Better Together - The Essential Components of the Integrated Knowledge Translation Collaborative Process for an Interdisciplinary Collaborative Research Project in Environmental Health

by

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ABSTRACT

Academia has transformed research to be more collaborative to address complex questions such as understanding the relationship between human health and the environment. Such collaborations harness diverse expertise and perspectives of various stakeholders including researchers, practitioners, decision makers and other knowledge users to ground and enhance the depth and breadth of research and promote translational efforts. One such collaborative approach is Integrated Knowledge Translation (IKT), which promotes the application of research findings by building partnerships between researchers and knowledge users throughout the entire research process. Many acknowledge the benefits of research collaborations to the creation and translation of knowledge; however, there is a growing interest and need to understand what shapes these research partnerships. Different assets are available for a research project at the outset, such as the vision, resources, frameworks, and individuals' expertise, experience, curiosity, attitudes, and will. These ingredients form the foundations for team growth, but more needs to occur.

The objective of the thesis was to understand the essential components of the collaborative process of IKT for an interdisciplinary and knowledge user-oriented collaborative research project, and how these processes manifest and evolve in real-life research collaboration.

This qualitative case study followed the Data Mining & Neonatal Outcomes (DoMiNO) project engrained in the context of environmental health research, over its five years of operation. Participants of the study included all 24 DoMiNO team members. Data were collected and generated through interviews, focus groups, surveys, and participant observations, for which I conducted an iterative analysis process using inductive thematic analysis procedures. Data and analysis contributed to the cumulative understanding of the case, the essential components of the collaborative research process, and the IKT evolution of the case.

The thesis provides the background on collaborative research in the context of environmental health, descriptions of the case (including its context and challenges), and the eight essential components identified; including their meanings, dimensions, and how they manifested in the DoMiNO project.

The partnership evolved by establishing friendly and collegial relationships, advancing individual growth, and building team capacity, which require the maintenance of alignment, keeping everyone on the same page, regarding progress, expectations, and knowledge. These steps were fundamental to establishing trust in each other and in procedures and outcomes, for the project's progression. Developing individuals' sense of shared ownership was also important, leading to the performance and production of new knowledge, and the development and implementation of the KT plan. Furthermore, operative elements fostered the evolution of the collaborative climate. These included maintaining communication channels, creating a supportive environment for learning, ensuring an inclusive setting, and embracing an attentive leadership style that sets the tone for the collaborative process. Additionally, individual attitudes played a role in supporting the collaborative climate through individuals' commitment of time and attention to the project, engaging in active dialogue and reflection, and keeping an open mind towards other epistemologies.

Together, all the identified components created collaborative climate conditions, which contributed to growth and achievements. In different situations, these components hindered or facilitated the project's progression. Moreover, each one of these components was interconnected as part of a web and impacted each other as the project progressed. Thus, the evolution of the IKT collaborative process was achieved by the components directly and indirectly as a cumulative effect that supported the team performance, productivity, co-creation, outcomes, and KT.

Based on both the researchers and knowledge users' perspectives, this empiric study contributes to current literature by providing an in-depth description of individual and collaborative team processes in which interdisciplinarity and IKT are managed for the co-production of knowledge and KT. This study illuminates essential components of collaborative research and their joint evolution as one comprehensive evolutionary process, and their contribution to shaping, implementing, and maintaining IKT. The study focused on research collaboration in environmental health research, which was unique in its context, but one that may be similar to other projects regarding the processes and conditions required to enable a collaborative climate. Hence, learnings from the case and the empirical evidence this case provides may be valuable to researchers, funders, and practitioners from different research fields.

PREFACE

This thesis includes an original work by Osnat Wine. The research project, which this thesis is a part, is the Data Mining and Neonatal Outcomes (DoMiNO) Project at the University of Alberta, entitled "Spatial data mining exploring co-location of adverse birth outcomes and environmental variables", and co-led by Dr. Alvaro Osornio Vargas and Dr. Osmar Zaïane. The project received research ethics approval from the University of Alberta Research Ethics Board, No. PRO 00039545, in 2013.

Some of the research conducted for this thesis forms part of the DoMiNO project. Two manuscripts included in this dissertation (**Chapter 2** and **4**) were created in collaboration with members of the DoMiNO team and other collaborators. The manuscripts are presented in the thesis as they were published with minor adjustments to align with the thesis format.

Chapter 2 has been published as: Wine O., Ambrose S., Campbell S., Villeneuve P.J., Kovacs Burns K., Osornio Vargas A., and the DoMiNO Team. (2017). Key components of collaborative research in the context of the environment and human health: A scoping review. *The Journal of Research Practice,* 13, 2. I was responsible for the study design, selecting, preparing, and analyzing publications for review and writing the manuscript. Sarah Ambrose assisted with data selection and preparation for analysis, reviewed and edited the final manuscript. Sandra Campbell conducted the literature search, reviewed, and edited the final manuscript. Drs Villeneuve, Kovacs Burns and Osornio Vargas provided theoretical advice, reviewed, and edited the manuscript.

Chapter 4 has been published as: Wine O., Zaïane R.O., Osornio Vargas A.R. and on behalf of the DoMiNO Project team. (2019). A collaborative research exploration of pollutant mixtures and adverse birth outcomes by using innovative spatial data mining methods: The DoMiNO Project. *Challenges*, 10, 25. I was responsible for the conceptualization, methodology, analysis,

and writing. Dr. Osornio Vargas and Dr. Zaïane were involved in the conceptualization, review, and editing.

Other collaborative studies undertaken throughout my Ph.D. studies include:

Serrano-Lomelin J.A., Nielsen C.C., Jabbar M.S.M., **Wine O.**, Bellinger C., Villeneuve P.J., Stieb D., and the DoMiNO Project Team: Buka I., Aziz K., Kumar M., Chandra S., Yuan Y., Hystad P., Erickson A., Demers P., Shah P., Aelicks N., Crawford S., Phipps E., Zaïane O.R, Osornio-Vargas A.R. (2019). Building robust hypotheses on associations of mixtures of industrial air pollutants with adverse birth outcomes. *Environment International,* 131.

Wine O., Buka I., Day A. Terris S., Clarkes M.A., Osornio Vargas A., Kovacs Burns K. (2019). Building a children's health and environment research agenda in Alberta, Canada: A multi-stakeholder engagement process. *Gateway: International Journal of Community Research and Engagement, 11, 2.*

Li J, Adilmagambetov A., Jabbar M.S.M, Zaïane O.R, Osornio-Vargas A.R, **Wine O.** (2016). On discovering co-location patterns in data sets: a case study of pollutant and child cancer. *Geoinformatica*, 20, 2.

To my beloved late parents, Victoria and Zion Lev, and father in law Brian Wine - I miss you

To my husband and best friend, Eytan - you are my love and my inspiration

To my wonderful children, Itai, Roey and Noam- I am so proud of you

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I feel extremely fortunate to have had the guidance, encouragement, and constructive mentoring of my supervisory committee members. I have learned so much from each one of you. Michael van Manen, thank you for always providing practical solutions and advice. Thank you, Kathy Kovacs Burns, for your continuous guidance and support on so many levels. Your experience and wisdom provided me with a great learning experience, and your long-standing and continued support was always so reassuring. Thank you, Jude Spiers, for being a great source of support, guiding me through the complex pathways of qualitative research, and for always

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CHAPTER 1

INTRODUCTION

Academic and societal interest drive research endeavors to address complex research questions, such as understanding the connection between the environment and human health. In trying to address such complex questions, the academic approach is being transformed towards collaborative research, harnessing diverse expertise in order to extend the depth and the breadth of the research and its implications. Such collaborations call for different disciplines to display and accomplish scientific integrity, rigour, progression, and innovation. Additionally, input from stakeholders and users helps to position and steer the research, as well as advance the application and impact of the research findings. While collaborative research is desirable, it may not be a simple practice since individuals who differ in backgrounds and expertise need to join forces. What needs to occur within the collaborative process of research teams? How can a research team work better together and maximize their performance, scientific output, and translational efforts toward increased outreach and impact? These questions inspired the exploration described in this thesis.

1.1 RESEARCH IN ENVIRONMENT AND HUMAN HEALTH: CO-CREATION OF KNOWLEDGE AND KNOWLEDGE TRANSLATION

Co-creation of knowledge

Environmental risk factors contribute to the burden of disease worldwide, specifically in children, driving a growing interest and need in children's environmental health research to inform policy (CEHN, 2020). (**Appendix 1.1** contains definitions for environmental health and other terms used throughout the thesis) . Of special interest is the study of air pollution and its significant impact on children's health and survival. The WHO reports that approximately 93% of all children globally are exposed to air pollution levels above WHO guidelines (WHO, 2018a). In order to truly understand the relationship between air pollution and health, research efforts need to make sense of the 'soup of chemicals' in the air and the related health outcomes. This creates a complex research setting, which requires the inclusion of big data (*i.e.,* many variables and different sources) and calls for sophisticated and advanced analytic methods. Addressing such research requires the expertise and experience of researchers and stakeholders from different disciplines who produce new knowledge through interactions between them based on mutual learning for a joint goal (Repko, 2008; Van De Ven & Johnson, 2006); a process often named *co-creation* (Fazey & Evely, 2013) or *co-production* (Graham, McCutcheon, & Kothari, 2019).

Scientific collaborations refer to research conducted by more than one individual, in small and large teams, sometimes referred to as *team science* (Cooke, National Research Council, & Hilton, 2015). Research teams can differ by the levels of integration among the disciplines involved. In *multidisciplinary research,* insights from two or more disciplines are placed side by side and each discipline makes a separate contribution. *Interdisciplinary research* refers to a

process of addressing a complex topic, which draws on several disciplinary perspectives and integrates their insights to produce a more comprehensive understanding beyond the scope of a single discipline (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2005; Repko & Szostak, 2017). One metaphoric analogy which can be used to explain, in a simple way, the difference between the two relates to multidisciplinary research as a fruit-salad, in which fruits are placed side by side, whereas interdisciplinary research is analogous to a smoothie, which blends all the individual tastes and exemplifies an integration process of the different disciplines' perspectives (Nissani, 1995). Integration is situated as a central aspect of interdisciplinary research. Repko and Szostak (2017) define integration as "a cognitive process of critically evaluating disciplinary insights and creating common ground among members to construct a more comprehensive understanding" (p. 21). The integration is of information, data, techniques, tools, perspectives, concepts, and theories from two or more disciplines (National Academy of Sciences et al., 2005). Although integration usually refers to a team it could also occur within a single mind (Wagner et al., 2011), required from individuals as part of the interdisciplinary collaborative process. Another collaboration among different disciplines and partners is transdisciplinary research (I expand on that approach below).

In a research context such as environmental health, interdisciplinarity is key for addressing complex research questions used by many research initiatives. Interdisciplinary research provides many obvious benefits but can also introduce challenges to the team, such as high diversity among members, deep and profound knowledge integration, large team size, goal misalignment, changes in the team and project boundaries, geographic dispersion, and task interdependence (Cooke et al., 2015). Others raise awareness to the practical, personal, and professional costs of co-production (Oliver, Kothari, & Mays, 2019). These situations can create discomfort and require research team

members to learn how to collaborate and be able to overcome barriers to build joint capacity and work together towards a common goal (Freeth & Caniglia, 2020).

Knowledge translation

Research collaborations have been increasingly applied, as evaluated by screening of publications number and the diversity of authors involved and citations from different disciplines used (Cooke et al., 2015; Van Noorden, 2015); moreover, there is recognition that research collaborations can improve the outcomes and translational efforts. For example, publications are traditionally used to evaluate scientific innovation and team effectiveness (Wagner et al., 2011); larger teams have been found to have more publications, which were published in higher impact journals (Newig, Jahn, Lang, Kahle, & Bergmann, 2019). However, another integral part of the research process and measure of success beyond the co-creation of new knowledge is the translation, outreach, and utilization of the research to useable avenues to support changes in policies, practices, and research and to ultimately improve children's health (Gavidia et al., 2011). While in the past, passive diffusion of research findings through publications and public presentations was the usual route of research outreach; there has been a shift towards more interactive measures with potential users and stakeholders. The Canadian Institute of Health Research (CIHR) has named this process Knowledge Translation (KT). It refers to "*a dynamic and iterative process between researchers and knowledge users that includes synthesis, dissemination, exchange, and ethically sound application of knowledge*" (CIHR, 2016b).

