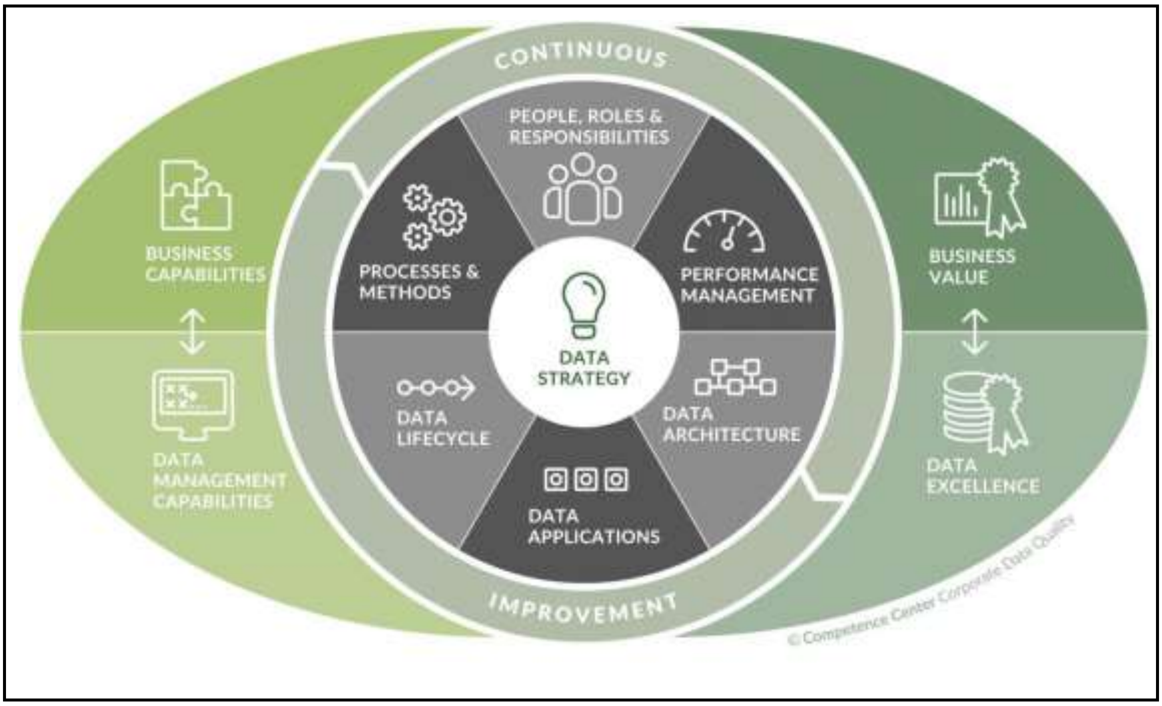

Figure 23 - The Data Excellence Model

The following most common data management design areas are considered to be *enablers*: data strategy, performance management, organization, processes and methods, data architecture, and data management application*s*. These design areas were already part of the initial version and confirmed as very relevant by the data managers in the consortium research program. However, to address the requirements of the digital economy, were considered – based on the practitioners' inputs – five further design areas. To align data management with the business, capabilities in the model's goals section were introduced. Capabilities describe what a company does or it should be doing. By first reviewing *business capabilities* and then identifying the required *data management capabilities*, data managers are able to directly align with the business. Data management has two outcomes. On the one hand, data management directly impacts data itself, defined as *data excellence* in the reference model. These data-related results consider data quality levels and the fulfillment of data compliance, data security, or data privacy requests. On the other hand, data excellence helps to create value in the business, as reflected in the *business value* design area.

The Data Excellence Model is available as a visual tool that can be printed as a poster and used with sticky notes during workshops. It also comprises a set of PowerPoint templates that may be filled by teams and may be adjusted along corporate identity guidelines. It is published under a creative commons license.

Adoption and use. The Data Excellence Model is widely adopted in practice. Hundreds of European professionals have been trained on the Data Excellence Model (and its predecessor). It is extensively used by companies from different industries (among them chemical and pharmaceutical industry, consumer goods, machinery and automotive, infrastructure providers). They typically use it to inquire into the corporate data strategy in a series of workshops with a larger number of stakeholders from business, IT and data management. The DXM is also used to analyze specific digital and Big data scenarios, for instance preventive maintenance for smart machines or digital marketing, in order to design the data strategy and future data management practices. It is also used to analyze specific digital scenarios, for instance smart machines, and to design the required data management capabilities. Finally, it is also used to assess the as-is state and monitor progress.

3.2 Process of theory development

To theorize the design, we both attended to Lee and colleague's (2011) framework for how to formalize knowledge from design science research projects and Gregor and Jones' (2007) anatomic structure of what a design theory should contain. These two frameworks were used to formalize and accumulate knowledge. The development of the design theory was also informed by the process defined by Kuechler and Vaishnavi (2012) and insights from our own experiences within our research projects. In their framework (Kuechler and Vaishnavi 2012, Figure 1, p. 399), our development corresponds to a Design-Relevent Explanatory/Predictive Theory (DREPT). That is, we aim to provide explanatory and predictive guidance on how to develop tools that support cross-boundary teams in jointly inquiring into the class of wicked management problems.

To develop the theory, we first identified the constructs that were relevant in the respective kernel theories of the three design science research projects. We focused on constructs that relate to the problem our cases address, and how they propose to solve it. In that sense, what appeared to be important were the two constructs of wicked management problems and the process of joint inquiry to solve them (Dewey 1927; 1929; Steen 2013). We identified for both these constructs the insights we had accumulated from our research projects and that proved useful for our aim of developing prescriptive knowledge. Regarding wicked management problems, we identified that the main issues were related to the confusing, emergent, and uncertain nature that made them hard to solve (see Avdiji et al. 2018b). Regarding joint inquiry, we identified the main activities that are involved in this process – i.e. jointly discussing and exploring the problem, and jointly discussing and evaluating alternative solutions – and how our cases addressed these. The goal here was to capture the relevant aspects that both identify the problem and the solution we propose with our design theory. Doing this is important as these constructs inform and are captured implicitly in the design of the artifacts (Arazy et al. 2010).

The identification of these constructs was also reflected in the major stages of the three design science research projects (see Table 24). The three cases were first concerned by identifying and exploring the respective wicked management problems they face. In this stage, the problem was framed using different means such as the development of an ontology for the Business Model Canvas (Osterwalder 2004) or the synthesis of the main building blocks of data management reference models for the Data Excellence Model (Pentek et al. 2017). These stages highlighted the need for the artifact to frame the wicked management problem they tried to address and thus informed our first set of design principles (Table 25). This frame was then translated subsequently into a shared visualization, which informed our second set of design principles. Finally, different use cases and scenarios were developed for the three cases to guide the process of joint inquiry. This informed our last set of design principles. Observations of the practices of use allowed us to foresee and predict potential mutability routes for the three artifacts, and thus generalized to the three flexibility issues we cover in our design theory.

Overall, the development process was motivated by the goal we had in mind and which is in line with the description by Kuechler and Vaishnavi (2012), i.e. the need to develop capture knowledge that was acquired during the design science research project and that cannot be uncovered when merely analyzing the resulting artifacts. Therefore, we identified not only the material and functional characteristics of the artifacts, but also the process of their development to find similarities and differences between the three cases that proved valuable for the formalization of the design theory.

3.3 Theorizing the Design Knowledge

The detailed process we followed to formalize the design theory was informed by the design theorizing framework by Lee et al. (2011), which is characterized by four theoretical elements (instance problem, instance solution, abstract problem, and abstract solution) that require four theorizing activities. It takes the form of an ideal process that scholars may follow to theorize their design knowledge regarding one or more of the four domains. The authors distinguish between the abstract and the instance domain. In the instance domain, a particular solution is designed or registered for a specific instance problem. On the other side, the abstract domain denotes a generalized (rather than particular) problems class that is addressed by searching for an abstract solution. The theorizing process is characterized by interplays between problems and solutions in each domain and the transition from one domain to the other (i.e. abstraction and de-abstraction). This framework proves particularly useful for our study, since it distinguishes between instantiated design knowledge and general design theories, a distinction required to delimit the knowledge that was acquired during each DSR project separately and the design theorizing, which is the object of this paper. Also, to our best knowledge, it is one of the rare theorizing processes that is proposed for abductive reasoning in DSR.

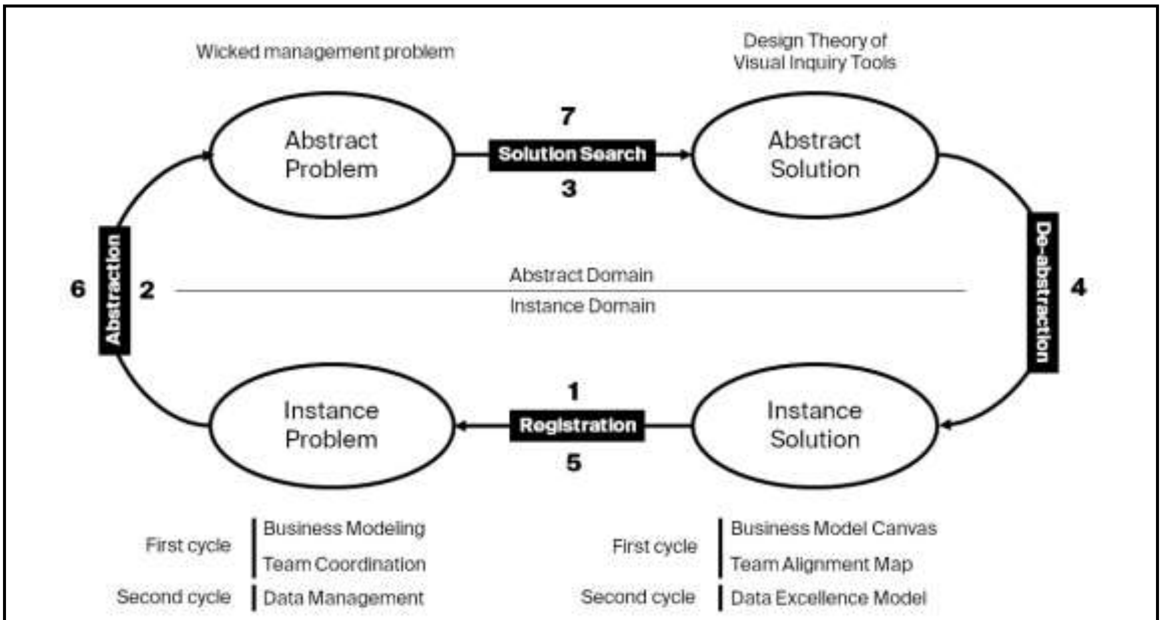

Figure 24 - Cycles of theorizing based on Lee et al. (2011)

We performed two theorization cycles according to the framework. In cycle 1, we initiated the design theory by comparing the Business Model Canvas and the Team Alignment Map. In cycle 2, we refined the theory by reiterating the theorizing process with the Data Excellence Model. We used the same analysis process for both cycles. We will now explain the two theorizing cycles (Figure 24).

3.3.1 Cycle 1: Initiating the Design Theory

The development of our design theory started with the comparison of two existing solutions, the Team Alignment Map and the Business Model Canvas. As noted, these two instance solutions had been part of two separate design science research projects that sought to address two different instance problems (1. *registration*): team coordination for the Map and business modeling for the Canvas. We identified similarities both on sides of the instance problem and the instance solution. Regarding the problem, both tools address management problems that are ill-structured, complex to handle, and require close collaboration between different stakeholders. Regarding the solutions, both tools are visual poster prints and promote techniques for joint inquiry in their usage, using sticky notes. The two cases differ in the problems they address and the contexts in which they are used. This allowed for the sound replication of our findings, since the tools are similar regarding their form and function but displayed different utilities as they addressed different instance problems.

We theorized the knowledge that was acquired in both cases to help designers to create effective and rigorous similar tools. Here, we identified that the different problems the two tools addressed actually displayed an extensive number of commonalities: both business modeling and cross-boundary coordination are collaborative problems that require active participation, they have no right or wrong solution, they are complex to manage and are usually regarded as problems that are difficult to frame and structure. Since these elements proved to be characteristic of wicked problems, we framed the abstract problem (2. *abstraction*) as wicked *management* problems, to underline the tool's managerial context.

Once we had identified the abstract (or common) problem addressed by both tools, we developed a set of design principles which we related in the proceedings of an IS conference (3. *solution search*). We anchored the development of the principles in the abstract problem, i.e. wicked management problems. We analyzed how these problems' characteristics were addressed by our artifacts. We first identified the main phases of the two DSR projects as they all resulted into instantiations that had similar characteristics and principles. For instance, the first phases of the Business Model Canvas and the Team Alignment Map were concerned with the development of ontologies for their respective wicked problems. These ontologies were later instantiated into shared visualizations. These phases helped us to delimit the conceptual efforts by the designers during each phase and instantiation. This helped us to analyze the layers of principles of the current artifacts and to understand their principles of form and function. We also compared the tools' characteristics and analyzed their similarities and functions.

For this paper, we formalized the knowledge we had acquired from the two cases using Gregor and Jones' (2007) framework, which provides a more complete and consistent representation of design knowledge than the initial set of design principles we had defined in the IS conference proceedings. We elaborated more detailed design principles for the three initial design principles we had defined in the conference proceedings. This theorization was driven by the need to have a balance between fit and actionability. We aimed for a design theory that would apply to a generic tools class similar to our cases, while at the same time being concrete enough for future designers to apply the principles. In the five evaluation criteria for design theories as identified by Aier and Fischer (2011), this is the tension that exists between having a broad scope and a simple design theory that is easy to understood and apply.

3.3.2 Cycle 2: Refining the Design Theory

We further refined the theory by comparing the abstract solution we had derived from the two cases (Avdiji et al. 2018b) with the Data Excellence Model for the wicked problem of data strategizing (4. *de-abstraction*). The first two sets of design principles we had identified were projected into the Data Excellence Model: (1) the artifact framed the problem of data management and strategy by identifying the relevant design areas that stakeholders must jointly inquire into to develop a data strategy (Penteck et al. 2017), (2) the artifact was represented into a shared visual problem space. The latter was different to the Business Model Canvas and the Team Alignment Map in that it both served as visual support to guide the conversations between stakeholders and in various cases, as the problem space in which stakeholders would directly encode the alternative solutions to the data strategy with sticky notes. This flexibility of use drove us to change the third design principle in that, as it is presented here, it does not only allow for reflecting and trying out different solutions, but also to dive in the details of each building block. In that sense, the Data Excellence Model also includes templates that allow users to analyze each block and communicate them to stakeholders of other building blocks (e.g. through PowerPoint templates). Therefore, we added a new design principle in which communication is stressed (DP3.3) and which also appeared to be important for the Team Alignment Map and the Business Model Canvas, although less explicitly formalized in the study by Avdiji et al. (2018b).

We then analyzed how the instance solution of the Data Excellence Model tackled the instance problem of data strategies and data management (5. *registration*). We compared this data management process to the characteristics of wicked management problems (6. *abstraction*). To name a few, data management is also considered as a wicked problem with no one optimal solution and that requires the collaboration of stakeholders from different functions and boundaries. We also noticed similarities of the tool in its form and functions, for instance. the shared visualization and the use of joint inquiry techniques.

It was mainly in the last step (7. *solution search*) that we refined the design theory. We refined the theory's scope and purpose into greater detail, applied the design principles to the Data Excellence Model and changed them when this case provided additional insights. For instance, we amended the design principles relating to the directions for use as the Data Excellence Model is also used to a great extent to assess current situations and to transform them. In fact, the Data Excellence Model is not only used for joint inquiry but also for the analysis and specification of the specific building blocks of the model (greater detail is provided in the design theory). This allowed us to draw the line between the principles of forms and function that are suitable and appropriate to joint inquiry, and those that support analysis and specification.

Finally, we compared the refined design theory with the three cases. We ended theorizing when we found that our analysis led to crystallization (Janesick 2000), when the design theory covered knowledge that was crucial to the three cases and at the same time exhibited coherent relationships between all the theory's components.

4 A Design Theory for Visual Inquiry Tools

Our design theory provides prescriptive knowledge for developing what we term visual inquiry tools, i.e. visual tools that guide teams of practitioners to inquire into hypothesis and potential solutions to specific wicked management problems. In other words, the purpose of the design theory is to support researchers and practitioners in developing such tools. The scope (meta-requirements) of the design theory applies to contexts in which heterogeneous practitioners form a cross-boundary team to address a wicked management problem. These teams are characterized by the diversity of their members with specific experience and background, but are not necessarily experts in a wicked management problem's domain. The visual inquiry tools help cross-boundary teams (1) to explore and articulate the wicked problem, (2) to try out and evaluate different hypotheses on how to solve a problem and to (3) to facilitate the transition between an actual state of the solution and a future desired state. Users can illustrate the current state as well as solutions of the wicked problem on the visual inquiry tool and make use of these to evolve towards new hypotheses and solutions of the problem.

Visual inquiry tools help teams of practitioners form, explore, revise, and challenge such hypotheses by guiding their reflection. As mentioned earlier, these tools represent a novel class of tools and differ in their purpose and scope from traditional management tools, that mainly seek to support practitioners in analyzing, specifying, implementing, optimizing or making decisions regarding management problems. They also should not be confused with modeling tools for enterprise architecture and business processes, for example, that help to specify the solution on the path towards its implementation. To facilitate the solution of wicked management problems, the primary function of visual inquiry tools is to allow practitioners use design thinking to explore and experiment with different understandings of a problem and different solutions. However, the characteristics of visual inquiry tools (which we will outline below) are well-suited for this iterative and experimental approach. While visual inquiry tools allow one to generate and evaluate different hypotheses on how to solve the problem (i.e. different implementation strategies), they do not primarily aim to help individuals implement the solutions. In that sense, visual inquiry tools do not mainly assist practitioners in analyzing and reflecting on their wicked management problem, they also support them in prototyping and trying out different solutions (as noted in Table 23). This exploration of solutions is a key process in the process of joint inquiry (Dalsgaard 2017; Dewey 1927; Steen 2013) and the design thinking approach to management (Comi and Bresciani 2017; Dunne and Martin 2006) that this new type of tools tries to encompass. Visual inquiry tools are therefore close to the definition of strategic tools (Camillus 2006; Jarzabwoski and Kaplan 2015) or the conception process as outlined by Dalsgaard (2017). That is, they are used to define, strategized, and organize the work that is needed to address the wicked management problem at a high-level. They are not aimed at analyzing to understand specific elements of the wicked problem in detail, rather trying out and defining a course of actions between different stakeholders. Another key characteristic of the visual inquiry tools addressed by the design theory is their simplicity, which is particularly well-suited for cross-boundary teams with a diversity of members who are not necessarily experts in a wicked management problem's domain.

A summary of the design theory is provided in Table 25. I first start with explaining all the principles of form and function as they represent the core of our design theory. An exhaustive illustration of the design principles with the three cases appears in Appendix 1.

Table 25 - Components of the design theory for visual inquiry tools, based on Gregor & Jones' (2007) framework		
Component	Description	Application
1. Purpose and scope	"What the system is for," the set of meta-requirements or goals that specifies the type of artifact to which the theory applies and in conjunction also defines the scope, or boundaries, of the theory.	This design theory is intended for designers who wish to develop visual inquiry tools. The purpose of these tools is to guide teams of practitioners in jointly inquiring on specific wicked management problems. Joint inquiry is the process through which individuals (1) articulate and explore the wicked management problem, and (2) develop and evaluate alternative hypotheses about how to solve the problem and to (3) to facilitate the transition between an actual state of the solution and a future desired state.
2. Constructs	Representations of the entities of interest in the theory.	Wicked management problems; Joint inquiry; Ontology of the wicked problem; Shared visualization; Inquiry techniques.
3. Principles of form and function	The abstract "blueprint" or architecture that describes an IS artifact, either product or method/intervention.	DP1 – Ontology: To structure the wicked management problem, frame it with an ontology describing the relevant building blocks (components) of the problem that teams can act on. The ontology should be modeled according to academic justificatory knowledge and be kept parsimonious. DP1.1 – Frame: The ontology should identify the components which teams should inquire into to address the wicked problem, and which they can act on. The components of the ontology should be both mutually exclusive (components are well-defined and scoped) and collectively exhaustive (they cover the central dimensions of the wicked problem). DP1.2 – Rigor & Relevance: The development of the ontology should be based on academic justificatory knowledge. Designers should assess the relevance of the ontology with practitioners, and if it corresponds to a reality faced by users. DP1.3 – Parsimony: The ontology should be accessible for heterogeneous team members with different backgrounds and knowledge bases and a variety of contexts. To avoid information overload and to prevent a prohibitive level of detail in joint inquiry, the number of components in the ontology should be parsimonious. Designers can merge some components into higher order components. If subcomponents are deemed important, they can be used to develop additional tools. DP2 – Shared visualization: To facilitate communication between users, represent the ontology into a shared visualization by structuring the components logically into a visual problem space. DP2.1 – Practicality: The components of the ontology should be represented as empty problem spaces to support the directions for use, i.e. they should allow for exploration, solution generation, and presentation. DP2.2 – Arrangement: To increase the affordance of the tool, building blocks should be arranged according to their relationships in the ontology. These relationships should be masked to reduce the complexity of the visual. DP2.3 – Facilitation: Appropriate images, metaphors, tags, or visual arrangements should be used to increase the affordance of the tool. These visuals should provide a simple common language understood by all.

Table 25 (cont.)		
Component	Description	Application
3. Principles of form and function	The abstract “blueprint” or architecture that describes an IS artifact, either product or method/intervention.	DP3 – Directions for use: Define and specify techniques that allow for joint inquiry. DP3.1– Exploration: The directions for use should stimulate and guide the creation and exchange of ideas, insights, and alternatives for the wicked management problem. DP3.2 – Hypothesis generation: The directions for use should support users in developing, transforming, evaluating, and selecting alternative hypotheses on how to solve the problem. DP3.3 – Presentation: The directions for use should create tangible marks that users can use to present and critique the design/solution.
4. Artifact mutability	The changes in state of the artifact anticipated in the theory, that is, what degree of artifact change is encompassed by the theory.	Flexibility of use: The design theory covers tools that address specific wicked management problems but is not constrained to specific contexts. The BMC addresses the wicked management problem of business modelling. Its initial prescribed use was to inquiring into one’s own business model but it is sometimes used to design the business model of competitors. Flexibility of evolution: The ontology can be represented visually in different ways and on different media. For example, it can be represented on a paper-based shared poster or it can be instantiated into a computer-aided design. Flexibility of integration: While the purpose of the tools is to address specific wicked management problems, they do not and cannot cover all the aspects of the wicked problem. Integrations or synergies between the visual inquiry tools and tools that cover additional aspects of the specific wicked problems can be anticipated.
5. Testable propositions	Truth statements about the design theory.	The visual inquiry tools that implement the aforementioned principles can be tested on the following criteria: TP1– Validity: The visual inquiry tool supports the process of joint inquiry into the wicked management problem. TP2 – Intelligibility: Users easily understand the components of the ontology, and consequently, of the tool. TP3 – Usability: The shared visualization should facilitate the ease of use and understandability of the tool. TP4 – Usefulness: The visual inquiry tool is useful and adopted outside the team who designed it. TP5 – Satisfaction: Users are mutually satisfied with the process and outcomes of using the tool. TP6 – Efficiency: Best practices for different usages emerge within the community of users.

Table 25 (cont.)		
Component	Description	Application
6. Justificatory knowledge	The underlying knowledge or theory from the natural or social or design sciences that gives a basis and explanation for the design (kernel theories).	Our design theory is supported by theoretical developments in ontology development, shared visualization, joint inquiry, and wicked problems in management. The design theory is also supported by the knowledge accumulated through the three DSR cases and their related physical instantiations.
7. Principles of implementation	A description of processes for implementing the theory (either product or method) in specific contexts.	The process of implementation of this theory is highly iterative. All the principles are interrelated and interdependent. Each of the three principle should be applied in iterative phases of design and testing. First, the designers should develop an ontology, evaluate it and refine it until they reach a point of stabilization. Then they should instantiate it into a shared visualization that needs to be tested and refined. This instantiation might indicate some inconsistencies in the ontology, which might require a refinement of the ontology. When the visual instantiation reaches a point of closure, designers can consider specifying the directions of use for their tool. Because the directions of use are highly dependent on the visualization, designers might have to refine the visual before reaching a point of stabilization.
8. Expository instantiations	A physical implementation of the artifact that can assist in representing the theory both as an expository device and for purposes of testing.	The Business Model Canvas The Team Alignment Map The Data Excellence Model

4.1 Design Principle 1 – Ontology

The first principle in the tool's design is to develop an ontology that frames and articulates a wicked management problem of interest. This is often regarded as the first and most crucial activity when tackling wicked problems (Guarino 1997; Restrepo and Christiaans 2004). Wicked management problems characterize a situation that is uncertain or complex for practitioners to outline. In such cases, practitioners are confronted with a number of dimensions and facets of a wicked problem that should be coordinated (Funke 2010). Thus, visual inquiry tools should help users to frame and understand a wicked problem's characteristics, via the ontology in which designers should identify the relevant components of the problem that teams can act on and their associations (Hadar and Soffer 2006). This is the first step toward the development of the tool. It is important to note that our use of the term ontology departs from its traditional definition. Here, an ontology defines all the components of the wicked management problem, a semantic that outlines and defines the main aspects of the problem. For example, one of our principles refers to parsimony which may be counterintuitive if understood in the traditional ontological engineering sense (Gomez-Pérez et al. 2004). Our design theory is intended for visual inquiry tools that are simple and straightforward to use. Therefore, an exhaustive modeling of all the components of the ontology will be counterproductive. Moreover, the ontology should focus on the areas that teams must address and inquire into for the wicked management problem. Peripheral elements such as components and classes pertaining to the users or their environment can be modeled but should not be used for the ontology of the visual inquiry tool. Our definition joins Doty and Glick's (2014) conception of ontologies which are based on the assumption that complex theories and organizational forms can be translated into a parsimonious framework so that they can be understood and use by practitioners.