KT processes can help to maximize the translation and implementation of outcomes of knowledge-producing activities framed to respond to a recognized need or problem (Fazey & Evely, 2013; Kitson et al., 2013; Straus, Tetroe, & Graham, 2009). However, to date, there is a

gap in our understanding of effective methods for moving knowledge to practice (Bowen & Graham, 2013b). Different models have been proposed to enhance the effectiveness of the dissemination and implementation of research (Tabak, Khoong, Chambers, & Ross, 2012), including the 'knowledge-to-action framework' (Straus et al., 2009). Collaborations between different disciplines and practitioners from different sectors have shown to increase the likelihood of advancing knowledge to practice, supporting action, and informing policies for change (Reed, Stringer, Fazey, Evely, & Kruijsen, 2014; Rycroft-malone et al., 2016; Van De Ven & Johnson, 2006).

Given the complexity of research and the fragile nature of outcomes in environmental health research that deals with risk and uncertain and sensitive outcomes with potential impacts on different aspects of society (*e.g.,* economic, political) (Briggs, 2008), unique knowledge translation, exchange, and mobilization approaches are required to address the complexity of this research field. The Literature on different collaborative processes in environmental health research had limited discussion on KT as part of the research. Only a few publications identified in the scoping review (**Chapter 2**), addressed KT development and the consequent application of KT in a meaningful way in this context (Jack, Brooks, Furgal, & Dobbins, 2010; Reed et al., 2014; Strosnider, Zhou, Balluz, & Qualters, 2014). Often, KT was mentioned as a possible additional avenue of the collaboration and the development of intricate findings that required complex procedures for co-creation and KT.

1.2 INTEGRATED KNOWLEDGE TRANSLATION AND COLLABORATIVE RESEARCH

In addition to integrating multiple perspectives of researchers, the input of stakeholders and potential knowledge users can contribute to addressing questions, such as those related to environment and health.

Hence, framing environmental research studies based on a collaboration of researchers and stakeholders or knowledge users can address the complexity and the uncertain and sensitive outcomes that environmental health research presents (Briggs, Sabel, & Lee, 2009). It can support co-creation and KT - *i.e.,* development of communication methods, strategies, and messages, which help inform policies (Garnett, Green, Chalabi, & Wilkinson, 2019; Wartenberg, 2009).

Several frameworks promote the inclusion of different perspectives and expertise in the co-creation process. In particular they are committed to translational efforts and the impact and intake of the research; to name a few: mode 2, participatory research, engaged scholarship, and integrated knowledge translation. These approaches differ in their orientation, historical roots, and the roles partners play. They also have several similarities; all frameworks focus on pursuing true partnerships, embracing similar core values and principles of inclusion, co-creation, reciprocity, trust, relationships, collaboration, respect, co-learning, active participation, democratization of knowledge, shared decision-making, equality, and equitability. They all consider team dynamics and the research practice, and all require considerable time investments (Jull, Giles, & Graham, 2017; Nguyen et al., 2020). Furthermore, all collaborative research frameworks may face challenges resulting from the integration of different perspectives, such as different languages, agendas, political forces, engagement, as well as the impact on academic outputs (*e.g.,* longer time required) (Brown, Deletic, & Wong, 2015; Fazey et al., 2014; Newig et al., 2019).

Of specific interest to this thesis is *Integrated Knowledge Translation* (IKT). The IKT approach was coined in 2007 by the CIHR. Research funders developed it to engage with decision makers as part of the Knowledge-to-Action framework (CIHR, 2016b) (Graham et al., 2006) to promote improvements in healthcare systems.

IKT fosters processes for co-creation, drawing on principles that promote equitable participation of both researchers and knowledge users or stakeholders in all parts of the research project. Knowledge users are individuals who could act upon the findings or outcomes of the research; they are individuals that could include practitioners, patients, caregivers, communities, community-based organizations, health care institutions, decision-makers, policy-makers, and other stakeholders. Those who participate in the research project are referred to as 'integrated knowledge users' (CIHR, 2015). Knowledge users and other stakeholders in research often understand the complexities and nuances inherent to the context, which enables them to contribute to the breadth and depth of the research and its implications. They can support translational activities and promote the employment of research findings into usable applications in research, policy, and practice. Contributions from practitioners from an early phase of the research have been shown to positively influence the production and application of certain societal and practice relevant outcomes (*e.g.,* changes in policy, production of guidelines, raising awareness) in sustainability research (Newig et al., 2019). In IKT, knowledge users and other stakeholders are engaged at the outset of the research project and take an active part in the research formulation, co-creation of new knowledge, knowledge translation, and knowledge exchange (CIHR, 2015; Kothari & Wathen, 2013).

IKT integrates co-creation with knowledge translation and has been positioned as an ideal approach to address the problem of the under-utilization of research findings and a promising

avenue for closing the gap between knowledge to action in health care (Kothari & Wathen, 2017). The rationale for this is two-fold; researchers better understand the users' needs and context, and users can help steer the project in a manner that will result in the production of relevant outcomes, which can then be implemented. Knowledge user participation in partnerships with researchers increases their understanding of the project's strengths and limitations. Thus, it increases awareness and appreciation for the project outcomes to then identify how best to apply those (CIHR, 2015). To date, IKT has been widely accepted (Nguyen et al., 2020), and recently been adopted by WHO to support the development of evidence briefs, for example (WHO, 2019).

IKT was conceived under the general umbrella of health research (CIHR, 2016b). However, existing scientific literature mostly focuses on healthcare settings to improve healthcare outcomes (Gagliardi, Kothari, & Graham, 2017; Nguyen et al., 2020). There are some examples of publications that described IKT in different contexts than health care, such as the public health research context (Kothari, Sibbald, & Wathen, 2014; Lapaige, 2010; McIsaac et al., 2018; Rishworth, 2016; Sibbald et al., 2012). However, I could not find any published examples of IKT approach in environmental health research. As I describe in the thesis (**Chapters 2 and 4),** environmental health research and accompanying KT have complex characteristics (*e.g.,* complex research framework, uncertainty, large-scale implications). Therefore, I assumed that the research field's context was important to consider for the application of IKT in any research field, especially EH, since it created a unique and complex setting for co-production and KT. Furthermore, preliminary literature searches identified sporadic examples of collaborative frameworks in the context of environmental health that are similar to the IKT approach (*i.e.,* promoting collaborative co-production with the intent to support KT). There are different research frameworks such as OneHeath, EcoHealth, and Planetary Health, which are aimed to understand environment and

health issues in a more holistic way (Lerner & Berg, 2017) or Briggs's (2008) framework for environmental health assessment. All call for a more interdisciplinary research approach and collaboration with stakeholders across sectors to promote the breadth of the research and its usability but were lacking details on the processes involved.

Transdisciplinary research is another collaborative approach. It aims to bridge the gap between knowledge production and knowledge needs by innovation and creative solutions for societal needs. Generally, it focuses on large-scale questions (*e.g.,* environmental health and climate change) following an interdisciplinary approach to the research questions (Hadorn et al., 2008). Unlike interdisciplinary, transdisciplinary research crosses both disciplinary boundaries and sectors of society by including stakeholders from the public and private domains to create methodologies that integrate knowledge (Gray, 2008) and at times, includes translating research findings to practical solutions (Cooke et al., 2015).

Additionally, participatory research such as *Community Based Participatory Research* (CBPR) has significantly contributed to the understanding of collaborative research. These research projects build on partnership between academic researchers and individuals or communities promoting social and environmental injustice to empower the community and advance impactful change (Israel, Schulz, Parker, & Becker, 1998; Macaulay, 2017; Nguyen et al., 2020).

Research collaborations contributed to exciting improvements and scientific revelations; moreover, they need to continue and address the burning issues our society encounters (Cook et al. 2015). Research collaborations have been promoted by funding agencies (Ledford, 2015). Identifying what makes a team effective can justify these investments and promote scientific and translational advancements (Stokols, Misra, Moser, Hall, & Taylor, 2008).

Multiple papers have recognized the need to think of and address questions about increasing team effectiveness. Learning about the effectiveness of teams requires the understanding of the complexity of tasks, the integration involved at different levels (individual, team, and contextual), and a recognition in the dynamic interactions and evolution of a team over time (Cooke et al., 2015). Different elements were identified to impact the effectiveness of teams. These include factors external to the team, such as organizational factors (*e.g.,* institutional incentives and support systems), physical factors (*e.g.,* spatial proximity of team members, work and meeting space), technologic factors (*e.g.,* infrastructure for remote engagement, high level shared data storage and security, team technologic readiness), and socio-political factors (*e.g.,* policies supporting intellectual property and ethics, collaboration among different countries). There are also interpersonal factors that pertain to elements among the team members such as effective communication, diversity, ability to learn from each other and to be flexible, and intrapersonal factors that refer to attitudes and values, readiness, and experience of individuals in the team (Cooke et al., 2015; Stokols et al., 2008). Internal team processes, such as shared understanding of goals and roles, and team cohesion have a direct impact on team performance; *i.e.,* the team's capacity to achieve its goals and objectives. Furthermore, in a comprehensive report on the effectiveness of collaborative teams three pillars that impact team processes on an individual and team levels were identified: team composition, team leadership, and professional development (Cooke et al., 2015).

1.3 COLLABORATIVE RESEARCH: WHAT ARE THE GAPS?

There is a growing interest in learning more about collaborative research processes in research teams in different contexts and fields. Specifically, many researchers identified a gap in understanding the dynamics and strategies to improve the performance and productivity of research teams, especially noting a lack of empirical research (Bozeman & Youtie, 2017; Cooke et al., 2015; Gagliardi, Berta, Kothari, Boyko, & Urquhart, 2016; Graham et al., 2018; Hall et al., 2018).

IKT, for example, has been widely accepted as a research approach that can increase the relevance, applicability, and impact of research. However, there is limited research on how to best conduct and support IKT for health research and learning about IKT processes and outcomes are of great interest (Graham et al., 2018). Moreover, little has been published on collaborative research, specifically as aligned with the IKT process, in the research field of environmental health, and even less regarding children. In the context of healthcare, synthesized studies that empirically evaluated IKT experiences in health systems, lack details on activities and strategies of IKT to achieve beneficial outcomes (Gagliardi et al., 2016). It was suggested, that in order to advance IKT practice (*i.e.,* planning and application), future research should center on effective processes for partnership formulation and collaboration based on empiric evidence. Other avenues for future research on IKT include studying other collaborative approaches, learning from real life experiences from multiple perspectives, and developing evaluation of IKT outcomes (Gagliardi et al., 2017; Graham et al., 2018; Kothari & Wathen, 2017).

The interest in advancing the understanding of team processes was also pronounced in other contexts. Social scientists indicated that literature on team science have provided concepts,

frameworks, and propositions. However, they identified a lack of empirical work on the operation and dynamics of scientific teams (Bozeman & Youtie, 2017). Particular interest for future research was focusing on individual factors and team dynamics, and their influence on the effectiveness and productivity of teams (Cooke et al., 2015). Others recommended applying qualitative case study methods for the purpose of theory generation, development of measures and metrics, and the study of complex interacting factors in real-world environments of research collaborations (Hall et al., 2018).

1.4 RESEARCH OBJECTIVE

This dissertation addresses the gap and interest in further understanding collaborative team processes and in particular considering the emerging need to support knowledge synthesis and translation. The thesis provides insights on the collaborative process in IKT for establishing partnerships, supportive of building research and KT capacity, within the complex and unique context of environmental health research. My research study responds to an identified gap by pursuing an in-depth understanding of intra-team and individual processes and provides empirical evidence that can advance current knowledge about interdisciplinary and IKT collaborative processes.