This design principle is reflected in the three cases' development process (Table 24). The first phase the designers engaged in was the development of an ontology or conceptual model of the problem of interest. For instance, the development of the Business Model Canvas started with the development of the business model ontology using Uschold and King's (1995) methodology. Via an extensive literature review, the designers identified the key building blocks (components) of a business model that an organization impacts on. Similarly, the Team Alignment Map's designers instantiated Clark's (1996) theory into an ontology for coordination within project teams. The Data Excellence Model's designers had to first clarify the overall scope of model for managing data as a strategic resource. In the three cases, the development of the ontology was the most critical and arduous activity, which can easily require up to several years of investigation on the wicked management problem so as to grasp its characteristics. Since wicked management problems are hard to define, the ontological role of visual inquiry tools should not be underestimated. The three cases also informed us about three particular considerations that are of utmost importance for the development of ontologies. We will now describe these design principles in some detail.

4.1.1 Design principle 1.1: Frame

The first subprinciple that designers treat with care is to develop an ontology that appropriately frames the wicked problem. Since visual inquiry tools seek to support and guide joint inquiry, the ontologies are based on elements that teams can act on, i.e. that they can design, manipulate or transform.

The frame is critical as it sets the scope and purpose for the joint inquiry and thereby influences how practitioners will address the wicked management problem. Thus, designers should have a clear and explicit understanding of their paradigm or foundational assumptions about the problem. For instance, designers of the Team Alignment Map decided to address team coordination through a conversational lens. Various approaches to coordination exist; these include Malone and Crowston's (1990; 1994) contingency theory of coordination, the cognitive perspective with theories on team mental models or transactive memory (*e.g.*, Cannon-Bowers and Salas 2001; Klimoski and Mohammed 1994; Hsu et al. 2012), and the organizational perspective (*e.g.* Andres and Zmud 2002; Nidumolu 1995). However, the designers' assumption was that coordination in teams mainly depends on the conversations between participants during team meetings. They thus turned to a psycholinguistic account of coordination: Clark's (1996) theory on joint activities and coordination. Similarly, the Data Excellence Model's designers reviewed literature that considered data as a strategic resource, and purposefully selected a scope that embraces strategic, organizational and systems-related aspects. The Business Model Canvas' designers explicitly focused on the aspects of business models that a company impacts on. Thus, the three cases inform us on the need to have a clear scope and paradigm for addressing the wicked problem's characteristics as a starting point for developing visual inquiry tools.

Further, the building blocks of the ontology should simultaneously be mutually exclusive and collectively exhaustive. All the building blocks should be clearly scoped and defined so that there are no overlapping characteristics and attributes with other building blocks. This clarity in the definition of the building blocks will facilitate the identification of the relationships between them. Designers should also ensure that the building blocks cover all of a problem's relevant aspects. There are different ways to judge whether the building blocks are exhaustive. In the case of the Business Model Canvas, the literature review provided an exhaustive list of the characteristics that the research had covered. In the case of the Team Alignment Map, the theory that is used for the ontology had outlined the fundamental requirements that need to be addressed when coordinating in any type of joint activity. When developing the Data Excellence Model, the researchers conducted literature reviews and focus group meetings to ensure that the building blocks are exhaustive with regards to the strategic, organizational and technical layers of data management (Pentek et al. 2017).

4.1.2 Design principle 1.2: Rigor & Relevance

The ontology should provide a rigorous and relevant account of a wicked management problem. On the one hand, the development of the ontology should be based on academic justificatory knowledge to ground some validity and accuracy. Different strategies for the development of the ontology can be used. The ontologies for the Business Model Canvas and the Data Excellence Model were both based on extensive literature reviews. The Team Alignment Map's ontology was based on an existing theory, which was instantiated and adapted from its original discipline to the context of team coordination. On the other hand, the ontology should be relevant in that it accurately represents the reality faced by practitioners. In all three cases, relevance was ensured by extensively testing and refining it in real contexts. For instance, the Team Alignment Map's ontology was initially evaluated in cross-boundary teams within three different organizations, in which the designers assessed to what extent the ontology covered the coordination needs of practitioners and how useful it was considered to be (Mastrogiacomo et al. 2014). The relevance can also be evaluated via simulations, ex post case analyses, or criticism by the targeted practitioners. Designers can refer to Milton et al. (2012) and Gómez-Pérez et al. (2001) for additional evaluation criteria that are tailored to ontologies, but they should at least address rigor and relevance.

4.1.3 Design principle 1.3: Parsimony

Finally, the ontology should be simple both to ensure that it is easily understood by the heterogeneous members of cross-boundary teams, and to avoid a prohibitive level of detail that would undermine its affordance. Thus, the number of building blocks should be parsimonious, which was between four and eleven in the three cases. However, according to the experiences with the Data Excellence Model and the Business Model Canvas, nine to eleven building blocks clearly represent an upper limit. The more building blocks are presented, the more important it is to logically structure the building blocks in the visual inquiry tool. In all three cases, decisions had to be made about merging some building blocks into higher-order ones in order to keep the ontology parsimonious. If these subcomponents are deemed important, they can be used for the development of additional tools that would focus the process of joint inquiry on that problem. For instance, the Business Model Canvas' designers developed the Value Proposition Canvas as a tool for inquiry into value propositions. The Business Model Canvas remains at the higher abstraction level of the value proposition and does not include the specific subcomponents of the value proposition (e.g., gains, pains, and jobs). Designers may also consider dismissing the building blocks that are not central to a wicked management problem. This decision can be informed by evaluating the ontology with practitioners in real contexts who may consider that some building blocks are peripheral or relevant only in specific situations (DP 1.2).

4.2 Design Principle 2: Shared Visualization

The second design principle is to instantiate the ontology into a shared visualization via various techniques. Shared visualization has several benefits such as helping individuals to elicit and integrate information easily, facilitating the creation of shared understanding, and making explicit the interdependencies between facets of a problem (Eppler and Platt 2009; Miller et al. 2001). These benefits are particularly important for inquiring into wicked management problems. To leverage these benefits and facilitate the process of joint inquiry process, designers should visually represent the ontology and can use different visualization techniques for this (e.g. visual problem spaces, layout, images, metaphors). For instance, the ontology's building blocks should be structured on a shared display as empty problem spaces that practitioners can use to develop and evaluate different hypotheses about how to solve a wicked problem. The shared visualization should also guide and facilitate the conception of the wicked management problem so that all team members can clearly articulate the problem's dimensions and understand it the same way (Mason 1997). Designers should follow three subprinciples, which were informed by the three cases in order to develop an effective shared visualization. They can also call upon experienced graphic designers, as was done by the designers in the three cases.

4.2.1 Design principle 2.1: Functionality

The shared visualization should support the tool's intended functions of the tool. Thus, they should be aligned with the directions for use (DP3) and allow for exploration, hypothesis generation, and presentation. In the three cases, this was achieved by representing the ontology's components as empty problem spaces or building blocks. This representation provides two benefits that are crucial for wicked management problems (Dalsgaard 2017). On the one hand, the visualization should structure the articulation and exploration of a wicked problem, so that it is understood and interpreted by all in the same way. Thus, shared visualization can provide a nearly "universal language" that can be understood by all (Mason 1997). On the other hand, the shared visualization provides a design space within which team members can work out and evaluate alternative hypotheses on how to solve it (Fiore and Shooler 2004; Granados 2000). In all three cases, practitioners would generate hypotheses by using tangible marks in the form of sticky notes that are added in the building blocks. This allows team members to represent their opinions and assumptions on a wicked problem. Thus, it is important that the spaces are large enough to accommodate a certain number of sticky notes. Building blocks that are expected to lead to the greatest number of hypotheses can be made larger than the others. For instance, in the Business Model Canvas, some building blocks are larger than others, since they are expected to accommodate more hypotheses, while the building blocks in the Team Alignment Map and the Data Excellence Model are of mostly equal size.

4.2.2 Design principle 2.2: Arrangement

To facilitate the affordance of the tool, the associations between the building blocks should be masked but implied by the way they are visually arranged. In the Data Excellence Model the building blocks are grouped into three categories: goals (business capabilities, data management capabilities), enablers (e.g., processes and methods, data lifecycle, data architecture), and results (business value, data excellence). All the building blocks are interlinked in a continuous improvement cycle. The circular shape suggests that users can either start by inquiring on the data strategy's goals (move from left to right) or the expected results (move from right to left). The Team Alignment Map organizes the building blocks from left to right, following the conventional reading direction, to suggest that users should inquire into joint objectives first and should then move on to the joint commitments, and so on. Their arrangement reflects the processual associations between the building blocks. If the associations are important for the users to understand explicitly, designers can incorporate them either in the directions for use or through illustrative use cases.

4.2.3 Design principle 2.3: Facilitation

Finally, designers can make use of various aesthetics to facilitate the affordance of the tool and to provide a shared language that is understood by all users. The designers of the three cases used techniques such as appropriate metaphors, icons, written explanations, or shapes. For instance, every building block of the Business Model Canvas is named and has a corresponding metaphor in the form of an icon. The value proposition is depicted as a gift, suggesting that it is what the company should offer its customers. The Data Excellence Model took a similar approach and uses icons to depict the building blocks. The Team Alignment Map's designers created written descriptions of each building blocks with names and visual icons. The descriptions were made lighter so that users would not interpret it as a crucial part of the tool and would not be distracted. However, such descriptions were however not used in the two other tools. The Team Alignment Map' designers also used an arrow and a darker shade for missing resources and joint risks, suggesting that users should seek to transfer these into objectives or commitments to the greatest extent possible. Thus, risks and missing resources represent obstacles that can be overcome if someone does something to mitigate them, hence their translation into objectives and commitments.

4.3 Design Principle 3: Directions for Use

The last design principle relates to the need for designers to define and specify directions for use that guide the joint inquiry process in a wicked management problem. Designers should conceive a visual inquiry tools in a way that it facilitates (1) the exploration of a problem space, (2) the generation of hypotheses on the solutions to a problem, and (3) the presentation and criticizing of the solution. The directions for use should be clear so that users can make the best use of the tool. The directions for use promoted by the designers of the three cases are similar: they suggest that the tool be used simultaneously and collectively within teams (as opposed to individuals) with sticky notes for exploring and generating hypotheses on their wicked management problem. These directions appear in greater detail below. Nevertheless, it is important that designers to observe the best practices that emerge in the community of users, as the initial and intended directions for use may be complemented by emerging and unforeseen practices. For instance, the Business Model Canvas' designers counted more than 14 different practices (Strategyzer 2015).

4.3.1 Design principle 3.1: Exploration

The directions for use should be defined in a way to stimulate the creation and exchange of ideas and insights between team members. A key characteristic of wicked management is that there is no single best solution practitioners must be supported in their ideation and creativity processes. All three tools promote a collaborative use in cross-boundary teams in which individuals can tap on their diverse set of knowledge, expertise, and resources so as to generate and share creative ideas (Edmondson and Harvey 2017; Katzenbach and Smith 2015). For instance, it is suggested that the Business Model Canvas and the Data Excellence Models be used by all stakeholders in a wicked management problem to allow for insights from each domain of expertise to emerge. Also, the use of sticky notes facilitates the process of generating ideas as they force individuals to generate small chunks of information that can be combined and recombined to come up with an extensive number of possibilities (Sibbet 2011). The Team Alignment Map's designers suggest that each team member individually reflects upon the four building blocks and writes down their ideas on sticky notes. The ideas are only aggregated in step 2. This technique avoids the emergence of *groupthink* or the dominance of certain parties, which are proven to impede on creativity (Badke-Schaub et al. 2006; DiMicco et al. 2004).