I conducted a qualitative case study based on an interdisciplinary research project (DoMiNO - Data mining & Neonatal outcomes) (DoMiNO, 2014) and its IKT approach embedded in the complex context of exploratory research in environmental health. The thesis provides empiric findings exploring an interdisciplinary setting with its benefits and challenges, which brings

additional complexity to the already complicated IKT process and introduces a perspective on research practice not usually considered in this research field.

The project included a dedicated evaluation of the collaborative process; exploring the essential components of the collaborative aspect was the focus of this dissertation. I followed the DoMiNO project over its five operational years. I learned from the perspectives of team members what the essentials components of the collaborative process were, and of their significance for the DoMiNO project IKT approach (*i.e.,* the potential to facilitate or hinder progression). I examined why and how these components contributed to the team's growth and progress towards team performance and productivity, creating new knowledge, and knowledge translation.

The thesis was developed to answer the following research questions:

- What are the significant components of the collaborative process for IKT in DoMiNO?
- Why were these components considered significant for DoMiNO's performance and productivity, and how did they manifest in DoMiNO?
- How were these components attained, and what contributed to their initiation and evolution?

1.5 DISSERTATION OVERVIEW

The dissertation follows a *mixed-format thesis* style, in which there is a blending of published and yet to be published research. The research objectives correspond to the following chapters:

Chapter 1 introduces the dissertation topic, characterizes environmental health research, describes IKT and other collaborations for knowledge creation and translation, and identifies

research gaps. It presents the research questions that guided this study and provides a broad context and overview of the dissertation.

Chapter 2 is a scoping review that provides the background for this study. The review identifies the key components (facilitators, barriers, and challenges) of collaborative research processes and potential research gaps in the existing literature regarding collaborative processes, in environmental health research. The scoping review was published in the *Journal of Research Practice* in 2017 (Wine et al., 2017).

Chapter 3 presents the theoretical and methodological framework undertaken to construct this thesis. The chapter includes theoretical assumptions, the research approach, the case study setting, and participants, researcher stance, data collection and generation methods, analysis procedures, rigour strategies, and ethical considerations.

Chapter 4 describes the DoMiNO project as a case report from a collaborative lens. The chapter provides details on the DoMiNO project context of research, the research and collaborative (IKT) frameworks, the team, the different phases of the project including outcomes and KT, and preliminary insights about the facilitators and challenges the project encountered. The case report was published in the journal *Challenges* in 2019 (Wine, Zaïane, & Osornio Vargas, 2019).

Chapter 5 presents the themes identified through the case study analysis as the essential components of the collaborative process in IKT. It describes the dimensions of each of the components, and how they manifested in the DoMiNO project throughout its operation and contributed to the performance and productivity of outcomes and KT.

Chapter 6 presents a deeper interpretive level of analysis to provide additional affirmation of the components' significance to the collaborative team processes. This analysis extends the components' dimensions through exploration of the essential components under different research settings, the connection between them, and by examining the components through participants' views in retrospect. It illustrates the essential components for IKT in a conceptual framework.

Chapter 7 discusses the implications of the thesis findings in reference to the literature on team processes in collaborative teams in environmental health research and in other research teams and contexts. The chapter provides insights into the development of KT and IKT, discusses the thesis strengths, limitations, the researcher's stance as an insider, a reflection on the research journey, and future implications.

CHAPTER 2

KEY COMPONENTS OF COLLABORATIVE RESEARCH IN THE CONTEXT OF ENVIRONMENTAL HEALTH: A SCOPING REVIEW

Osnat Wine, Sarah Ambrose, Sandy Campbell, Paul J. Villeneuve, Katharina Kovacs Burns, Alvaro Osornio Vargas, and on behalf of the DoMiNO team.

The following chapter is a scoping review conducted with several collaborators and published in *The Journal of Research Practice.* 2017 volume 13, issue 2. The aim of the scoping review was to provide the background from studies, which explored collaborative research processes and KT as the context for studying similar processes in environmental health research and identifying research gaps.

ABSTRACT

Interdisciplinary researchers and multi-sectoral stakeholders' participation in a collaborative research process support the co-creation, translation, and exchange of new knowledge. Following a scoping review methodology, we explored the collaborative research processes in the specific context of environment and human health research. Initially, our literature search strategy identified 1,328 publications. After several phases of reviewing and applying screening criteria to titles, abstracts, and full text, 45 publications were selected for final review. Data were charted by different topics and then collated, summarized, and analyzed thematically. From the different experiences and research approaches analyzed, we identified comprehensive details of the key

components, facilitators, challenges, and best practices that impact the collaborative research process. Specifically, we identified the following seven emerging themes: (a) allocating time and resources, (b) addressing disciplinary and sectoral issues, (c) building relationships, (d) ensuring representation, (e) embedding participation in the research, (f) supporting ongoing collaboration, and (g) developing knowledge translation and exchange.

2.1 BACKGROUND

The global burden of disease attributed to environmental factors was estimated by the World Health Organization to be close to 22% and even higher in children (Prüss-Ustün, Wolf, Corvalán, Bos, & Neira, 2016). *Environmental health* research aims to explain how the environment (*i.e.,* the biological, chemical, physical, and social factors external to a person) impacts human health (for more detailed definition of this and other related terms, see **Appendix 1.1**). This is an evolving and complex research field aimed at creating new knowledge to support and influence practice, policy, or further research and ultimately, improve human health (Finn & O'Fallon, 2015). Environmental health research considers different levels of investigation, ranging from genetic and cellular effects to population health. It also applies multiple methods of inquiry and expertise from various disciplines and sectors. Current trends in research are also shifting from exploring the relationship between a single exposure and one health outcome of interest to exploring the complex interplay between multiple exposures and outcomes, which imply a 'web of causation' (Briggs, 2008; Dixon, 2002; Dominici, Peng, Barr, & Bell, 2010; Mauderly et al., 2010).

With this type of research, there is an expectation of additional complexity due to the high level of uncertainty accompanying its conceptualization (*e.g.,* incomplete or aggregated data), the analysis of results (*e.g.,* confidence levels, exploratory nature of the research), and communication of the results (*e.g.,* no research is perfect, and no results are absolute) (Briggs et al., 2009). Furthermore, this field of research is highly context-sensitive, since it deals with health-related risk issues that can have significant social, political, environmental, and economic impacts (Briggs, 2008). These impacts can have repercussions beyond the immediately affected communities as the policy requirements for change often have a significantly broader economic and political cost. For example, the use of coal to generate electricity that would presumably create jobs to stimulate the economy, also contributes to air pollution and occupation disorders, which may have severe impacts on the global climate and population health (Lipton & Meier, 2017).

All these factors contribute to the unique aspects related to the study of the environment and human health. Interdisciplinary and collaborative processes were identified as appropriate approaches for co-creating and co-producing new knowledge and practices, and *knowledge translation* (Briggs, 2008; Fazey & Evely, 2013). This emphasizes the contribution of engaged scholarship among academics, practitioners, and stakeholders to respond to big complex unanswered questions (Van De Ven & Johnson, 2006) and facilitate the process of creating and translating new knowledge to inform change (National Institute of Environmental Health Studies, 2020). Additionally, due to the sensitive context of environmental issues and human health, there is a need for an elaborated decision-making process that defines the knowledge translation plan (CIHR, 2016b) (*e.g.,* deliverables, messages, audiences, and strategies) and how the new knowledge should be used (Hage, Leroy, & Petersen, 2010) for the benefit of communities and researchers (Brown et al., 2015). The expectation is that co-produced knowledge is more likely to

be accepted and used by *knowledge users* for action, implementation, decision and policy making, and identification of future research needs (Annerstedt, 2010; Cook et al., 2013; Reed, 2008).

Collaborative and interdisciplinary research may appear ideal; however, this research tends to present practical and conceptual challenges. In this context, there is a need to further understand and learn how to best support collaborative and interdisciplinary research (Krebbekx, Harting, & Stronks, 2012; Meadow et al., 2015). Knowledge on the collaborative process is somewhat fragmented in this area. As well, we are not aware of any publication that solely addresses the collaborative process in the context of environmental health or provides a specific framework for the kind of research conducted in this context.

Thus, in this *scoping review*, our aim was to explore and identify the extent and nature of the scholarly literature regarding research studies that address or describe experiences or research on the collaborative research processes in the context of environmental health research, and with the intent of capturing the following:

1. The key components, facilitators, barriers, and challenges of collaborative research processes in environmental health research context.
2. Potential research gaps in the existing literature regarding collaborative processes in this context.

We expected that collating and summarizing the knowledge and experiences identified in the literature and disseminating our findings would support better understanding of the processes and the accompanying challenges. Our review is intended to provide an overall view of what is known on the collaborative research process and its key components. More specifically, this review will be useful for the collaborative process of an ongoing environment and health project conducted by

our research team (*i.e.,* the Data Mining and Neonatal Outcomes [DoMiNO] (DoMiNO, 2014), as well as the work of other similar health research partnerships.

2.2 METHODS

Based on our inability to easily locate studies and publications on collaborative research and other processes specifically related to the environmental health context, the study team opted to conduct a scoping review instead of a systematic review. Scoping reviews differ from systematic reviews mainly by the nature of the research question and a concern for the quality of the studies to be included. A scoping review tends to be broader in scope than a systematic review as it aims to map the field in question and identify literature gaps, whereas systematic reviews aim to generate conclusions related to specifically focused research question. Systematic reviews involve an assessment of the quality of the studies to be included; scoping reviews may not involve that kind of assessment. A scoping review would support the need to map out what key collaborative process components, concepts, theories, practices, and related topics had been published and where there were identified gaps (Arksey & O'Malley, 2005; Brien, Lorenzetti, Lewis, Kennedy, & Ghali, 2010). Once we had a clear understanding of what existed in the literature, we could formulate more specific questions related to collaborative processes in the environmental health context.

We implemented the scoping review framework stages suggested by Arksey and O'Malley (2005) and Levac, Colquhoun, and O'Brien (2010). The authors of this review, composed of diverse environment, health, and knowledge translation expertise, were involved at the different stages of the review process. Here, we outline the stages we followed.

Stage 1. Identifying the Research Question

The purpose of our scoping review was to identify what the literature describes regarding collaborative processes in the environmental health research context. Our guiding question was: What are the specific components that influence the collaborative research process in environmental health research?

Stage 2. Identifying Relevant Studies

Relevant literature was searched in August 2015 by an expert librarian (third author, Sandy Campbell), who identified related publications containing the concepts: "environmental health/pollution," "knowledge co-creation/co-production," and "knowledge translation." Individual searches were executed on the following databases using key search terms that responded to these concepts: Medline (Ovid), EMBASE (Ovid), CINAHL (EBSCO), Global Health (Ovid), SocINDEX (EBSCO), Scopus, Pollution Abstracts (ProQuest), Environment Complete (EBSCO), ProQuest Dissertations, and Theses Global. Dissertations were included, except when the same author and topic were also identified in journal publications. The full extent of all databases included material published any time before August 2015, with follow-up search adjustments made appropriately for each database. Additional references were identified through citations or other known publications. References were exported to the RefWorks citation manager.

Stage 3. Study Selection

The publication selection process is described using the PRISMA (Preferred Reporting Items for Systematic Reviews) flow diagram (Moher, Liberati, Tetzlaff, & Altman, 2009), see **Figure 2.1**. Publication selection started by removing any duplicates. Titles and abstracts where then reviewed for relevance by two reviewers (first and second authors, Osnat Wine and Sarah Ambrose), and sorted into *Yes*/*No*/*Maybe* lists, based on selection criteria (**Table 2.1**). The two relevancy lists were then compared. Publications that did not match between the two reviewers or were classified as *Maybe* were discussed by them, and with a third member of the authors' team (sixth author, Alvaro Osornio Vargas), until consensus was reached. Selected items were fully read, and a second phase selection took place considering the selection criteria. Finally, 45 publications were included in the scoping review.