4.3.2 Design principle 3.2: Hypothesis generation

The directions for use should also guide the generation, transformation, evaluation and selection of hypotheses on how to solve a wicked problem. The use of sticky notes facilitates this process, since users can easily and flexibly fill the building blocks with hypotheses. The sticky notes provide great flexibility, since they are easy to add, move, or remove. The Business Model Canvas' designers recommend that a color code be used for different business model alternatives, so that they are easy to visualized and compare. The Data Excellence Mode's designers also provide PowerPoint templates and frameworks that practitioners can use when inquiring on a building block in order to detail their solution. The sticky notes are used to generate a first set of hypotheses and evaluate their coherence, while the templates are used to analyze and specify the hypotheses in greater detail. For the purpose of joint inquiry in workshop settings (as opposed to analysis and specification), using sticky notes in the building blocks seems appropriate.

4.3.3 Design principle 3.3: Presentation

The visual inquiry tools should be designed in a way to create tangible marks of the hypotheses and solutions so that they are easy to present, referred to, or criticized. Visualization is suitable for presentation purposes (Horn 1998). Sticky notes provide a good means to make tangible and visible hypotheses and elements of the discussion, so that they can be presented and criticized by someone from inside or outside the team. Sticky notes provide direct access to the information that is manipulated (Sibbet 2011). With a physical version, users can also take a picture of the visual inquiry tools after they are filled with the elements so that they can be referred to. This is a common practice in the Team Alignment Map, of which pictures are taken to ensure that everyone is on track with their commitments. In addition, one of the goals of the visual inquiry tools is to facilitate the transition between an actual state and a future desire state. Presenting and keeping tangible marks of a version of a solution on the tool allows users to plan the activities to attain the future state and assess the progress. For instance, users of the Data Excellence Model can use it to illustrate a current data strategy and develop another Model to envision their future strategy. The comparison of the two versions of the tool will facilitate the evolution towards the new strategy, by allowing users to compare the areas of the models that are changed or to be worked towards.

4.4 Artifact Mutability

Gregor and Jones (2007) underline the importance of capturing the mutability and the inherently dynamic nature of design theories. Design science researchers must account for mutability so as to inform future designers on the changing conditions of the prescriptive statements they develop (Gregor and Livari 2007). Because the presented artifacts are designed iteratively and in a spirit of continuous improvement, they are in nature mutable. In this design theory, there are three different forms of this mutability: (1) flexibility of use, (2) flexibility of evolution, (3) flexibility of integration. First, the use of the artifact can be deviate from its initial purpose and different uses of the tool can be drawn. The design theory we propose supports joint inquiry but the tool is not constrained to this use. For instance, the Business Model Canvas was aimed at designing a business model and strategizing about it, but we already noticed fourteen derived uses of the Canvas; these include people using it as a dashboard, as a tool for understanding competitors, or even as a personal development tool.

Users of the Data Excellence Model do not only use it in the joint inquiry process, but also to monitor transition towards the future solution and to assess date management maturity. Second, the evolution of the artifact is flexible. Simon (1996) sees this as a possibility for the artifact to be redesigned via feedback loops. Once the designers have developed a rigorous ontology, this ontology's instantiation can be done in many different ways and on different supports. For instance, the Team Alignment Map was first instantiated in a mobile application, but users expressed willingness to have a paper-based shared visual instead. Our design theory can also be instantiated in computer-aided design (CAD) tools. In the case of the Data Excellence Model, the artifact has significantly evolved since its first inception in 2006. The current version refines the original one to address the evolving requirements towards data management. Certain building blocks were added to link data management to (business) goals and results, but the main building blocks (the so-called enablers) remain stable. Third, it is possible to integrate different instantiations of the design theory. Because the tools seek to address a specific wicked problem, they do not and cannot cover all the aspects of a specific problem. Such problems are so complex and wide that practitioners generally make use of a collection of tools that have different purposes (Nicolini et al. 2012). The Team Alignment Map only supports the joint inquiry into team coordination, not implementation. Once the objectives and commitments are outlined at a general level, users usually resort to additional tools such as the Work Breakdown Structure to detail, specify, and optimize everybody's tasks. The designers of the Data Excellence Model anticipated the needs for specification and analysis, and developed a set of templates that can be used within each building block. Moreover, the visual inquiry tools can be combined to form a toolbox of inquiry. For instance, a team must use the Business Model Canvas to define a business model or strategy and use the Team Alignment Map to design its coordination for the implementation of the strategy.

4.5 Principles of implementation and testable propositions

According to Gregor and Jones (2007), principles of implementation should provide a description of the processes for implementing the design theory in a specific context. The process of implementation of our design theory is highly iterative, since all the principles presented in the theory are interrelated and interdependent, but there is a clear sequence that emerges from their implementation. This sequence is reflected by the different phases in the development of the three visual inquiry tools. The designers of the three visual inquiry tools started with the development of an ontology to frame the wicked management problem of interest and identify its properties. Once the ontological foundations were set, designers were concerned with finding adequate visualizations to create a shared understanding. Graphic designers were involved in the three cases to work on the visual representation of the building blocks and the layout of the model. Through interactions with practitioners, the role of the visual inquiry tool became clearer and the directions of use were elaborated.

Based on the three cases, we have identified two decisions that designers should make: a design decision and a stabilization decision. The process for developing visual inquiry tools

(Figure 25) starts with a design decision, namely the decision to develop a tool to address a wicked management problem. Once the design is initiated, designers must undertake the two fundamental activities of design and evaluation in iteration.

The first cycle relates to the design of the ontology which should be done following the related design principles outlined above. The ontology is then evaluated against its validity (TP1 in Table 25) and intelligibility (TP2). The validity of the ontology depends on its ability to help team members inquire into the wicked problem they face. If the ontology is missing some elements or is not effective, the tool may fail to help users jointly inquire into the problem adequately. The ontology should also be tested against its intelligibility to ensure that its components are correctly and easily understood by the users. After evaluating these propositions, designers need to make a new design decision. If the evaluations are not conclusive, designers should perform a new design cycle for the ontology and test it again until the evaluations are satisfying. The development of the Data Excellence Model is a good illustration for this cycle. The DSR project for the development of the Model was extensively concerned with the validation and refinement of the ontology (Figure 25). Three phases were required to assess the validity of the ontology before instantiating it into the visual inquiry tool.

In that case, designers should then proceed to the design of the shared visualization and evaluate its usability (TP3). The shared visualization should facilitate the ease of use and understandability of the tool. Users should understand the functions of the tool without much effort and explanations from designers. Again, designers must make sure that the evaluation provides conclusive results and redesign and test the shared visualization if needed. For instance, the designers of the Team Alignment Map developed several alternative shared visualizations and tested them with 12 teams of 6 students working on innovation projects at a management school. Based on these comments, visual elements of the Map

The final design cycle concerns the development of directions for use that should allow team members to jointly inquire to the wicked management problem. The evaluation of the directions for use is based on three propositions: usefulness (TP4), satisfaction (TP5), and efficiency (TP6). First, the tool and its directions for use should be considered as useful for addressing the wicked problem. This is usually reflected in the adoption of the tool outside the team who designed it. Designers should also pay attention to the emergence of best practices which might reveal that the tool is used for different purposes which might be included in the directions for use of the tool. For instance, the Business Model Canvas has been downloaded and used by more than five million individuals with 14 different use cases, some of which were integrated in the directions for use. Designers should also evaluate the users' satisfaction with the directions for use and the outcome of using the tool. Dissatisfaction may suggest that directions for use need to be adapted or refined. Resorting to interviews with users can provide rich and detailed feedback on the areas of improvement of the tool.

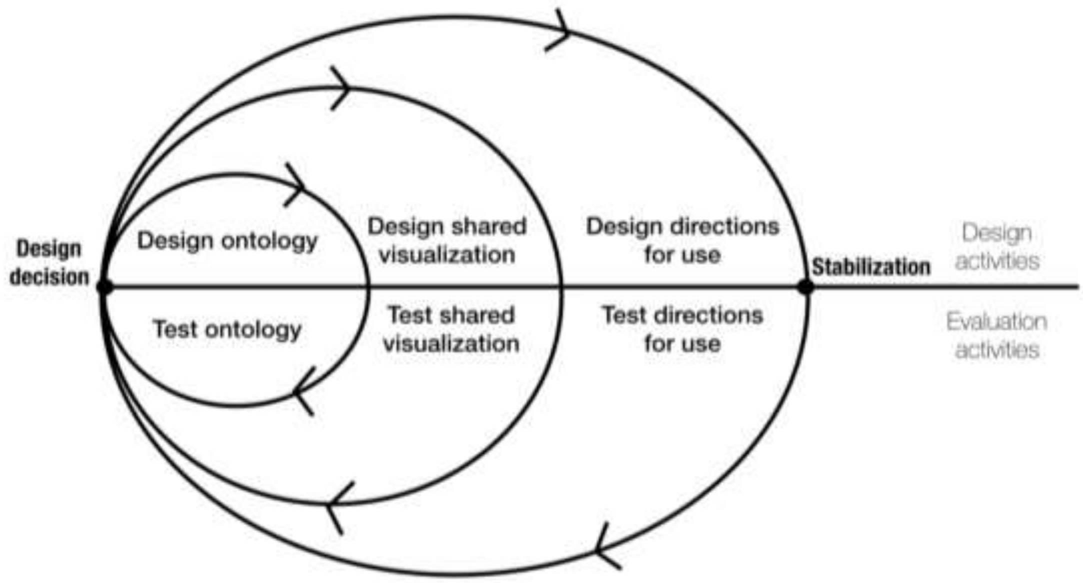

Figure 25 - Process of implementation of the design theory

These evaluations are done until the designers feel that the tool has reached stabilization. The decision to stabilize the tool should be based on the results of the evaluation and the designers' judgment. Evaluations may provide extensive and continuous feedback for improvement and designers should decide when the integration of additional feedback provides only incremental enhancements.

As stated before, the three sets of design principles are interrelated. Hence, if the tool is not yet stabilized, it could be attributed to one principle or a combination of them. Therefore, our process suggests that the cycles all come back to the design decision. For example, the users' dissatisfaction with the process of using the tool could be attributed to ineffective or irrelevant directions for use, or could also manifest inconsistencies in the ontology which might be too difficult to grasp for practitioners. In this case, designers should redesign the ontology. It could also be a reflection of the misalignment between the shared visualization and the directions for use.

4.6 Implementation of instantiated artifacts

The three DSR cases also provide prescriptive knowledge on the implementation of the final instantiation. In the case of inexperienced users, designers should be aware that they may require the assistance of a group leader or facilitator (Fiore and Schooler 2004). These leaders or facilitators could help to guide team members to examine the problem-solving process and focus on conceptualizing of and inquiring into the problem (Gersick and Hackman 1990; Maier 1967; Oxley et al. 1996). Through their mutability, the visual inquiry tools can be used in different situations and for different purposes, thus impacting on the tool's implementation. And because teams are increasingly working in distributed settings, designers should consider Johansen's (1988) time-space matrix. For instance, if the users are not in the same physical place (remote interactions), instead of using a large print poster with sticky notes, designers should consider a computer-aided design, to support teams with a digital shared visual that can be seen by all team members simultaneously. If users are working asynchronously (coordination), the designers must carefully consider that the tool provides digital marks of the conversation, to be able to be stored in a shared repository that is accessible by all team members from anywhere at any time. If users are in the same place but work at different times (continuous task), the visual inquiry tool should provide a physical mark of the conversation. Hence, it could take the form of a large print poster that is stored at a place accessible by all users at any point in time. And if users at at the same place at the same time (face-to-face interactions), the visual inquiry tool can take the form of a large print poster and be used with sticky notes.

5 Synthesis of Studies 5 and 6 and future research

5.1 Designing visual inquiry tools

We started this paper by highlighting the research question that motivated our project: *How do we develop visual inquiry tools that guide teams in addressing wicked management problems?* We contributed to this question by providing a design theory based on the cases of the Business Model Canvas, the Team Alignment Map, and the Data Excellence Model. The design theory provides prescriptive guidelines for designers who wish to develop visual inquiry tools for specific wicked management problems. We have outlined that most developments of visual inquiry tools are done either without a clear conceptualization of the intended design or simply by replicating the apparent features and structure of existing tools. We address this concern by providing guidelines for the development which we based on the three extensive DSR projects. We have outlined a process for implementation that can guide designers in their development. We suggest that designers follow the same process as our three cases which were initiated by the recognition of a wicked management problem triggering three design cycles: (1) the design of an ontology to frame the elements of the wicked management problem, (2) the representation of this ontology into a shared visualization, and (3) the development of directions for use that allow for joint inquiry. These characteristics of visual inquiry tools reflect the metaphor of the focal frame for wicked problems (Figure 26), in which the Team Alignment Map is displayed as the hourglass, while other tools may be added to complement the joint inquiry into additional wicked management problems.

Within each design cycle, designers should perform two activities, designing and evaluating. Our design theory provides the principles of form and function that designers should follow for the designing activities. We have developed a set of design principles for each cycle, namely the ontology, the shared visualization, and the directions for use. For the evaluation activities, we provide a list of testable propositions that designers can rely on to evaluate the effectiveness each design cycle. We expect the design theory to provide valuable guidance for future developments of visual inquiry tools.