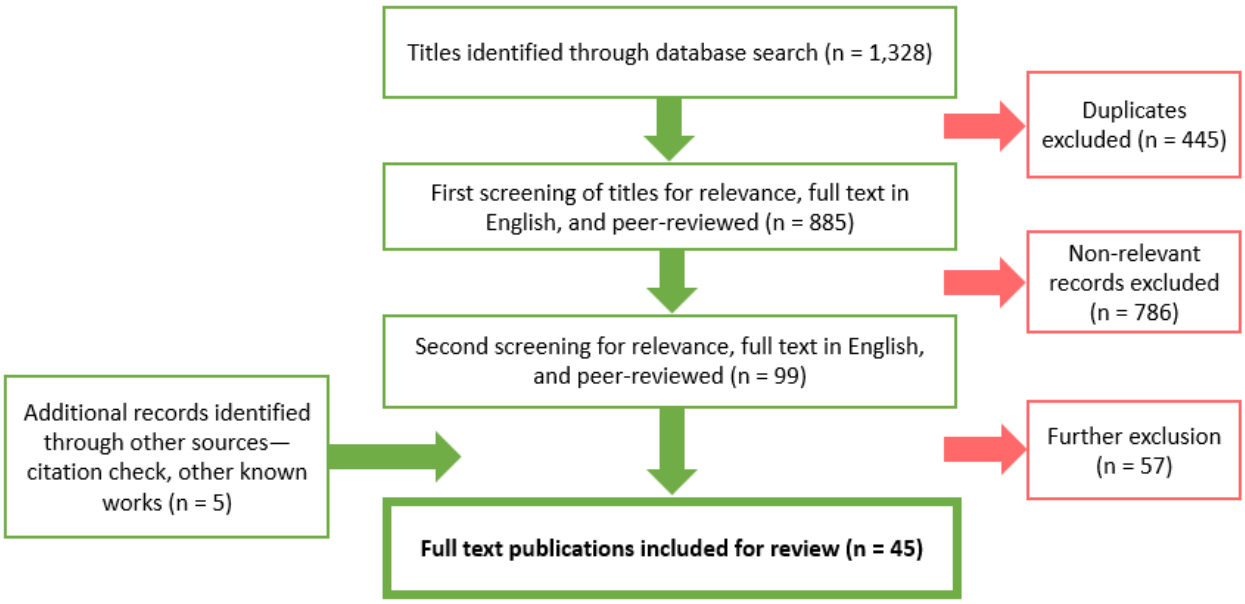

Figure 2.1: PRISMA flow diagram describing the search strategy.

Table 2.1: Inclusion and exclusion criteria for publications

Characteristics	Selection Criteria
1. Environmental health research context and purpose	(a) Research that explores the association between the environment and human health or is within the context of the impact of the environment on human health. Environmental health is defined as different exposures (biological, chemical, physical, and social) that can have a positive or negative health effect. (b) The purpose of the research must be to create new knowledge on the impact of the environment on human health or in the context of the impact of the environment on health. (c) The research could be policy or action driven. (d) This review excluded publications presenting collaborations for the purpose of intervention, education or raising awareness, networking, and / or creating a research agenda.
2. Collaborative partnership characteristics	(a) Background of partners: Research partners (*e.g.,* collaborators, stakeholders) not only from academia but also from multi-sectoral agencies or public / community groups. (b) Nature of engagement: Engaged throughout the research process (not only in one phase of the research, *e.g.,* framing questions or prioritizing research agenda).
3. Collaborative process	(a) Publications describe and add insight to the collaborative process by specifically exploring the collaborative process or describing research experience employing collaborative research.
4. Publication features	(a) Published in English (b) Peer-reviewed (including thesis/dissertations) (c) Full text available (d) Published before August 2015 (literature search end-date)

Stage 4. Charting the Data

Data from the selected publications were extracted into a spreadsheet. Information gathered included the publications' characteristics and context, collaboration characteristics, and the collaborative process facilitators, challenges, and best practices. Extraction was done by one reviewer (second author, Sarah Ambrose) and, in an iterative review process, the extracted data were reviewed by a second reviewer (first author, Osnat Wine).

Stage 5. Collating, Summarizing, and Reporting the Results

The extracted data were collated and summarized. We also conducted thematic analysis of the identified data on the collaborative process facilitators, challenges, and best practices. The identified emerging themes are reported in the results section.

Stage 6. Consultation with Potential Knowledge Users and Stakeholders

Consultation with stakeholders took place at different times during the scoping review process, in order to share preliminary findings, and to provide opportunities for feedback and advice regarding the scoping review design, resources, findings, and meanings. These stakeholders were mainly environment and health interdisciplinary researchers and research partners involved with the Data Mining and Neonatal Outcomes (DoMiNO) research project mentioned above.

2.3 FINDINGS

2.3.1 PUBLICATIONS CHARACTERISTICS AND CONTEXT

We identified 45 out of 1,328 publications for final review, describing various aspects of collaborative research in environmental health (**Figure 2.1**). The identified publications were published between the years 1998-2015, and included original research, reviews, and commentaries from different locations. **Table 2.2** provides a list of all identified publications and their detailed characteristics (location, context, collaborative account/type, and collaborative approach). A list of 57 publications that were excluded from this review in the second screening phase is provided in **Appendix 2.2**.

Our search process identified publications that originated from diverse research fields, such as health, environment, biology, education, policy, environmental management and assessment, and environmental justice. The context of environment and human health was discussed differently by the publications. Most publications referred to exposures and health outcomes as comprehensive/broad concepts (n = 14). Some indicated a specific health outcome (e.g., respiratory morbidities, cancer); others explored specific exposures already known to impact health (e.g., air pollution, toxicants, or multiple exposures) (n = 31).

Table 2.2: Details on the 45 publications included in the Scoping Review
(CBPR: Community-based participatory research)

	Publication	Location	Environmental Health Context	Environmental Exposure	Collaborative Account	Collaborative Approach
1	Angelstam et al., 2013	Sweden	Comprehensive	Not specific	Principles	Trans-disciplinary
2	Arcury et al., 2001	USA	Specific	Pesticides	Principles	CBPR
3	Austin, 2010	USA	Specific	Not specific	Experiences	CBPR
4	Bharadwaj, 2014	Canada	Comprehensive	Not specific	Principles	CBPR
5	Boon et al., 2014	Nether-lands	Comprehensive	Not specific	Experiences	Trans-disciplinary
6	Brown et al., 2012	USA	Specific	Indoor and outdoor pollutants	Experiences	CBPR
7	Burger et al., 2009	USA	Specific	Radiation	Experiences	CBPR
8	Burger et al., 2007	USA	Specific	Radiation	Experiences	Other
9	Collman, 2014	USA	Specific	Uranium, arsenic, air pollution from cook stoves	Principles	CBPR

10	Conrad et al., 2013	USA	Comprehensive	Not specific	Principles	Trans-disciplinary
11	Corburn, 2007	USA	Specific	Pollution	Experiences	Other
12	Cummins et al., 2011	USA	Specific	Water pollution	Experiences	CBPR
13	Downs et al., 2009	USA	Specific	Air pollution	Experiences	CBPR
14	Ferris & Sass-Kortsak, 2011	Canada	Comprehensive	Not specific	Principles	Other
15	Garcia et al., 2013	USA	Specific	Air pollution	Experiences	CBPR
16	Gonzalez et al., 2011	USA	Specific	Diesel bus emissions (air pollution)	Experiences	CBPR
17	Harding et al., 2012	USA	Comprehensive	Not specific	Principles	CBPR
18	Haynes et al., 2011	USA	Specific	Airborne manganese exposure	Experiences	CBPR
19	Israel et al., 2005	USA	Comprehensive	Not specific	Principles	CBPR
20	Israel et al., 2001	USA	Comprehensive	Not specific	Principles	CBPR
21	Israel et al., 1998	USA	Comprehensive	Not specific	Principles	CBPR
22	Jack et al., 2010	Canada	Comprehensive	Not specific	Principles	Other
23	Johnson et al., 2014	USA	Specific	Lead	Experiences	CBPR, trans-disciplinary
24	Matso et al., 2008	USA	Comprehensive	Not specific	Principles	Other
25	McCauley et al., 2001	USA	Specific	Pesticide	Experiences	CBPR
26	Meadow et al., 2015	USA	Specific	Climate science	Principles	Other
27	Metzler & Higgins, 2003	USA	Comprehensive	Not specific	Experiences	CBPR

28	Minkler, 2010	USA	Specific	Diesel bus emissions (air pollution)	Experiences	CBPR
29	Minkler et al., 2006	USA	Specific	Diesel bus emissions (air pollution)	Experiences	CBPR
30	Minkler et al., 2008	USA	Specific	Pollution (including air, lead, other toxic exposures)	Experiences	CBPR
31	Nielsen, 2001	Canada	Comprehensive	Not specific	Principles	Trans-disciplinary
32	Parker et al., 2003	USA	Specific	Air pollution	Experiences	CBPR
33	Parkes et al., 2004	New Zealand	Specific	Campylobacter	Experiences	Other
34	Pereira et al., 2009	Italy	Specific	Atmospheric composition change	Experiences	Other
35	Ramirez-Andreotta et al., 2014	USA	Specific	Contaminated sites / hazardous waste	Principles	Trans-disciplinary
36	Ravenscroft et al., 2015	USA	Specific	Land and water environmental toxicants	Experiences	CBPR
37	Reed et al., 2014	UK	Comprehensive	Not specific	Principles	Other
38	Romero-Lankao et al., 2013	USA	Specific	Air pollution	Experiences	Other
39	Rosenthal et al., 2007	USA	Specific	Climate change associated exposures	Experiences	Other
40	Schell et al., 2007	USA	Specific	Organochlorides, lead, and mercury	Experiences	CBPR
41	Schell et al., 2005	USA	Specific	Polychlorinated biphenyls	Experiences	CBPR
42	Schell & Tarbell, 1998	USA	Specific	Polychlorinated biphenyls	Experiences	CBPR
43	Strosnider et al., 2014	USA	Specific	Air and water pollution	Experiences	Other

44	Wing, 2002	USA	Specific	Hog odors and waste from hog operations	Experiences	Other
45	Witten et al., 2000	New Zealand	Specific	Water pollution	Experiences	Other

2.3.2 COLLABORATION CHARACTERISTICS IN ENVIRONMENTAL HEALTH RESEARCH

Our selection criteria required that all the selected publications should describe projects involving participation of partners from various sectors in the research process. Partners involved in the research included academic researchers, community members (public and leaders), advocacy groups and non-governmental organizations (NGOs), policy and decision makers, government agency representatives, and other various stakeholder groups (*e.g.,* church, farmers, and private sector). The engagement of stakeholders and knowledge users varied throughout different phases of the research, such as problem formulation, data gathering, analysis, and knowledge translation and dissemination. The collaborative processes described in the publications included:

(a) Descriptions of various research experiences in the context of environmental health research, which included accounts about strategies, partners, evaluation, perceptions, policy promotion, ethical considerations, stakeholder involvement, governance, promotion and support to policy and action, and environmental risk impact and assessment (n = 31).

(b) Research on the principles or frameworks for best practices related to collaborative research such as ethics, disclosure, health disparities, building and maintaining partnerships, and informing future research (n = 14).

The publications reviewed included two main collaborative approaches: *community-based participatory research* (CBPR), also described as community partnership research (n = 25), and *transdisciplinary research* (n = 6). No specific collaborative approach was identified in the other 14 publications. One publication presented a project described as both CBPR and transdisciplinary research.

We identified that the purposes of collaboration in the publications were mainly for co-producing new knowledge and/or *knowledge translation and exchange*; that is, initiatives aimed at cultivating mutually-beneficial connections between researchers and knowledge users, thus, establishing a link between environmental health research and the improvement of health research, policies, programs, and practices.