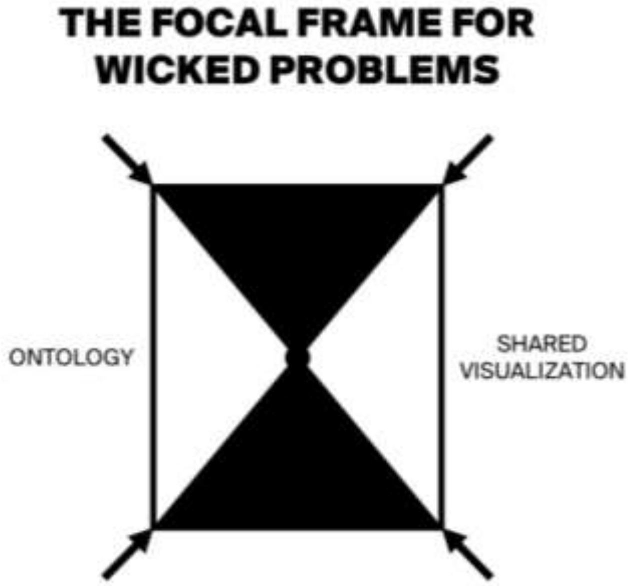

Figure 26 - Visual metaphor of the focal frame for wicked problems

In this study, we addressed the lack of methods for the construction and evaluation of artifacts as stressed by Bucher and Winter (2008). Our design theory outlines an iterative process for their development which is based on two fundamental activities: designing and evaluating. We proposed design principles along three categories (ontology, shared visualization, and directions for use) to guide the design of such tools and formulated six testable propositions that designers can rely on for the evaluation. We believe our design theory to provide valuable guidance for designers that want to address various wicked management problems.

It is important to underline here that we have not instantiated the design theory with an ex-post development given the relatively recent development of the three visual inquiry tools we present here and the extensive effort that is required to develop such tools. In fact, the three DSR projects spanned over several years with the ontology requiring substantial work. We invite other design science researchers to instantiate our design theory, especially if they have already developed an ontology for a wicked management problem that they wish to incorporate into a visual inquiry tool. Such developments would provide external validations for our design theory. We have, however, projected our design theory into our three cases, which advances that it is applicable to three cases as a minimum. These cases were part of extensive and rigorous DSR projects that have been previously evaluated and published. Baskerville and Pries-Heje's (2014) insights and illustrations suggest that our projectability into three cases provides great projectability and entrenchment. We thus expect, with some level of confidence, that our design theory can be projectable in future ex-post instances.

Our design theory also reflects its mutability which provides insights on the potential expansion of our study. Our design theory is flexible in its evolution as it can be instantiated into different media. We thus lay the foundation of what would be required to develop CAD inquiry tools. The ontology of the visual inquiry tool is a basis for the specification of the data architecture of the CAD inquiry tool. The ontology developed with our design theory can be translate into a formal ontological language such as the web ontology language (OWL) or the lexical OWL ontology matcher (LOOM). The design theory can also be used to inform the design of the interface of the CAD inquiry tool. However, our design theory does not specifically address such tools, which calls for further development tailored to CAD.

Our design theory is also flexible in its integration with other visual inquiry tools and tools that address specific components (building blocks) of the visual inquiry tool. Our theory could stimulate the development of this new generation of tools. It is possible to foresee the development of a *toolbox for managers*, which would be an inventory of the wicked management problems that most practitioners face and for which a specific visual inquiry tool is dedicated. It is important to note that such a toolbox would not lead to the replacement of any existing management tool, rather the visual inquiry tools would be used in the first step into addressing a wicked management problem, before using other tools for decision-making, analysis, specification, or implementation purposes.

5.2 Accumulating design knowledge

Our project also makes important methodological contributions regarding the accumulation of design knowledge across multiple separate DSR projects and instantiations. This paper provides an empirical illustration of how design knowledge can be accumulated and theorized across multiple cases. We used Lee and colleagues' (2011) process of theorizing to develop knowledge about the design theory (abstract solution) for wicked management problems (abstract problem) from three cases (instance solutions) that address three different management problems (instance problems). While Lee and colleagues do not provide guidelines on the activities that should be undertaken for each step of the process of theorizing should be approached, we provide concrete examples of one possible way of following their framework to theorize design knowledge. Our study was initiated by comparing the instance solutions which displayed similarities in their features, the way they are used, and their purposes. We then compared the instance problems and defined the abstract problem based on the similar characteristics of such problems. We suggested that business modeling, team coordination, and data management are wicked management problem, as these three problems are hard to define, complex to solve, and have no universal solution. This allowed us to identify how the principles of the three visual inquiry tools addressed these characteristics. We have noted, for instance, that the difficulty to define the problem is answered by the ontology, and the difficulty to solve the problem is offset by the directions for use that promote joint inquiry between individuals with diverse expertise, backgrounds, and resources. We add that the principles of form and function were also informed by analyzing the design process of the three cases. For instance, we noted that all three DSR projects were initially concerned with the development of an ontology for a wicked management problem, which was later represented visually into different tools with different use cases. By looking at the major phases of DSR projects and the intermediate artifacts they produce, designers can untangle the layers of form and function from the artifacts. These can then be compared to the properties of the abstract problem to determine the principles of form and function that prove interesting and important for the abstract solution. Due to its projectability on three cases, our design theory is not related to specific instance problems and can thus be used for management problems that display the properties of wicked problems (i.e. hard to define, complex to solve, and no single solution) and which require joint inquiry from cross-boundary teams.

We also raise several critical points that require further development on methodological insights for the accumulation of knowledge in DSR. We suggest that additional work is required on both the presentation and the development of design theories based on multiple cases. For the presentation of the multiple cases, we encountered the same concerns that have been identified in other disciplines and with different methodologies. For descriptive multiple case studies, Eisenhardt and Graebner (2007) highlighted the tensions that researchers must manage between providing a rich story about the cases and remain within the space constraints. Single case studies (by analogy with single DSR projects) are in fact easier to present as the richness of the qualitative data is in line with a rich description of the case (DSR projects). With multiple cases, the challenge is to manage the trade-off between a story that is rich and having a well-grounded theoretical development. We chose to manage this tension by providing only the main points that readers must know regarding the cases (motivation for the development of the tool, description of the tool, development process, and adoption) and kept the details for the description of the design theory. Although our design theory was developed by accounting for the three cases, we often only demonstrated our theoretical development with illustrations from one or two cases. We refrained from describing each principle with the three cases to keep reading from being overloaded and cumbersome. Following the example of Eisenhardt and Graebner, we provided tables and visual frameworks to synthesize the information from our cases. We kept peripheral details about the three cases for the design principles in the appendix. We also followed their advice for the organization of the argument. We arranged the presentation of our design theory around its main parts: design principles, mutability, principles of implementation, and testable propositions. We contend that this may seem counterintuitive for the abductive nature of design science research (Lee et al. 2011) as presenting results in this manner could suggest that the theory was developed from deduction. However, we believe this issue can be easily overcome if the abductive nature of methodology is clearly explained and outlined. Findings can also be presented by explaining how the cases informed the development of the theoretical parts, rather than how the theory was deduced from the cases.

Another point that calls for further discussion is the tension between developing abstract design principles that can be used for multiple instantiations and the need for these principles to be actionable and clear enough so that they can be provide valuable prescriptions to designers. Various scholars have developed prescriptions and evaluation criteria for the quality of design theories and principles (*e.g.*, Aier and Fischer 2011; Chandra et al. 2015). Designers should simultaneously assess whether their design principles are projectable (i.e. they can be projected into multiple instantiations) and clearly framed. Descriptions and examples of the design principles can facilitate understanding and provide illustrations that designers can rely on. We join Chandra et al. (2015) in their suggestion that design principles should be materiality and action-oriented. That is, they should "prescribe *what* an artifact should enable users to do and *how* it should be built in order to do so" (p. 4043). We believe one means to assess the effective formulation and description of design principles is by evaluating it with designers outside the team of the authors, so that the former would follow it with no explanation from the latter. This echoes the limit of the current study we outlined above, namely the need to have a design theory instantiated ex-post. We thus believe it is important to comment on the usability of existing design theories whenever building on them to develop our knowledge on how to frame projectable design principles effectively.

In general, our study illustrates the opportunities that the IS discipline has for contributing to the management discipline. Various scholars stressed the need for management and IS research to provide practical and prescription-driven knowledge on top of descriptive theoretical developments (van Aken 2004; Gregor and Jones 2007; Peffers et al. 2007). They argued that management research suffers a lack of relevance and impact in the business world due to the paucity of academic and prescriptive knowledge on how to solve a class of managerial problems. In fact, van Aken (2004) called for more "field-tested and grounded technological rules to be used as design exemplars of managerial problem solving" (p.221). Osterwalder and Pigneur (2013) suggest that the IS discipline is well-equipped to contribute to the design of management tools as it has a long tradition in DSR. We concur that the IS discipline can build on its strength in the modeling, formalization, and representation of practical problems to design solutions for the realities of management. Our study is an illustration of how the IS discipline can contribute to management research – and still remain true to its own identity – by designing visual inquiry tools for a variety of wicked management problem.

SUMMARY OF CHAPTER 6

Cross-boundary teams are typically immersed in situations with great novelty and complexity. These characteristics make the problems they work on wicked: intangible, complex, with shifting requirements, and with no optimal solution. A variety of **visual inquiry tools** has emerged to support teams in inquiring into wicked management problems. However, they have mainly relied on the imitation of existing tools or intuition. Therefore, I seek to provide **rigorous guidance** to designers of future tools by answering the question: *How can we design visual inquiry tools that guide cross-boundary teams in solving wicked problems?*

STUDIES 5 & 6

In this study I sought to develop a design theory using Gregor and Jones' (2007) framework of the eight components of a design theory.

DESIGN SCIENCE RESEARCH CASES

I based the development of the design theory on **three extensive design science research projects** which resulted in three tools: the Team Alignment Map, the Business Model Canvas for business modeling, and the Data Excellence Model for data management.

PROCESS OF THEORIZING THE DESIGN

I relied on Lee and colleagues' (2011) **process for theorizing design**, which differentiates between the abstract problem and solutions, and the instance problems and solutions.

DESIGN THEORY

Our design theory covers the eight components by Gregor and Jones (2007). I provide **three overarching design principles** suggest that designers must rely on: (1) the design of an ontology to frame the elements of the wicked management problem, (2) the representation of this ontology into a shared visualization, and (3) the development of directions for use that allow for joint inquiry. We also outline the process through which these principles can be followed.

KEY TAKE-AWAYS OF THE TWO STUDIES

With these two studies I provided a **design theory** to formalize the development of visual inquiry tools that guide teams in jointly inquiring into wicked management problems. This study confirms the relevance of the process of joint inquiry for cross-boundary teamwork, as it is well-suited to address the novelty and uncertainty in which cross-boundary teams evolve. I have also provided **methodological guidelines** on how to theorize and accumulate knowledge across multiple design science research cases, which has rarely been done before.

CHAPTER 7

SYNTHESIS AND PERSPECTIVE

1 Synthesis of the manuscript

My doctoral research project was motivated by the need to address the challenges that cross-boundary teams face. In this project, I have focused on the three challenges that are within the team's reach, i.e. the challenges that team members can address by modifying their ways of carrying out teamwork. Therefore, I have focused on coordination, cooperation, and wicked problem solving challenges. I have ruled out additional challenges such as boundary spanning strategies and the acquisition of organizational support as they are external to the teams. This decision was motivated by the overall contribution I aimed to make in this thesis: addressing cross-boundary challenges by providing prescriptive knowledge through the design of collaborative tools. I have illustrated how design science research can contribute to the organization and management literatures by providing prescriptive guidance on how to go about practical challenges. To do so, I undertook a design science research project consisting of six studies which I organized around the three internal cross-boundary challenges. An overview of the contributions of all the studies is provided in Table 26.

1.1 Synthesis of Studies 1 and 2

In Studies 1 and 2, I have addressed coordination challenges which stem from the difficulty of cross-boundary team members to create shared understanding to integrate their contributions effectively. Previous literature had suggested that coordination challenges be addressed through shared cognition, language, and objects. These three streams of research had evolved independently from each other. I bridged these streams of research by building on the Coopilot conceptual model which describes how teams develop common ground through conversations during team meetings. The conceptual model was extensively based on Clark's (1996) theory of joint activities and Mastrogiacomo et al. (2014). It states that team members must converse during team meetings to establish common ground on four requirements for effective coordination: joint objectives, joint commitments, joint resources, and joint risks.

Table 26 - Synthesis of the contributions of the six studies				
Studies	Research gap	Research question	Contributions to prescriptive knowledge	Contributions to descriptive knowledge
Studies 1 and 2 - Chapter 4	Literature suggests that teams coordinate through shared understanding, language, and objects. These streams evolved separately and there is no actionable guidance on how to coordinate effectively.	How can we support cross-boundary teams in measuring and augmenting common ground to coordinate effectively?	Three design heuristics that support the evaluation and augmentation of common ground for coordination: (1) define the content of shared understanding, (2) allow team members to state their perceived understanding, (3) include a set of remedial actions.	Extension of the Coopilot conceptual model with a process model of team coordination that outlines the main activities: (1) interacting on the four requirements to establish common ground, (2) monitoring the level of common ground to repair any common ground breakdowns.
Studies 3 and 4 - Chapter 5	Shared leadership describes the quality of cooperative interactions in teams. No study suggested how the emergence of shared leadership could be supported.	How can we support cross-boundary teams in developing shared leadership to cooperate effectively?	Shared visualization and shared problem space address cross-boundary cooperation challenges as they support the emergence of shared leadership as they address the three antecedent conditions. The two characteristics also support the process of joint inquiry.	Extension of the Coopilot conceptual model with the process of joint inquiry into the four requirements. This outlines the interactional activities to overcome cross-boundary coordination and cooperation challenges. Social contracts represent the crossing point between cross-boundary cooperation and coordination.
Studies 5 and 6 - Chapter 6	There is an emergence of visual inquiry tools being developed for a variety of wicked problems. Yet, there is no rigorous guidance on how to design such tools.	How can we design visual inquiry tools that guide cross-boundary teams in solving wicked problems?	Design theory with three design principles for visual inquiry tools: (1) frame the wicked problem with an ontology, (2) represent the ontology into a shared visualization, and (3) define and specify techniques that allow for joint inquiry.	Methodological contribution: illustration of the accumulation of knowledge across multiple design science research projects.

In Study 1, I have instantiated the conceptual model into two versions of the Coopilot App which support the measure of the level of common ground on the four requirements and the repair of common ground breakdowns. This tool is the first to measure the level of common ground between team members. I evaluated the usability, usefulness, and validity of the two versions of the Coopilot App in different settings. The first version of the app was evaluated with four cross-boundary teams in various organizations. The second version of the app was evaluated with thirteen teams of undergraduate students. Overall, the results of the evaluation of both versions suggested that the use of the Coopilot App supported effective coordination. The app thus proved effective in supporting the coordination challenges that cross-boundary teams face. I provided three design heuristics to understand how coordination challenges can be supported artificially: (1) define the content of the shared understanding that cross-boundary team members must have to coordinate for their specific joint activity, (2) allow team members to state their individual perceptions of understanding through the artifact, and (3) include a set of remedial actions to guide team members' behaviors.

These insights informed the theoretical development of a process model of team discursive coordination in Study 2. The aim of this study was to address the lack of practicality of traditional accounts of coordination as they did not outline the specific actions and events that must occur for effective coordination. The process model I proposed in this study defines discursive coordination as two activities: that of interacting – by grounding the four requirements for coordination and continuously monitoring the level of common ground – and contributing to the joint activity. These activities were added to the Coopilot conceptual model to include the process through which common ground is established and maintained. This study also suggested that the most critical activity in effective coordination is the monitoring of the level of common ground and the identification and repair of common ground breakdowns. Given that the monitoring of common ground is difficult and cumbersome in situations where there are more than five individuals, these studies underline the need to design artificial support to help cross-boundary team members assess their level of common ground.

Overall, I have argued in these studies that a discursive and material conception of team coordination provides solid bases for the development of tools that can support coordination challenges. These two studies suggest that coordination in cross-boundary teams is a triangle between language, common ground, and objects. My dissertation is an illustration of how these three domains can be bridged to provide prescriptive guidance to cross-boundary teams for coordinating effectively.

1.2 Synthesis of Studies 3 and 4

In Studies 3 and 4, I addressed cooperation challenges which stem from the pragmatic knowledge boundaries in cross-boundary teams. Such boundaries reflect the differences in interests and agendas that individuals across different functions and organizations may have. Literature has suggested that teams who display shared leadership dynamics are well-equipped to overcome cooperation challenges. Carson et al. (2007) identified three antecedent conditions that lead to shared leadership: shared purpose, social support, and voice.

In Study 3, I aimed to design a tool that supported these conditions. I presented the Team Alignment Map which is a paper and digital tool that allows individuals to jointly inquire into the four requirements to coordination. The tool builds on the Coopilot conceptual model and displays the four requirements as empty columns (or shared problem spaces) that cross-boundary team members must fill with sticky notes after collective discussions and agreement. I evaluated the Team Alignment Map with ten cross-boundary teams working on different innovation projects. The findings showed that the Team Alignment Map allowed for the emergence of shared leadership as it supported the three antecedent conditions identified by Carson et al. (2007). An additional antecedent condition emerged in the findings, i.e. social contract. These four conditions were supported by two principles of form and function: shared visualization and shared problem spaces. The findings from Study 3 also suggested that the Team Alignment Map drove practitioners to follow a process of joint inquiry, which appeared to be closely linked to the emergence of shared leadership. Cross-boundary cooperation can be conceived as a triangle between joint inquiry, shared leadership, and support with collaborative objects.

In Study 4, I sought to assess whether this process of joint inquiry was relevant and important to understand not only cooperation challenges as suggested by Study 3, but also coordination challenges. To do so, I have proposed to add Dewey's (1927; 1929) process of joint inquiry to the Coopilot conceptual model for coordination. I evaluated the Team Alignment Map with the 10 cross-boundary teams in Study 3 and 12 teams of undergraduate students working on innovation projects. Results suggested that process of joint inquiry proved relevant for coordination as well, as users jointly inquired into the four requirements to coordinate effectively. Coordination was effective because the tool supported them in creating common ground and having visibility over their future course of action.

The conclusion that I drew from the two studies is that the process of joint inquiry is important and valuable to understand how both coordination and cooperation challenges can be overcome. Social contracts emerged as the crossing point between cross-boundary cooperation and coordination, as they secure cooperation which then allows individuals to coordinate their contributions. I used the visual metaphor of an hourglass in which the cooperation triangle (joint inquiry, shared leadership, objects) feeds the coordination triangle (common ground, language, objects) through the crossing point of social contracts. Overall, these studies have shown that objects that support joint inquiry can prove useful to overcome both the coordination and cooperation challenges.

1.3 Synthesis of Studies 5 and 6

In studies 5 and 6 I have extended this notion of joint inquiry to develop a design theory that supports cross-boundary teams in inquiring into wicked management problems. Such problems are characterized by great uncertainty, changing requirements, and no straightforward solutions. A recent trend of tools, called visual inquiry tools, has emerged for supporting cross-boundary teams in addressing a variety of wicked management problems. There is however no clear conceptualization of what makes these tools more or less effective. Also, these tools have mostly been developed through the imitation of existing tools such as the Business Model Canvas or mere intuition. Therefore, I aimed to develop a design theory based on three rigorous design science research projects that resulted in the design of the Team Alignment Map (for team alignment), the Business Model Canvas (for business modeling), and the Data Excellence Model (for data management). The theorization of the design of these three tools has led to the identification of three general design heuristics that should allow for the rigorous design of visual inquiry tools: (1) frame the wicked problem with a parsimonious ontology that outlines the main dimensions and is based on academic justificatory knowledge, (2) represent the ontology into a shared visualization by structuring the components logically into a visual problem space, and (3) define and specify techniques that allow for joint inquiry.

I have used the visual metaphor of a focal frame which supports the process of joint inquiry into a wicked problem through an ontology that frames the wicked problem and shared visualization that directs the team members' efforts. The frame contains the Team Alignment Map, which can be combined with other additional tools in the blank spaces, such as the Business Model Canvas and the Data Excellence Model. I argue that solving wicked management problems can be supported with a toolbox containing a variety of visual inquiry tools for the range of wicked management problems cross-boundary teams face. Finally, these two studies also allowed us to illustrate how knowledge can be accumulated across similar design science research projects for the development of comprehensive design theories.

2 Putting contributions in perspective

The five years I spent working on the six studies I have related in this dissertation have been a sinuous and often difficult journey. The reason this research project was not as straightforward as the convention would expect is that, throughout all six studies, I was not mainly addressing a research gap. This way of research through gap-spotting contrasts well with the approach I undertook, which is closer to the process of problematization that was suggested by Alvesson and Sandberg (2011). Writing this dissertation and consolidating all the studies and thought experiments I undertook has helped me delineate the contributions and the purpose of my research project.

2.1 Integrating different perspectives and disciplines

The greatest difficulty I have had – which has however turned into one of the main contributions of this dissertation – is the integration of different disciplines and concepts which have evolved separately. Throughout my research project, I have engaged with multiple perspectives: the traditional theories of cross-boundary teamwork in organization and management, theories of language use and coordination in pragmatic linguistics, theories on group cognition, the sociological account of joint inquiry, the research on materiality and objects in teamwork, and the paradigm of design science research.

Not only have I consolidated different perspectives on the same phenomenon – i.e. cross-boundary challenges – I have also integrated different units of analysis to provide a more comprehensive account of cross-boundary teamwork. A great part of research has been conducted through high-level studies of cross-boundary teamwork, leaving the meso and micro-level unaddressed. By combining the different perspectives, I have provided theoretical insights that address the meso- and micro-level of cross-boundary teamwork. I have integrated Clark's (1996) theory which addresses the micro-level of interactions between individuals who carry on a joint activity with the meso-level account of joint inquiry for wicked problems by Dewey (1927; 1929). These different units of analysis have allowed me to provide a more fine-grained understanding of the dynamics involved in cross-boundary teaming. In Studies 1 and 2, I placed the analysis at the level of individuals as I was interested in understanding how team members' individual perceptions resulted in common ground for coordination, and how they could be supported with the Coopilot App. In Studies 3 to 6, I placed the analysis at the level of the team through the concept of joint inquiry which was used for solving wicked problems and allowing for shared leadership to emerge. Both wicked problems and shared leadership are constructs at the team level.

2.2 Reconceptualizing cross-boundary teamwork

The integration of these different perspectives and units of analysis have allowed me to develop a comprehensive conceptualization of cross-boundary teamwork. My dissertation shows how the three cross-boundary challenges – coordination, cooperation, and wicked problem solving – are interrelated through novelty. This insight is in line with Carlile's (2002; 2004) argument that knowledge boundaries are interrelated and add up as novelty increases. Throughout my studies, I made two important additions to his framework.

Firstly, I characterize the novelty by stating that it corresponds to the wickedness of the problems cross-boundary teams face. Therefore, I suggest that the novelty that makes knowledge boundaries emerge is due to the complexity, uncertainty, and intangibility of the wicked problems. Edmondson and Nerbhard (2009) have made a similar claim when they outlined the uncertainty and complexity of projects is one of the problematic issues that cross-boundary teams face. I have shown in Studies 5 and 6 that the issue of novelty can be harnessed by helping cross-boundary teams frame their wicked problems. I have shown that one way to do so is to design visual inquiry tools that frame the elements of the wicked problems with ontologies, and make wicked problem tangible through shared visualization.

Secondly, I suggest that not only are the boundaries between individuals interrelated through novelty, the challenges they pose are also interrelated. I have shown how the Team Alignment Map supports teams in overcoming the three cross-boundary challenges, i.e. coordination, cooperation, and wicked problem solving. I have shown how the different sets of characteristics of the Map address these challenges. In Study 3, I related how the Map supported the emergence of shared leadership for teams to cooperative effectively. In Study 4, I showed how it helped teams coordinate in situations with great novelty and uncertainty. In Studies 5 and 6, I explained how the Team Alignment Map, along with the Business Model Canvas and the Data Excellence Model, supported the process of joint inquiry into wicked problems. Thus, the same tool provided valuable support for the three cross-boundary challenges. I do not, however, imply that the Team Alignment Map is an all-in remedy to cross-boundary challenges as teams also relied on additional tools during their projects. What I want to stress is that the Map was deemed useful for addressing the three cross-boundary challenges, which implies that there is something about the tool that is present for all three challenges. The question that arises here is what makes the Team Alignment Map related to the three challenges?

The common link is the process of joint inquiry that the Team Alignment Map encouraged and which was followed for the three cross-boundary challenges (Figure 27). Viewing cross-boundary teamwork as a process of joint inquiry departs from the predominant accounts which consider teamwork as a collection of parallel processes (e.g. Edmondson and Harvey 2017; Marks et al. 2001). My definition is more in line with that of Steen (2013) who suggested that teams who face design problems enter in a process of joint inquiry. It is important to remind that Dewey's definition of joint inquiry was melioristic and prescriptive. He prescribed that for individuals to ameliorate their situation, they should follow a process of joint inquiry into the problems or issues they face.