2.3.3 THE COLLABORATIVE PROCESS IN ENVIRONMENTAL RESEARCH

All 45 publications provided descriptions of research collaboration—offering either a reflection on their own collaborative research experience or the results of their research on the nature of collaborative research process, exploring its principles. The publications provide details on the different components that influenced the collaborative research process, covering factors both external and internal to research projects.

External Components

Some publications discussed the external contextual factors that could impact the collaborative research approach, such as institutional (n = 15) and socio-political (n = 9) factors. Authors of these publications identified institutional factors as critical in supporting collaborative

research and the partners engaged. These factors include: (a) available funding to support interdisciplinary and collaborative research, (b) acknowledgments and reward systems (*e.g.,* performance reviews), (c) adequate training on collaborative and interdisciplinary research to those participating in collaborative research, as well as (d) institutional priority and support services for collaborative research (*e.g.,* ethics review boards that advocate sharing results with participants, and/or policies that promote hiring community members for research purposes). Other external factors identified in the publications were socio-political in nature, which included the political climate as well as social and cultural structures, especially engagement structures to facilitate consultation with stakeholders.

Internal Components

Authors of some of the publications also identified components, which refer to internal collaborative research processes. They described facilitators and challenges that influence team development in different phases (**Appendix 2.3**). Some publications provided advice on the best practices based on research, experiences, and lessons learned. In response to our research question, we coded the literature and identified the following emerging themes with respect to internal factors influencing the collaborative process in environmental health research:

1. Allocating time and resources
2. Addressing disciplinary and sectoral issues
3. Building relationships
4. Ensuring representation

5. Embedding participation in the research
6. Supporting ongoing collaboration
7. Developing knowledge translation and exchange

The themes are described below.

Theme 1. Allocating Time and Resources

Time and resources were identified as instrumental. It was acknowledged that collaborative approaches were time consuming because they required a longer time to build and maintain trusting relationships, support ongoing and inclusive engagement, and mediate conflicts. Additionally, the need for individual time commitment was challenged by competing demands. The process also required adequate funding and planning to support activities such as relationship building (*e.g.,* face-to-face meetings, travel, and knowledge translation and exchange). Funds were usually required to cover the long timeframe necessary to reach these goals. Another challenge related to resources was the distribution of funds among partners, which can be a source of conflict.

Theme 2. Addressing Disciplinary and Sectoral Issues

The authors of the reviewed publications acknowledged that the collaborative process builds on the participation of representatives from different disciplines, with diverse expertise and experiences. It was suggested that leadership of the research project should be built with key participants and that additional knowledge users and staff should be considered to enhance diversity of perspectives (*e.g.,* support staff, community organizers, and activists). They also

described how the interdisciplinary context presents conflicts resulting of differences in cultures, ideas, goals, priorities, languages (*e.g.,* terminologies), and communication styles. Furthermore, learning from each other, conducting the ongoing research, mediating assumptions and views, and integrating different concepts of research were also identified as challenges. Other disciplinary challenges referred to disciplinary control (*i.e.,* domination of one discipline over other disciplines), traditionally focused disciplinary training, and the lack of experience and guidance on working with other disciplines/sectors and perspectives. Some also reported issues in maintaining discipline legitimacy, scientific independence, credibility, and the ability to demonstrate value and impact. Studies recommended avoiding disciplinary dominance and encouraged the willingness to challenge norms, take in new ideas, adopting a holistic understanding of environmental issues, promoting understanding of interdisciplinary expectations (i.e., how the research will be conducted), and accepting different disciplinary cultures, languages, and methods. It was also suggested that more training opportunities in interdisciplinary and transdisciplinary research should be offered.

Theme 3. Building Relationships

Developing strong and trustworthy relationships within research teams were identified as essential to supporting the collaborative process. Moreover, studies described that partner engagement could help build research capacity: building on competence, interest, and prior relationships, and by focusing on knowledge co-production. However, authors of the reviewed publications reported that developing and maintaining strong, trusting, and respectful relationships were a challenge that demanded teams to learn how to communicate effectively. This challenge was especially great if team members had prior negative experiences. Building and maintaining

relationships considering human constraints (*i.e.,* availability, personality, etc.), power imbalances within the team, and personnel turnover were other obstacles identified. Continuous investment in building trust and sustaining long-term relationships was noted as essential for the collaborative process and important factors that could help balance power issues.

Theme 4. Ensuring Representation

Authors of the reviewed publications identified that the representation of different sectors is instrumental to the collaborative research process. However, some publications described difficulty in identifying and obtaining adequate disciplinary or sectoral/community representation to create a diverse team. In some cases, this was due to an inaccessibility of different stakeholders, and in other cases, communities with previous negative experiences with research projects did not want to get involved in research again (*e.g.,* aboriginal communities).

Theme 5. Embedding Participation in the Research

It was suggested that mitigating the challenges and obstacles that collaborative research presents can be done by embedding participation in the research. Embedding participation includes identifying and involving partners early, and ensuring their participation throughout all research phases, including jointly framing the research questions and responding to user needs in the publication process. It was advised to build on previous mutual experiences to support the collaborative process. Additionally, it was recommended to perform a thorough preliminary background work including contextual factors and policy processes in order to better frame participation in the research.

Theme 6. Supporting On-going Collaboration

Reviewed publications reported that supporting on-going engagement as well as sustaining relationships are essential components of the collaborative process. They advise that this can be achieved by having continuous dialogue, two-way communication, meetings in person, and providing multiple opportunities for collaboration. Providing learning opportunities (context, languages, and methods) was also identified as essential. However, maintaining the ongoing collaboration was identified by some as challenging with regard to mediating conflicts and debates, involving partners in all research phases, creating an equal working environment, defining the level of partners' commitment, keeping an iterative and collaborative process, and balancing research and action. Some suggestions to overcome these challenges were that the partners identify and clarify early on the common and different goals, strategies, limitations, and model of participation. Inclusion of a social scientist who could support effective collaboration and formative evaluation of the collaborative process, governance, and decision-making was recommended. Publications also recommended that the collaborative process should build on feedback and critical reflection, partners' joint development of operating norms, obtaining consensus or agreement during and at the end of the project, and allowing the process to be creative and flexible for changes in the research protocol.

Theme 7. Developing Knowledge Translation and Exchange

Another significant aspect identified in the publications related to different components that supported or challenged the process of developing knowledge translation. The publications acknowledged that the research design should involve knowledge translation and exchange from an early stage of the research process. Negotiating knowledge translation strategies as well as

assessing knowledge user needs should be maintained throughout the research project. Reviewed publications also recommended keeping clear communication strategies about the knowledge translation plans, committing to implementation, delivering tangible outcomes to users early in the project, as well as sharing findings in an accessible and relevant format for different audiences. However, some publications identified that the ethics approval process involved in sharing findings with participants and the lag time between knowledge exchange and outcomes were challenging. Additional challenges identified included differing views of the research products, ownership of the data and results, and the dissemination of results. Some publications suggested early agreement on data sharing with participants and using knowledge brokers whose role as intermediators would be to support the dissemination process and activities that could mitigate conflicts.

Finally, the publications also discussed the importance of passion, commitment, motivation, respect, and shared values/goals in positively contributing to and facilitating the collaborative process, and helping to overcome some of the barriers and challenges.

2.4 DISCUSSION

The selected publications addressed the collaborative research processes in the context of environmental health research. We identified contributions from different research fields including, health, environmental management, and other disciplines, highlighting the interdisciplinary nature of environmental health research. Moreover, what we have found in this

scoping review for key components of collaborative research may apply not only to environmental health research but generally to other collaborative research contexts.

The collaborative and interdisciplinary approach (*i.e.,* participation of different disciplines and stakeholders) has been acknowledged to benefit the breadth and depth of research in this field by integrating different perspectives, methods, and experiences (Annerstedt, 2010; Matso et al., 2008; Podestá, Natenzon, Hidalgo, & Ruiz Toranzo, 2013) as well as contributing to the relevancy and usability of the research (Campbell et al., 2015; Cook, 2008; Reed, 2008). Partners benefit from learning experiences, contributing to issues of individual and societal interest, and building long lasting relationships. However, challenges result from the differences among partners and among the disciplines or organizations they come from (Armstrong & Jackson-Smith, 2013). Careful planning and framing of the research and the ongoing partnership can help to mediate differences. One approach to enhance interdisciplinary and collaborative capacity is training of students, faculty, and other partners in the theory and practice of interdisciplinarity, transdisciplinarity, and collaborative research (Ramirez-Andreotta et al., 2014; Repko & Szostak, 2017) or by supporting the development of transdisciplinary individuals (Morales, 2017).

Interdisciplinary and collaborative research approaches are increasingly practiced and being promoted by funding agencies (Ramirez-Andreotta et al., 2014; Rylance, 2015). In the environmental health research context, which is an emerging field of research, and still grappling with the complexities and challenges inherent in its interdisciplinary and collaborative research approach, this requires attention from researchers, institutions, publishers, and funders (Brown et al., 2015). As more research team collaboration is required for credible research results, there will be more need to examine the significant components of collaborative research.

2.4.1 CONTEXTUAL BARRIERS

The identified publications addressed contextual and external barriers, which may hamper collaborative research processes. These include institutional, political, social, and cultural barriers. For example, the political atmosphere can dictate if environmental health research is funded or not, and whether or not agencies or stakeholders would be included as partners. Social constructs can also impact the nature of research and partnerships. For example, stakeholders from different backgrounds may not view the partnership and research success in the same way.

Institutional support for academics and for different organizational representatives, in terms of funding and acknowledging the time requirements, is crucial to enable collaborative research and sustain collaborative research teams. The lack of suitable reward systems in place for those engaged in collaborative research could be challenging (given greater time commitment from those involved in such research and different outcomes of interdisciplinary collaborative research compared to discipline-based research). Reviewed publications suggest the need for new reward systems for researchers engaged in collaborative research, viewing these researchers as *scholars of outreach* (Ramirez-Andreotta et al., 2014). Although there has been ongoing discussion around these contextual issues, they continue to influence current collaborative research practice and still require attention.

Thus, on a policy and organizational level, changes may be required in the culture and practice of research support agencies. Specifically, changes are required in the allocation of funding for collaborative research projects, ongoing support of their sustainability, adjustments of expectations around research progress and outcomes, establishment of reward systems, and support for training programs that focus on collaborative and interdisciplinary research.

2.4.2 APPROACHES TO RESEARCH COLLABORATION

There are several approaches to research collaboration, including: transdisciplinary research, participatory research, community-based participatory research (CBPR), integrated knowledge translation, team science, mode 2 research, and engaged scholarship. While each approach has a somewhat different emphasis on the various elements of the collaborative process, these may also share common elements. The main collaborative approaches we identified in this review include transdisciplinary research and CBPR. Many of the identified publications have used a CBPR approach.

CBPR is a well-defined collaborative research approach aiming to respond to environmental health problems. The principles of CBPR include a research partnership approach with community stakeholders, building on the strengths and resources of the community and responding to community needs. It involves power sharing with the community, so as to build an equitable relationship among the collaboration partners. CBPR aims to achieve community engagement in all phases of the research, including the dissemination phase. Through co-learning and capacity building, CBPR aims to integrate knowledge gained with action, which may benefit all partners (Cook, 2008; Israel et al., 2005; Israel et al., 1998; Parker et al., 2003). In this review, the issue of power imbalance among research partners was raised only in publications using CBPR (Arcury, Quandt, & Dearry, 2001; Downs et al., 2009; Israel et al., 1998; Israel, Schulz, Parker, & Becker, 2001; Johnson et al., 2014; Metzler & Higgins, 2003). Power imbalance could arise in all types of research teams and may be based on many factors (*e.g.,* seniority, gender, discipline, sector, etc.).