My dissertation does not come to dissimilar conclusions. In fact, the studies I conducted on the Team Alignment Map (Studies 3 to 6) suggested that the process of joint inquiry allowed team members to overcome the three cross-boundary challenges. Therefore, I suggest that for cross-boundary teamwork to be effective, it should be considered through the lens of joint inquiry. I believe that conceptualizing cross-boundary teamwork as a process through which team members (1) explore and define their joint problem, and (2) explore and evaluate alternative solutions, rather than a collection of parallel processes is most capable of proving effective.

One of the reasons it proves valuable is that the novel and uncertain realities that cross-boundary teams are most likely to face are better encompassed by the notion of joint inquiry. In fact, the process of joint inquiry is inherently characterized by novelty as it involves the exploration (inquiry) into the problem and the solutions. As cross-boundary teamwork cannot be disassociated from novelty (Carlile 2002; 2004; Edmondson and Harvey 2017; Edmondson and

Nembhard 2009), it proves crucial for future research to endorse a conceptualization that encompasses this novelty. This view informs the dynamics of the interactions between cross-boundary team members when they face novel situations and problems, which is less straightforward in the predominant conceptualizations of cross-boundary teamwork.

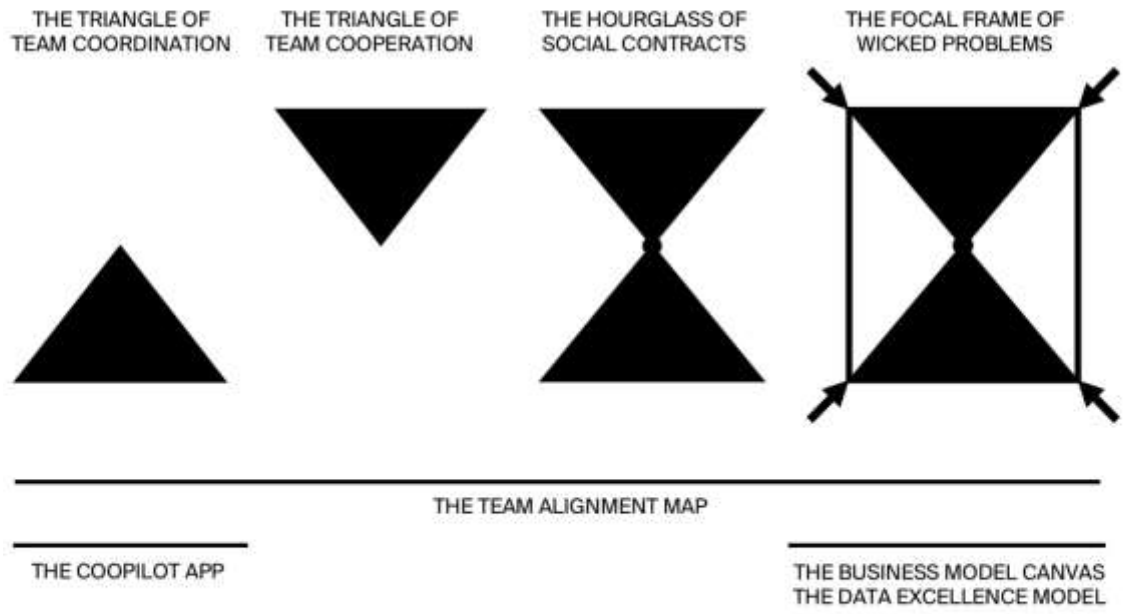

Figure 27 - Visual metaphor of the dissertation

Conceptualizing cross-boundary teamwork through joint inquiry also has the advantage of being applicable to a variety of problems. In Studies 5 and 6, I have shown how joint inquiry can be applied to the problems of business modeling with the Business Model Canvas and data management with the Data Excellence Model. In Study 4, I have also shown how cross-boundary teams jointly inquire into the problem of coordination. The types of problems that cross-boundary teams encounter are then of upmost importance. I suggest that they may even be considered as the phenomenon of interest that should drive future studies. So far, most literature has treated cross-boundary teamwork as the phenomenon of interest. My conceptualization suggests that cross-boundary teamwork becomes the context, which has its own set of characteristics such as novelty and the knowledge boundaries, and the types of problems and challenges they face become the phenomena of interest (Figure 28). This new perspective will differentiate between the problems teams encounter so that research can provide more fine-grained descriptions and guidance that are related to the specifics of the problems that are faced. I will now explain how this perspective might lead to the development of better guidance for cross-boundary teams.

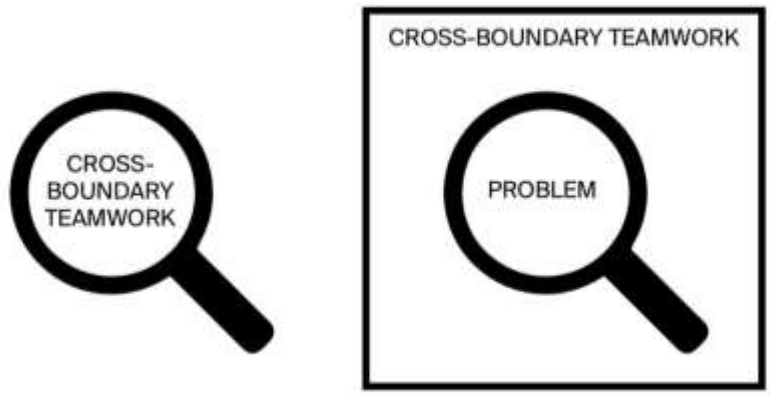

Figure 28 - Visual metaphor of traditional perspectives on cross-boundary teamwork (left) vs. new the conceptualization (right)

2.3 Designing the toolbox for cross-boundary teams

With this focus on the problems that cross-boundary teams face, I seek to underline one avenue that future research might gain in taking. In Studies 5 and 6, we made the claim that future research efforts should be dedicated to the development of a toolbox with visual inquiry tools that address the variety of wicked problems that cross-boundary teams face. The Team Alignment Map, the Business Model Canvas, and the Data Excellence Model are examples of an initial set of tools for cross-boundary teams. Other tools could support, non-exhaustively, the wicked problems of defining the requirements for new information system development projects, defining a brand identity, or the establishment of partnership agreements with external organizations.

All these problems represent wicked management problems. That is, they are complex and intangible problems related to management, and with shifting or uncertain requirements. Our design theory for visual inquiry tools suggests that wicked management problems can be addressed through (1) an ontology that frames the fundamental components of the wicked problem that should be addressed, (2) shared visualization that makes intangible thoughts and discussions visual, and (3) the definition of techniques for joint inquiry. Following these principles can address the complex (ontology), intangible (shared visualization) and uncertain (joint inquiry) nature of wicked management problems. Design science researchers may thus build on our design theory to address other wicked management problems through the design of visual inquiry tools. This design theory should however not be regarded as a comprehensive and exhaustive prescription for designing tools to support cross-boundary teamwork. It provides a solid foundation on how to address cross-boundary joint inquiry. I thus encourage design science researchers to use our design theory as a baseline that can be complemented with any additional prescriptive knowledge. The design theory should be conceived of as a starting point so that design science researchers are not short of prescriptive knowledge on how to address wicked management problems.

Also, various scholars have outlined the extensive reliance of cross-boundary teams on material support (Jarzabkowski et al. 2013; Lee and Amjadi 2014, Nicolini et al. 2012). As I have argued throughout the whole dissertation, most accounts of objects and materiality in cross-boundary teamwork have only provided descriptive analyses of the supporting role of objects. There is thus room and need for design science researchers to contribute with the development of prescriptive knowledge and artifacts that guide cross-boundary teams in solving different wicked management problems. I also think the relationship is reciprocal, as the need for a toolbox for wicked management problems highlights an area of research that is worth investing for design science researchers. My call echoes that of researchers in co-design which have long investigated how to support the intangible and uncertain process of design thinking with materiality (Dalsgaard 2017). Researchers in this stream have designed a variety of tools ranging from conceptual maps to computer-aided design (Détienne 2006).

There has been one recurrent theme throughout the whole dissertation, i.e. visualization. In Study 1, I highlighted the importance of visualizing and materializing team members' perceptions so that they can *see* their level of common ground to coordinate effectively. In Study 3, I have shown how shared visualization supports the emergence of shared leadership. In Studies 5 and 6, I defined shared visualization as a critical characteristic of visual inquiry tools for wicked management problems. These insights corroborate the visual turn that Eppler and his colleagues (Eppler 2007; Eppler 2009; Eppler and Platts 2009; Eppler and Burkhard 2007) have seen in the analysis of teamwork. My dissertation seconds their call for the development of research on visual collaboration.

3 Limitations

In this section, I would like to make the reader aware of the main limitations regarding the findings of the six studies I have related here. I will first outline the main issues with the methodologies for the evaluations I have used and which relies mostly on interviews. I will explain the rationale behind this choice and how my findings can be strengthened, further confirmed, or nuanced with additional studies. I will then reflect on the concerns that are related to the conceptual model which is at the core of my six studies.

3.1 Methodological issues and potential research avenues

I have already outlined the limits of each study in their respective chapters and I invite the reader to refer to them as I would like to outline an overarching limitation that relates to my dissertation in general. The goal of dissertation was mainly exploratory in the sense of Eisenhardt and Graebner (2007) for all six studies. In fact, I have not spotted gaps in well-researched phenomena, rather I have tried to problematize in the sense of Alvesson and Sandberg (2011) and identify new ways through which the coordination, cooperation, and wicked problem solving challenges could be supported through design science research. As the development of prescriptive knowledge for these challenges had only been partially performed before, I have extensively relied on interviews to be able to assess the relevance of the artificial guidance I developed. The rationale behind my choosing interviews as my method for collecting data is that they are particularly well-tailored to analyze phenomena for which little is known and that cannot be directly observable (Kvale 1996; Seidman 2013). In fact, I wanted to attend to the way the artifacts I had developed were perceived by their users and how they attended to them through their own perceptions in their natural environment. I sought to understand their appreciations and the meaning they attached to their experiences of teamwork and those of using the artifacts I have developed in the real settings they face.

However, it should be noted that interviewing has several disadvantages – besides the practical ones such as the intensive data analysis and preparation it requires – that must be taken into account to interpret the results of my dissertation. As noted by Hammersley and Gomm (2008), "what people say in an interview will indeed be shaped, to some degree, by the questions they are asked, the conventions about what can be spoken about; [...] by what time they think the interviewer wants; by what they believe he/she would approve or disapprove of" (p.100). In that sense, interviewee may not report the reality of their experiences, which may be biased by the social interaction with the interviewer. Also, interviewees may have faulty memories, incomplete knowledge, or even filter some of the experiences they are asked to relate (Miles and Huberman 1994). This implies that interviewing risks to account for only the most salient experiences of the interviewee, overruling other events that might prove crucial but are not deemed so by the interviewee. Therefore, qualitative data from interviews might fail to be a rigorous enough source to depict an accurate account of the phenomena of interest.

To avoid these biases, various strategies can be used. First, various researchers have suggested the use of data triangulation by including additional collection methods that may temper the issues of the single method (Eisenhardt 1989). In my dissertation, data triangulation could have been achieved through non-participant observation and the analysis of documents such as project documentation, emails, and additional written records that related elements that are relevant to the project cross-boundary teams were undertaking.

Another strategy would be to design an experiment which would allow to identify causal relationships and test hypotheses in controlled environments (Hacking 1983). Experimentation allows for the observation and manipulation of multiple independent variables of interest, while other independent variables may be controlled for using various techniques. Therefore, given that the exploratory phase of my research project has led to the identification of a number of constructs to address cross-boundary challenges, the validation phase should be done through experimentation in order to test and validate the (strength of the) relationships between these constructs. Or put differently, experimentation would provide more solid ground for assessing the impact of my interventions, i.e. the prescriptive knowledge I have developed.

To do so (quasi-)experiments could be designed for the Coopilot App and the Team Alignment Map following Kirk's (2003) guidelines. For the Coopilot App, several hypotheses can be tested regarding the impact of the Coopilot App on cross-boundary team coordination, such as (1) the application provides an accurate measure of the level of common ground, (2) the application increases the level of common ground compared to a conversation with no material support, (3) the use of the application negatively impacts the emergence of misunderstandings, (4) the use of the application negatively impacts the emergence of coordination surprises, and (5) the use of the application positively impacts team performance. The use of the application is the treatment (independent variable), for which sampling should also include control groups without the use of the application.