Other issues identified mainly in CBPR publications refer to the following challenges: (a) inaccessibility of partners from affected community members, (b) balance between participation and research project requirements demanding too much time investment, (c) developing leadership

within the community so that community members can head the community's engagement in the research, (d) lack of clarity about the ownership of data and results, (e) balance between action and research (in many cases, academics are cautious with research results while community stakeholders push for action), (f) conflicts around funds distribution among the research partners, and (g) the challenge of overcoming communities' previous bad experience with research engagement.

Another collaborative approach identified was transdisciplinary research, which is a collaborative interdisciplinary and multi-sectoral research approach where the focus is on addressing major real-world problems. It seeks to integrate knowledge and perspectives from different scientific disciplines as well as non-scientific resources (Repko, 2008). It has some participatory elements and seeks the unity of knowledge beyond disciplines (Hadorn et al., 2008).

2.4.3 PRACTICES TO SUPPORT COLLABORATIVE RESEARCH

This scoping review provided comprehensive description of the key components of the collaborative research process. Specifically, it identified the different facilitators and challenges and offered lessons, strategies, and advice for supporting collaborative research. We cannot identify one component that could be the sole factor to influence the process; rather, it is a complex process that requires attention to the different components. The themes we describe, although described separately, are all interconnected, and depend on each other. Different research project may have different emphases on these components.

Through the different themes described above, the publications reviewed offered good practices to optimize and strengthen the collaborative research process, many of which should be

considered by collaborative research teams. However, the publications reviewed do not completely address questions regarding the applicability and feasibility of their recommendations. For example, it is unclear whether partners would always embrace engagement, collaboration, and training, even if ample opportunities for these were provided. The impact of team size and the distribution of team members across different locations on the collaborative process is unclear [this point emerged from our consultations with the DoMiNO team members, see (DoMiNO, 2014)]. Additionally, the partners' difficulty in maximizing engagement given the other demands on their time was not fully explored. In many cases, locations, busy schedules, priorities, work habits, and other factors appeared to prevent partners from participating in the collaborative activities. Equal participation is not always possible but the principle of equity should be pursued and early decisions should be reached on the level of participation targeted and operating norms (Cargo & Mercer, 2008). One of the suggestions was to leave the management of the collaborative process to experts (*i.e.,* social scientists) (Meadow et al., 2015; Ramirez-Andreotta et al., 2014) or to a neutral collaborative research expert (Matso et al., 2008). This may not be feasible in every case. Alternatively, we could consider including collaborative research as part of academic training, so that the relevant expertise may be available more broadly.

2.4.4 KNOWLEDGE TRANSLATION

Another significant component that was identified through this review was the development of knowledge translation and exchange and the collaborative process that contributes to it. The reviewed publications portray the collaborative approach as means to knowledge creation and translation into policy or practice. Whereas past paradigms left knowledge creation to academics and knowledge was transferred as a product (Gibbons, 2000), the emerging paradigm treats

knowledge as a result of co-production or co-creation (Mauser et al., 2013; Rycroft-malone et al., 2016; Voorberg, Bekkers, & Tummers, 2015). The publications identified specific references to the inclusion of knowledge translation as part of the collaborative process to promote the use of the new knowledge created, which is an inherent component of environmental health research. Some of the publications acknowledged the contribution of collaborative approaches and the partners' role in supporting knowledge translation. Few elaborated on the process of building knowledge translation through the different phases of the research (Jack et al., 2010; Reed et al., 2014; Strosnider et al., 2014) and discussed the complex issue of sharing results (Ferris & Sass-Kortsak, 2011; Guimarães Pereira et al., 2009; Harding et al., 2012; Parkes, Eyles, & Benwell, 2004; Ramirez-Andreotta et al., 2014; Schell et al., 2015). Very few publications suggested the inclusion of *knowledge brokers* as those who could help disseminate results and serve as cultural brokers (Jack et al., 2010), despite recent attention to their roles in various domains (Dobbins et al., 2009; Lam, 2018).

Nevertheless, it would be beneficial to learn more about the development of knowledge translation planning and the process of decision-making (*i.e.,* determination of goals and audiences, messages, and strategies). It would be especially important in a context such as environment and health characterized by conflicting priorities.

2.5 CONCLUSION

This review contributes to an understanding of the collaborative research processes in the context of environmental health. Several key lessons were derived from this review:

(a) Understanding the collaborative process can be enhanced by learning from different collaborative research approaches.

(b) The collaborative research process is a complex web of interrelated components.

(c) The main components of collaborative research pertain to allocating time and resources, addressing disciplinary and sectoral issues, building relationships, ensuring representation, embedding participation in the research, and supporting on-going collaboration.

(d) Planning for knowledge translation is an important part of the collaborative research process.

A review of the short and long-term impact of the collaborative approaches in the study of environmental health would complement our review. Other future research could focus on the gaps identified here, which include: the applicability and feasibility of best practices for research collaborations, as well as knowledge translation development in research partnerships, and stakeholder engagement and contribution to the knowledge translation planning. These gaps may be answered through learnings from other real-life experiences.

Our own experience as participants in a collaborative research project motivated this review and ended up informing our collaborative activities. The significant components of collaborative research identified here may be of interest and use not only to individuals involved in the area of environmental health research but also to researchers across other areas and sectors.

CHAPTER 3

THEORETICAL AND METHODOLOGICAL FRAMEWORK

This chapter describes the overarching theoretical and methodological framework of my study, which informed and guided data collection, analysis, and interpretation of the data to respond to my research questions.

3.1 THEORETICAL ASSUMPTIONS

This qualitative case study was undertaken within specific theoretical assumptions that guide the interpretative and methodological framework of the study: (1) a relativist ontology – a belief in multiple individual realities, which does not necessarily mean all interpretations are equal but rather they are relative to their credibility and utility (Stake, 1995); (2) constructivist epistemology which implies: knowledge is built by subjective experiences and perspectives; (3) a researcher's position in the study, in which the researcher's individual values and stance are honored and negotiated; and (4) an inductive research process.

3.2 RESEARCH APPROACH: A QUALITATIVE CASE STUDY DESIGN

The qualitative case study research is one of the main approaches used by qualitative researchers (Creswell, 2013; Richards & Morse, 2013). The purpose of case study research is to

develop an in-depth understanding of a case. The case is defined as a *bounded system*; a unit of analysis, which is circumscribed by time and place and is 'a complex and functioning thing' (Stake, 2005) within a real-life contemporary context or setting (Yin, 2003). Case studies seek to understand a social situation or process by focusing on how they are played out in one or more cases (Richards & Morse, 2013). Case studies often focus on a single phenomenon, individual, community, institutional programs or incidents, they are context-sensitive (Patton, 2002) and considered as a valuable research design for developing theories, evaluating programs, supporting the development of interventions, and understanding processes (Baxter & Jack, 2008; Richards & Morse, 2013; Stake, 1995; Yin, 2003).

A case study is referred to as the object of the study, as well as the inquiry and its product; describing 'what is going on?' and providing interpretations that reach beyond description, to inquire 'what does it mean?', since the case was chosen for a reason (Richards & Morse, 2013). The case study approach implies a specific design that guides the procedures, or provides the framework, by which the study is conducted to respond to the research question. The design directs the scope of the research and the type of data required to guide the practicalities of conducting the research (*e.g.,* sample, data, ethics). A case study includes a prolonged, yet flexible, interaction with the case to study it at different points in time, and a detailed in-depth data collection that involves multiple sources and types of data. Relying on one source, or type of data is typically not enough. Thus, the employment of various sources of qualitative data, which also present different perspectives, may shed light on the topic, provide explanations to the evidence collected, and help understand what are the issues, experiences, and perspectives of the those involved in the case (Richards & Morse, 2013). The design and procedures enable the researcher to explore the interactions of significant factors that are characteristic of this phenomenon, reveal changes in

conditions or impacts, (Richards & Morse, 2013; Yin, 2003), and capture nuances, patterns, and latent elements (Berg & Lune, 2012; Stake, 1995). Together, the results complement each other to make a comprehensive whole picture.

The qualitative case study approach contributes to rich insights and to the development of concepts, generation of theories, and drawing specific implications. In some instances, the case is selected in the hope of informing and giving support to larger generalizations (Berg & Lune, 2012) and informing theory either by testing a theory, or by generating theory, which means theory can be uncovered and informed as a consequence of the data collection and interpretations through the development of the case study (Rule & John, 2015; Yin, 2003). Stake (2005) explains that case studies provide *particularization*, which is a step towards theory. Furthermore, the intimate linkage with empirical evidence suggest that theory developed from case study research is likely to have important strengths like novelty, testability, and empirical validity (Eisenhardt, 1989). Finally, learning as much as possible about the case helps describe the complexities of the case in order to provide descriptions of the case, interpret and report, the lessons learned so that others can understand the case and draw their own conclusions (Stake, 2005).

Following are the main features of this case study:

The Case: A longitudinal single case study that focused on the IKT process of the DoMiNO research project over the five years of operation.

The Purpose of the Case Study: Illustrate and portray a holistic understanding of an IKT approach from an actual real-life experience related to the DoMiNO case. DoMiNO was considered as an *instrumental case* (Stake, 1995) that helps understand a phenomenon, which may be an *issue* and happens in other *places*, while also having *intrinsic case* elements *i.e.,* having unique features.

In-depth Understanding of the Case: Many forms of data were generated and collected from a wide range of sources. Analytic procedures were carefully applied to enable an in-depth understanding and provide a rich description of the case and key components.

3.3 SETTING: THE DOMINO PROJECT

The DoMiNO research project, over its five years of operation (2013-2018), constructed the setting for this case study. This interdisciplinary project investigated the associations between environmental variables (*e.g.,* mixture of air pollutants), maternal variables, and adverse birth outcomes across Canada, by using innovative data mining methods. The project utilized a pre-defined IKT approach, in which researchers with different expertise and knowledge users jointly engaged throughout all research phases in obtaining, analyzing, and interpreting useful information from large sets of data. Additionally, inherent to this approach was the commitment to plan and apply knowledge translation. The team engaged in different activities to maintain the IKT approach (additional details on the project context and activities are provided in **Chapter 4**). In fact, one of the DoMiNO project objectives was to evaluate the collaborative process to inform the on-going development of the project's IKT pathway. This setting provided an invaluable opportunity to study 'real-world' IKT in the complex context of environmental health.

3.4 PARTICIPANTS: THE DOMINO TEAM

All DoMiNO members were considered as the study participants, as part of a *total population sample* approach (Morse, 1991). This meant that all individuals involved in the project were included as participants, which enabled a holistic understanding of the collaborative process by encompassing the perspectives of all team members. Furthermore, the pre-designed evaluation of the collaborative process implied that all members of the project were included in evaluation activities.

The DoMiNO team included 24 members (*i.e.,* the participants), who were registered at the time the project started (including myself as the project coordinator). Members of the research team were academic researchers, clinicians, graduate students, and 'Integrated Knowledge Users' (*i.e.,* members who were registered as knowledge users as part of the whole project). Over time, there was some turnover. Some members left [researchers and students who graduated (n=4)], and others joined (n=3) (additional details on the team members are available in **Chapter 4).**

All team members gave their consent to participate in the evaluation process formally once the project began. Members who joined for a short period of less than a year (*e.g.,* undergraduate students) were excluded from individual interviews and focus groups. Otherwise, if they took part in group activities, they were included in the data collected (*e.g.,* observation, minutes). Team members who joined in the middle of the project were invited to participate in the case study.

3.5 BEING A COMPLETE MEMBER RESEARCHER

My role in this case study, was that of a *complete member researcher* (Adler & Adler, 1987), studying a setting in which I was fully affiliated as a member. This researcher role can also be

defined as an ‘insider researcher' - a member of an organization or community who undertakes academic research in their own organization while retaining their role as a member (Brannick & Coghlan, 2007). Thus, being an insider refers to the notion that the researcher shares the identity and experiential base with the study participants (Corbin Dwyer & Buckle, 2009). Examples in the literature of this researcher role include experiences as a coordinator of a research project (Flicker, 2008; Polk, 2014), a participant in the case studied (Unluer, 2012), and a researcher who experienced the issue studied (Corbin Dwyer & Buckle, 2009).