The cross-boundary teams can be formed artificially through a scenario such as the one used by for the AMI Meeting corpus (Carletta et al. 2005; McCowan et al. 2005). In this scenario, teams are constituted of four members with different roles (e.g. industrial designer, marketing expert) who need to design a new product (e.g. a new remote control) through four meetings. These meetings happen over one day. In between meetings, participants receive information from the researchers regarding their specific role, which constitutes the individual knowledge that participants must present to others to establish common ground (shared understanding). They also must perform some individual tasks until the next meeting that are related to their specific function. A typical meeting involves the presentation of the requirements for the new product regarding each function (e.g. the industrial designer might have some requirements in terms of materials and complexity of the product while the marketing expert will have requirements in terms of the preferred value proposition according to market analyses), and the planning of the individual tasks that each participant must perform for the next meeting. These meetings should be recorded in video.

As all the information that they need for their joint activity is provided by the researchers, it is easy to know the type and amount of information that participants need to have as common ground. The actual level of common ground can be computed by identifying instances in which participants grounded the relevant information. Utterances of evidence of understanding should be identified and complemented with questionnaires (after each meeting) evaluating the level of understanding that each participant has regarding what was shared during the meeting. These levels should then both be compared to the level displayed by the Coopilot App through one-sample t-tests with experimental groups. To evaluate hypothesis 2, the level of common ground should be compared through two-sample t-tests between control and experimental groups to evaluate whether participants who use the Coopilot App report higher levels of understanding in the questionnaires and through the identification of the evidence of understanding within the conversation of the meeting. To test hypotheses 3 to 5, a similar procedure should be followed, with the exception that the independent variables are measured differently and that all these involve two-sample t-tests between experimental and control groups. The emergence of misunderstandings (hypothesis 3) should be measured by identifying surprises, questions, and disagreements regarding what the team members plan in the conversations for the next meeting and through self-reports in questionnaires assessing their understanding of the joint goals for the next meeting. The emergence of coordination surprises (hypothesis 4) should be measured similarly, except that the focus is on the actions. For example, a coordination surprise occurs if individuals performed some actions in between meetings that are not what the team thought they agreed on. This could create surprises at the beginning of the next meetings when the teams integrate everyone's individual contributions. Finally, the performance (hypothesis 5) can be measured through self-reports in questionnaires on the individuals' satisfaction with the process and the outcome of the new product. An objective measure can also be made through the evaluation of the number of requirements that were met for the design, these being based on the requirements for the product that are given to participants by the researchers.

This scenario can also be used for the Team Alignment Map as it covers the same meta-requirements of the situations in which the Team Alignment Map is applicable and useful. The hypotheses to be tested regarding the impact of the Team Alignment Map on cross-boundary cooperation are: (1) the Team Alignment Map facilitates the emergence of the shared purpose, (2) the Team Alignment Map facilitates the emergence of social support, (3) the Team Alignment Map facilitates the emergence of psychological safety (voice), (4) the Team Alignment Map reduces divergent interests, and (5) the Team Alignment Map positively impacts team performance. All hypotheses should be evaluated with two-sample t-tests. To evaluate hypothesis 1, various events can be measured such as the speed at which the team comes to a shared purpose, the participants' satisfaction with the shared purpose, and the number of divergences and disagreements regarding the shared purpose. For social support (hypothesis 2), the number of utterances of help giving and help seeking can be computed, on top of self-reports of social cohesion and support in questionnaires. For psychological safety and voice (hypothesis 3), the measures can be based on Edmondson's (1999) study. Convergent and cooperative interests (hypothesis 4) should be tested by measuring the self-reported satisfaction of individuals with the shared purpose. Finally, the performance in hypothesis 5 can be measured through self-reports of the participants' individual satisfaction with the process and the outcome, on top of objective measures of the number of requirements that were met by the proposed new product.

This scenario, although not a naturalistic environment, is representative of the meta-requirements for the evaluation of the Coopilot App: it involves members with different functions, the joint purpose of the joint activity is wicked as it is novel and has no straightforward solution, participants do not necessarily know each other beforehand which makes knowledge boundaries even more important, the process to achieve the joint purpose is highly creative as members are not involved in linear problem solving rather creative thinking and imagination to design a new product. However, it is important to note that the scenario has one major drawback that should be accounted for in the interpretation of the results. The findings cannot be extensively generalizable to all situations in which the Coopilot App might be used as the experiment involves one type of wicked problem (i.e. new product development). Therefore, additional naturalistic case studies might prove valuable to provide insights that might emerge from practical situations, in order to, for instance, identify additional use cases and needs for improvement of the tools.

3.2 Concerns with the conceptual model

The other limitation of my dissertation relates to the fact that, throughout the six studies, I have relied on the Coopilot conceptual model which builds on two main theoretical foundations that have never been integrated before: Clark's (1996) and Dewey's (1927; 1929). In the previous section, I have outlined how this proved to be the main strength of my dissertation. I now turn to say that it can also turn out to be its main limitation. The issue that arises here is that their integration would need to be validated more extensively than I have shown in my dissertation. As they are the backbone of my work, it proves crucial to ensure that the conceptual model I provided is not only useful but also valid. But this leaves me with a question for which I have no finite answer, rather only potential lines of inquiry: How can the integration of two theories be validated? Consequently, how can the Coopilot conceptual model be validated?

I assume that one rigorous way to answer these questions would be to build experiments with control and experimental groups. The experiment (or treatment) would be to have groups of teams perform the same task but direct their dynamics and interactions in different ways, so that some would behave according to our conceptual model and some not. However, given the phenomena I was interested in (i.e. joint inquiry into wicked problems), one could expect that it would be difficult to single out and compare interactional dynamics at this level of abstraction. Since these phenomena relate to innovation projects that are characterized by wicked problems, establishing experiments to control for other processes and variables would require some extensive simplifications so that the behaviors between team members would be easier to identify and compared. But this simplification would precisely alter the phenomenon of interest, which is characterized by its complexity. So, this creates a paradox that, if unmanaged, may lead to a similar debate as is prevalent in sociology with the “Bourdieu versus Latour” type of arguments or as with the heated debate in the IS discipline around sociomateriality. As these theories are complex, they can only be exemplified, illustrated or demonstrated. And they all have been to a great extent. Yet, there is no clear answer as to which theory might be superior to the other, scholars often relying on their personal preferences and sympathies. And this could well be the case of my conceptual model.

I would suggest that one way to go around this issue is, simply, to do what I did in this dissertation: instantiate the conceptual model and design theories into additional artifacts, and evaluate these artifacts. As argued by Baskerville and Pries-Heje (2014), design theories may have their own way of being validated, which is through projectability. So, as more tools are designed based on the Coopilot conceptual model and evaluated, the contributions of my dissertation would be better grounded and corroborated.

So this leaves me questioning whether conceptual models are to be rigorously validated, or whether, if projectable, they should not primarily be conceived as lenses that guide the ideation and reflection of design science researchers, when analyzing their artifacts in use or when designing them. I do have personal sympathy for this argument, as the IS discipline could then use social theories and conceptual models as bases for informing what they want their performative design to be directed towards. As Niederrer (2007; 2013) argued, design should be mindful and ethical (2007).

This view would also be more likely to answer the calls that have been made for deeper engagement in the IS discipline with critical theory (McGrath 2005; Mitev 2006; Myers and Klein 2011). In fact, as researchers who design artifacts that can manipulate the course of actions, we ought to be highly critical of our intentions and the theoretical knowledge we base our designs on. Probably, this critical and ethical engagement would prove as equally important as theoretical validation in the IS discipline in the following years, as it is not yet a convention. However, I cannot argue for something without applying it to myself. Therefore, I will conclude the last paragraphs of this thesis with the critical and ethical views I have held in my dissertation.

4 Final word

I will spend my final words underlining something that has been implicit yet omnipresent throughout the whole dissertation. I have extensively made use of what I will call a “lexicon of the common”. I have used constructs such as *common* ground, *shared* understanding, *joint* inquiry, *co*ordination, *co*operation, *col*laborative objects, *joint* activities, *shared* leadership, *shared* visualization, *joint* objectives, *joint* commitments, *joint* resources, and *joint* risks. This is due to my significant reliance on foundational theories that emphasized the collective and the common, i.e. Clark’s theory of joint activities and coordination and Dewey’s (1927; 1929) joint inquiry.

The choice of these theories reflect my considering that research on cross-boundary teamwork should put greater emphasis on what is common rather than on boundaries. Most papers on cross-boundary teamwork focus on the differences between team members that give rise to the knowledge boundaries. In my dissertation, I have not considered boundaries as obstacles – rather as the places where bridges should be established. This is reflected in my using a lexicon of the common. I think that language shapes the way we experience reality, as has been suggested by the seminal works on social constructionism by Berger and Luckmann (1966) and Gergen (1999). Therefore, I believe that using a lexicon of the common encourages researchers and practitioners to construct a more inclusive reality. The careful choice of wordings emphasizing the common might implicitly direct researchers' attention toward supporting and analyzing how individuals with deep differences might display collective dynamics.

The naming of the central concept of my dissertation might to be not so anecdotal in the end. In fact, *cross*-boundary teamwork suggests that working in teams should be concerned with how one can *cross* the bridges over the boundaries.

Appendices

Appendix A

Answers for Study 1 to the question "What did the Coopilot App v2 provoke in your teams when it showed discrepancies between the votes of participants?"

Team numbe r	Verbatim reporting that Coordinator triggered a discussion or a debate within the team.
1	"A discussion to have everyone agree to our strategy." respondent 1 "A short questioning to convince everyone toward the majority." respondent 2 "More communication." respondent 3
2	"A discussion to get to an agreement." respondent 3 "We discussed to get to an agreement." respondent 4
3	"Not much, we discussed about it and moved on to our tasks." respondent 1 "We did not think about it. All members shared their opinion." respondent 2 "It created astonishment. We tried to share our own perceptions to understand where the discrepancies came from [...]" respondent 3
4	"A discussion to all have the same common ground." respondent 1 "A good discussion." respondent 2
5	"We discussed to question ourselves, talk it over and come to an agreement." respondent 1 "We tried to understand the differences and reconsidered the decision and its causes." respondent 2
6	"A questioning. We considered everyone's opinion in order to better understand." respondent 2 "We all shared our points of view in order to better understand each other." respondent 3 "A questioning, followed by a group discussion." respondent 4
7	"We talked about it after that and tried to clear the situation up." respondent 1 "We noticed everyone did not share the same opinion, we discussed to convince each other." respondent 2 "A debate in case of disagreement." respondent 3 "Misunderstanding and a debate." respondent 4 "We discussed about it again and got to an agreement." respondent 5
8	-
9	"We considered we should redo [one vote] to better coordinate." respondent 1 "A misunderstanding. But we all had the same answers eventually." respondent 2
10	"Triggered a discussion to move on faster." respondent 2
11	"A short 5-minute long overhaul to ensure that critical points were clear." respondent 2 "We discussed." respondent 4
12	"After talking about it we got a more mutual understanding. Mainly we were very close to each other's opinions." respondent 2 "We discussed briefly (5 minutes), then started working." respondent 3
13	"We discussed to understand everyone's points of view and tried to make plain what was not clear for some." respondent 1

Appendix B

Answers for Study 1 to the question "What did the Coopilot App v2 provoke in your teams when it showed no discrepancies between the votes of participants?"

Team number	Verbatim reporting that Coordinator triggered a discussion or a debate within the team.
1	"Satisfaction to be on the same wavelength." respondent 1 "Improvement of our cohesion." respondent 3
2	"We were satisfied." respondent 4
3	"We were happy, shows that we work on the same pace and understand the same things." respondent 1 "It was pleasant as it showed we thought the same way." respondent 2 "We were satisfied to concretely see that the group was worked well. In fact, we did not consider talking about aspects that were going well. This only confirmed what we guessed." respondent 4 "It reinforced our common vision, without leading to major changes". respondent 5
4	"Proof that we were on the same page." respondent 1 "General contentment." respondent 1
5	"It allowed us to know that we agreed and that we could continue the project without discussing differences." respondent 1 "We said to ourselves that everything was fine and that we could continue working." respondent 2 "Confirmed group bonding." respondent 4
6	"Some satisfaction to be aligned." respondent 1 "We were more satisfied." respondent 2 "A feeling of common understanding." respondent 3 "We were reassured that we knew where we were heading to and that common ground was well established." respondent 4
7	"Cohesion." respondent 1 "Enthusiasm because we then knew where we were going." respondent 2 "We could keep on knowing that we were on the right track." respondent 4
8	-
9	"It allowed us to see that we were on the same wavelength." respondent 1 "Good harmony." respondent 2
10	"It allowed us to confirm our choices." respondent 1 "That the issue was clear and understood and that we could move on to the next issue." respondent 2
11	"The feeling to know what we are doing and where we are heading to." respondent 2 "Coordinator showed that everything went well in our team." respondent 3
12	"A shared agreement that we could move on and that we all knew where we were." respondent 3
13	-

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