During the DoMiNO project, I played a dual role. I acted as a research coordinator for the first 4 years of the project operation (2013-2017) and early in the project's ‘life' (2014); I registered as a graduate student researcher. I was involved in building the DoMiNO research project from its inception and had extensive knowledge of the project and its activities and the team. As a coordinator, I was responsible for the ongoing operation of the project. This included communication among team members (website, emails, newsletters, etc.) and administration of different aspect of the project. I took part in the design and implementation of different activities of the project including annual meetings, and attended various team meetings [*e.g.,* the steering committee meetings, the core team meetings (principle investigators and students)], as well as other different small meetings between members of the team. I was also responsible for the evaluation of the collaborative process that informed and helped shape the ongoing application of the project’s IKT framework.

Thus, I had familiarity with many aspects of the project through the entire duration of the research process: progress, planning, and engagement. This formed a good acquaintance with participants/ team members as a colleague, and as a student researcher. I had the benefit of being part of the team as an *insider*, being a witness to activities and happenings, and observing how

those evolved over time. Being an insider provided access to participants, documents and extensive knowledge of the case and context; it also supported the willingness, openness, and trust of participants. At the same time, being a researcher also informed my role as a coordinator. As a researcher, I was learning about collaboration from and with the DoMiNO project team as one of the researchers in the project, which I could apply into the project operation. Therefore, I was well situated to document all activities and, pursue this case study research.

I acknowledge the limitations and challenges this position created for the case study research. Taking part in the management of the DoMiNO project (*i.e.,* in some of the decision-making processes of how IKT should operate, not only collecting data but also applying ongoing conclusions from evaluations towards the improvement of the collaborative process), and being invested in the DoMiNO project and its success, meant that it would be harder to establish a more neutral point of view in order to minimize potential bias resulting from my position. I addressed this challenge with different strategies:

Practical strategies

In year 4 of the DoMiNO project, my role as coordinator ended and my time was fully dedicated to the study of the case for my thesis research. Distancing from the project as the coordinator, helped me take a more neutral view of the whole project, as well as creating uninterrupted time to engage with the data (which by then was quite comprehensive and included most of the data) and analysis.

Methodological strategies

A prolonged engagement with the case and a comprehensive case study design enabled longitudinal collection and generation of data from multiple sources at different times using

various data collection methods provided numerous point-in-times snapshots of the case over-time as well as rich data. I was immersed in an iterative analysis process, which included revisiting the data, the analysis procedures, and outcomes to test the findings. I also engaged in constant reflection of my analysis (codes, themes, and writing) to question my assumptions and had many debriefings with peers (*i.e.,* supervisors) to identify areas lacking clarity. Additionally, I conducted member checks and reactive verification with participants, *e.g.,* focus group.

Full details on the data analysis procedures and verification strategies are provided below.

3.6 DATA COLLECTION AND GENERATION

Case studies require multiple types, or sources, of data (Berg & Lune, 2012). In DoMiNO these data were collected over 5 years, with the purpose of collecting comprehensive systematic and in-depth information about the case (Patton, 2002). The data consist of all the information that could provide familiarity and understanding of the case. Some data were available prior to the DoMiNO project start and before I joined as a researcher, however, most data were generated during and even after the DoMiNO project ended. Verbatim quotes from these data sources are used in this dissertation. Quotes are presented with minimal changes (*i.e.,* removing identifiers, redundancy, irrelevant parts, and discourse markers: *e.g.,* sentence fillers, and small grammatical edits) while trying to preserve the manner of speech (Sandelowski, 1994). The different data sources include the following: individual interviews, reflective discussions, project activities and documents, and researcher-generated data. The collection of the different data sources timeline is illustrated in **Figure 3.1**.

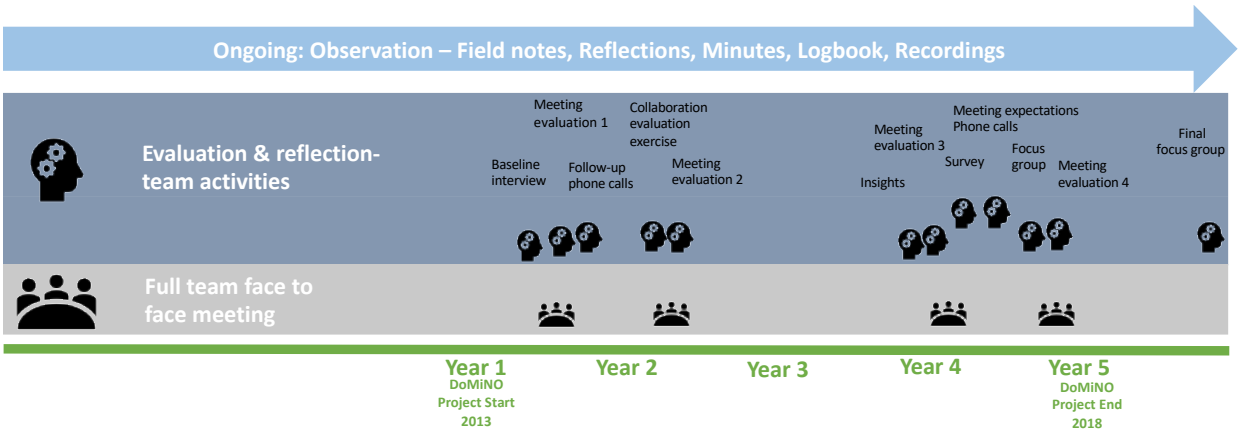

Figure 3.1: A collection of the different data sources overtime (Based on a figure created for Wine et al. 2019)

3.6.1 INDIVIDUAL INTERVIEWS

Individual interviews took place at the beginning of the DoMiNO project in November – December 2013. All 23 DoMiNO members were invited to participate (n= 23, excluding myself). Participation was voluntary, and 22 members agreed to take part in the interviews. For the interviews, I used a semi-structured interview guide, which was prepared by a former member of the team, and I conducted the interviews. The interview was designed to learn about previous collaborative experiences, attitudes towards collaborative research, expectations of this project, and possible challenges. We were also interested in advice for planning the first full team meeting and for ongoing project communication. Details on the interview question topics are available in **Box 3.1** below. All members who participated in the interviews gave their written or oral consent prior to the interviews, which were conducted over the phone or in-person, when this was possible. All interviews were recorded, summarized, and collated for a summary report that was presented on the first DoMiNO face-to-face meeting in January 2014.

Full verbatim transcriptions of the baseline interviews (18 of the 22) were available for analysis for this study in February 2017. Four interviews that were not fully transcribed verbatim (members who left, or difficulties with accents) were included as 'focused transcribing coding' (Interviews were listened to, and selective transcription was based on and confirmed with codes identified from the transcribed interviews).

Box 3.1: Baseline interviews topics

- Previous experience of the team members working in interdisciplinary research projects and with Knowledge Users.
- Team members previous experience of the advantages and challenges of this kind of collaborative research partnerships.
- The reasons team members joined the project and their expectations of the project.
- Expected challenges to this project.
- Expectations for the first meeting and meeting planning advice.
- Advice about the management of ongoing communication for the team.

3.6.2 REFLECTIVE DISCUSSIONS

The team engaged in several discussions to provide feedback and reflect on the collaborative process in different formats. Most discussions took place as part of the annual face-to-face DoMiNO meetings. These are the reflective discussions:

a) *Sustaining collaborative research* (meeting #2, 2014). This activity was led by the facilitator of the meeting (AD) and questioned the whole team: *"How do we need to move forward with our collaboration?"* Team members were divided into four groups and were asked to answer

this question by using the following feedback grid: more of, less of, start doing, and stop doing. Collated responses were used for analysis.

b) *Insights* (meeting #3, 2016). A reflective discussion (focus group style) with all team members present at that time. The discussion started with a brief recap of the IKT framework for DoMiNO and the significance of the evaluation of the collaborative process followed by a brief overview of the scoping review findings (**Chapter 2**). I led the discussion using questions prepared prior to the meeting (**Box 3.2**). The discussion was audiotaped and transcribed verbatim.

Box 3.2: Leading questions for the *Insights* discussion, Annual meeting 3

- What are the strengths of the team and the project?
- What kept the project going despite a long break in activities?
- What are the collaboration's challenges?
    - Are there still struggles with interdisciplinary challenges *e.g.* vocabulary, as was identified by members in the previous meeting?
- Do findings from the scoping review resonate with the team's perspectives?
- What could be the design for communicating DoMiNO outcomes?

c) *Focus group* (FG) (meeting #4, 2017). The discussion in this focus group was facilitated by a professional facilitator JG (the facilitator of the two-day meeting), who took notes on flip charts. I was an observer and did not take part in the conversation, except of providing an introduction and clarification of expectations and guidelines to the discussion. All DoMiNO members who had been part of the project for more than one year and had

participated in the two-day annual meeting in-person, were invited to take part in the discussion. The two principle investigators, and remote participants were excluded. Out of 13 invited, 10 participated in the focus group. They had different engagement levels with the DoMiNO operation and different seniorities and specialties. Written and audio consents were obtained from all participants. The discussion was recorded and transcribed verbatim. The Focus Group was conducted following the guide presented in **Box 3.3**.

Box 3.3: Focus group guide, Annual meeting 4

"Based on your experience and what you have learned from this IKT experience what would you advise a team going into a similar research project?"

Probes included:

- What kept the team going?
- What contributed to growth and performance that helped create new knowledge or the KT plan? what helped with that part of the project?
- What would you do differently?
- What challenges did the team experience?
- What advice would you tell somebody who embarks on a similar project?

d) *Final focus groups (FFG),* (2019). These final focus groups were held, more than a year after the DoMiNO project funding agency deadline was reached. All DoMiNO members were invited to participate. Discussions were conducted in groups of two to five team members, who participated in person or remotely (by phone). Groups were divided into students, principle investigators, and other team members as separate focus groups. In total, five focus groups and two individual interviews (due to time conflicts) took place. The facilitation of

all focus groups was conducted by an external facilitator to DoMiNO (Dr. Jude Spiers) (except of two individual interviews, which I conducted). Focus groups recordings were recorded, and transcribed verbatim, and focused transcribing coding was applied for the two individual interviews. As preparation for the focus group, participants received a two-page summary of the research results. Each focus group started with a short presentation on my study findings and the questions posed to participants were based on the final focus group guide (**Box 3.4**).

Box 3.4: Final focus group guide

How do the findings shared correspond with your experience?

- Is there anything you would like to discuss, add, or clarify?
- Which parts work and which don't in this model? Why?
- Looking back, what were the most significant aspects that supported the collaboration and achievement of goals in DoMiNO?

The themes are about collaborative process and their contribution to project outcomes, achievement of goals and knowledge translation. Of particular we are interested in:

- Establishing trust in each other and in procedures and outcomes
- Achieving and maintaining alignment of knowledge, progress and role expectations
- Taking ownership of the project or parts of it

How did alignment, trust and ownership play out for you?

For people involved in DoMiNO there were many expectations - some were individual, and some are team expectations (i.e. formal objectives from the proposal). Do you feel the project fulfilled these expectations? if not why?

(Probe for: individual expectations and team expectations, why yes and why not?

What did you take away from participating in the DoMiNO project?

What would you take with you from this experience to the next collaborative project you take part in?

3.6.3 PROJECT ACTIVITIES AND DOCUMENTS

Data collected for this study also included data portraying the DoMiNO activities and other documents that provided contextual information. The different types of data sources are as followed:

a) *Evaluation forms:* all annual face-to-face meetings concluded with an evaluation form of the meeting and general perspectives on the project progress. The evaluation forms included closed questions using a Likert scale and open questions. The forms were slightly modified for each of the four meetings to capture input on the collaborative process as needed (an example of the evaluation form is available in **Appendix 3.1**). Except of the first meeting, the evaluation form return rates were high (**Table 3.1**).

Table 3.1: Summary of evaluation forms from the annual DoMiNO face-to-face meetings

Annual Face-to-Face Meetings	Number of Participants	Number of Evaluation Forms
Meeting 1 (1/2014)	21	11
Meeting 2 (10/2014)	30 (including guests)	25 (including guests)
Meeting 3 (8/2016)	15 (+3 guests)	14 (+3 guests)
Meeting 4 (3/2017)	19 (+4 guests)	15 (+3 guests)

b) *Recordings:* All face-to-face meetings were audiotaped. All recordings were listened to and partial transcriptions (non-verbatim) were done with *focused transcribing coding.*

c) *Minutes:* Notes were taken during different team activities, which included: all face-to-face meetings, steering committee teleconferences, various small meetings, webinars, and survey phone calls.

d) *Project documents:* Different documents were constructed before and during the DoMiNO operation: *e.g.,* project's proposal, research findings interpretation survey, authorship agreement, newsletters, meetings' summaries, and emails.

e) *Logbook:* Recordings of different activities and events in DoMiNO were collected, as different entries, between one to four times a month depending on activities at the time.

f) *External observation:* In the second and third annual meetings *external observers* were assigned for some of the group activities. These observers were usually guests who were not involved directly in DoMiNO (students, young researchers). They received an observation guide (**Appendix 3.2**) and shared written observations with me.

3.6.4 RESEARCHER-GENERATED DATA

Sets of the data were generated by me throughout the study and comprised a record of my perspectives and interpretations, including observations, reflections, and audit trails.

a) *Observations* took place throughout the DoMiNO project's five years of operation. As the project progressed, observations were more focused and were guided by findings and gaps. For major activities, such as face-to-face meetings, I created an observation guide (Stake 1995). Also included under observation are memos recorded from informal conversations.

b) *Reflections* were recorded of the different activities and happenings in the project; often these accompanied other data sources. Other reflections were on decisions and conflicts with regards to my research process and analysis.

c) *Audit trail* included all information that reflected the process of data generation and analysis, such as: memos regarding analysis procedures, analysis reports of single or

combined data sources (*e.g.,* annual meeting report based on different documents and recordings), figures, mind maps.

3.7 Analysis

Iterative analysis happened throughout the entire research process, intentionally and unintentionally, starting with first impressions and followed by systematically drawing knowledge throughout the research process, to the final reports of the case study that give meaning to what was observed (Stake, 1995). When applying a case study design there are different approaches to the procedures that can be taken to analyze the data. Yin, for example, suggests a series of actions (theoretical propositions, rival explanations, and case descriptions) (Yin, 2003). I followed Stake's (Stake, 2005) analysis approach, which is based on individual instances and categorical aggregation, correspondence, and patterns (which can be based on thematic analysis procedures), and propositional generalizations (assertions) for *naturalistic generalizations* (conclusions arrived at by personal engagement of the readers). However, this approach provides little information about how analysis plays out to create themes or patterns. Therefore, to guide my analysis, I followed thematic analysis procedures to generate themes that would address my research question.

3.7.1 Thematic analysis

Thematic Analysis is an inductive analysis approach that enables the researcher to systematically identify, analyze, and interpret patterns of meaning (themes) within qualitative data, which allows the researcher to make sense of collective or shared meanings and experiences (Braun

& Clarke, 2012). This analysis approach offers flexibility in terms of the theoretical framework, research question, methods of data collection, and sample size. It 'permits' the researcher to combine analyses within their particular context, which is significant to the development of themes (Braun & Clarke, 2006). Furthermore, by incorporating manifest and latent aspects of the data, it can usefully summarize key features of a large body of data and offer a thick description of the data set. Patterns are identified through a rigorous process of data familiarisation, data coding, and theme development and revision (Braun & Clarke, 2013).

I followed thematic analysis procedures, within the case study design. This analysis process enabled the inclusion of context and provided a rich thematic description to the entire dataset to capture the dominant themes. The analysis process was inductive: bottom-up vs. theoretically down. It included a data-driven process - coding the data without trying to fit it into a pre-existing coding frames (Braun & Clarke, 2013). The analysis focused on both semantic and latent themes and the analytic process involved a progression from description, to showing patterns in semantic content, and to interpretation, where there was an attempt to theorize the significance of the patterns and their broader meanings and implication (Patton, 2002). At the latent level, thematic analysis goes beyond the semantic content and starts to identify and examine the underlying ideas, assumptions, and conceptualizations that are theorized as shaping or informing the semantic content of the data. Thus, for latent thematic analysis the development of the themes themselves involved interpretative work and the produced analysis, is not just descriptions, but is forming theory. This approach is in-line with the constructionist paradigm that seeks to theorize the socio-cultural contexts and structural conditions that enable the individual accounts (Braun & Clarke, 2006).

Thematic Analysis Procedures

For the research analysis and the construction of themes, the analysis started as soon as the data were obtained. I followed the thematic analysis research phases suggested by Braun and Clark (2006): a) Familiarizing with the data; b) Generating initial codes; c) Searching for themes; d) Reviewing themes; e) Defining and naming themes; f) Producing the report. It is important to note that although these phases may seem linear, the process and procedures are iterative, and analysis moved back and forth through these phases.

a) *Familiarizing with the data:* This phase starts the immersion in the data by repeated reading and searching for preliminary meanings or patterns. It includes preparation of the data (for example, transcribing, collating forms and surveys, listening to audio-recordings of meetings and recording significant instances), reading and re-reading data, and noting preliminary ideas.

b) *Generating initial codes*: The second phase included the process of coding interesting features (semantic or latent) of the data. Coding is the most basic segment of analyzing the raw data. It is an iterative process, working systematically and repeatedly through the entire dataset. Thus, each data source underwent coding, and each code had collated data relevant to it. Most data collected and generated for the case study were coded as the data were made. I initially coded on hard copy, and after generating a preliminary coding frame, continued to code using the software NVivo 11©. The initial coding included many potential codes and patterns as recommended by Braun and Clarke (2013). The generated codes had many forms. They were descriptive, topic codes (sometimes *in vivo* codes using words as they were in the data) and in some cases analytic codes that were more conceptual (Richards & Morse, 2013). Coding was an iterative phase and included a process of labeling and relabeling of data into codes and categories. Categories are a descriptive level of the explicit manifestation of participants' accounts. This stage of categorizing is part of

comprehending and sense making of the complexity of the data. Categorization is used at the beginning of the theme development process to classify findings and is the beginning of abstraction from codes to categories, concepts, patterns, and themes, which are theorizing processes (Richards & Morse, 2013).

c) *Searching for themes:* In this phase, the aim was to collate codes and categories into potential themes. A theme is a common thread that runs through the data (Richards & Morse, 2013). It captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the dataset, clustered around a central organizing concept (Braun & Clarke, 2006). Furthermore, it considers latent and manifest content (Vaismoradi, Jones, Turunen, & Snelgrove, 2016).

This phase implies further abstraction. Abstraction advances the researcher beyond description and summarizes the experiences of participants. Abstraction is the result of an active exploration of the data; from coding, to categorizing, and conceptualizing (Richards & Morse, 2013). In case studies, the goal of abstraction is to provide an authoritative account of the case and generalize from its accounts looking for patterns. Summary and review of the case and comparative analysis contribute to this abstraction (Richards & Morse, 2013).

As part of the analysis process and the search of patterns moving from codes to themes, I followed several procedures and strategies:

- Codes and themes reoccur in the data. A code will capture one idea, while themes have a central organizing concept and contain different ideas or aspects that relate to that concept and inform the reader on how this concept appears in the data, in relation to the research question (Braun & Clarke, 2013)

- Concepts can connect the data and codes. In some cases, a big and complex code or category may be promoted to a theme (Charmaz, 2006)
- Although frequency is important, themes should capture elements that are meaningful to answering the research question (Braun & Clarke, 2013)
- The search is for several themes with central organizing concepts that capture the most salient patterns in the data that are relevant to the research question (Braun & Clarke, 2013)

As part of the process of formalizing the themes, I had discussions with supervisors and colleagues through meetings and conferences, which continuously challenged my analysis and helped, identify instances in which assumptions were imposed on the data. I engaged in an iterative process of analysis (and worked…. and worked….) to formalize the themes. I used thematic maps, sticky notes (**Figure 3.2)**, figures and detailed descriptions of codes and categories to identify and construct themes and their domains in different phases of my study.

Figure 3.2: Theme-ing with sticky notes

Box 3.5 illustrates a list of codes identified in earlier phases of the analysis that later formed a theme. These codes and categories were reviewed multiple times for their content and meaning and were finally combined to conform a theme.

Box 3.5: An example of a list of codes, which later constructed a theme

Codes:

Sharing knowledge, building bridges, finding balance, understanding backgrounds, what we need to do, understand the different parts, where we were, role expectations and outcomes expectations, etc.

Theme:

Maintaining alignment

d) Reviewing themes: This phase implies ensuring that the themes resonate with the coded extracts and the entire dataset to generate a thematic map of the analysis. Braun and Clark (2013) define this phase as a process of 'quality control' in which themes are reviewed in relation to the developing analysis – checking to determine whether the candidate themes developed fit well with the coded data and the dataset, and whether themes represent the story of the dataset.

In this phase, I was engaged in an iterative review of the codes and candidate themes and their descriptions to ensure they are forming a coherent pattern and reflect the meanings of the dataset. This required reflection on the analysis process and findings and separating the participants' story from my assumptions. Different verification strategies supported this process (*e.g.,* memo writing, triangulation, member checks, peer checks, negative case analysis), details of which are described below. I was also keeping in mind that the analysis needs to respond to the question '*so what?*', looking for what was relevant or useful for my research question to guide the analysis process.

e) *Defining and naming themes:* This phase was also referred to as 'refine and define', which implies ongoing analysis to refine the specifics of each theme, finding their essence, the overall story the analysis tells, and generating clear descriptions and names for each theme. In this phase, analysis continues with a final list of themes and their essential characteristics.

f) *Producing the report*: According to Braun and Clark (2006), this phase is the final opportunity for analysis, where one can relate back to the research question and literature to produce a scholarly report of the research. However, in a complex and prolonged research process such as this case study, this phase could represent a stage within the iterative analysis process for major data sources. For example, I produced a report of a single data source - the baseline interviews. These sets of interviews were used as the baseline analysis and as the starting point to understanding the IKT process. I also performed analysis of other major data sources, such as the focus groups, insights, and evaluation forms, and produced reports for each one of these data sets. These reports later served as data sources for constructing and finalizing the findings.

3.7.2 USING SENSITIZING CONCEPTS IN THE ANALYSIS PROCESS

The case study pursued the exploration of the IKT collaborative process and in-depth understanding of related components, concepts, and processes. Data were collected and generated throughout the development of the project. Through an iterative process of coding and labeling (*i.e.,* defining the codes), recoding, and relabeling, codes and themes were created, while I still continuously was questioning their validity and strength. As indicated above, the six analysis phases described were at times fluid and required many repetitions, especially regarding themes' identification, description, naming, and report production, in order to achieve a satisfactory level of analysis and findings. The process started with initial understanding of the data in relation to the research aim. This was achieved through preliminary analysis, in which findings acted as sensitizing concepts for the following analysis processes with other data. Sensitizing concepts provided points of departure for an inductive exploration to deepen the understanding of the dimensions and aspects of these concepts (Doorward, 2010) and guided this inductive research. In the first phases of the analysis, some of these concepts were based

on published literature. Later on, concepts received support (or not) from other analysis findings throughout the research process. For example, in the scoping review I identified themes that related to concepts, such as trust and relationships, the complexity of interdisciplinary practice, and the maintenance of collaborations. These findings informed me of the significant issues that pertain to the collaborative process. The analysis of the baseline interviews also suggested possible relevant concepts that describe the essentials of the collaborative project. This dataset helped identify team members' perspectives on essential components of the collaborative process and possible challenges achieving those before this research project started. Several concepts were identified at this phase as presented in **Box 3.6**. Analysis of data generated throughout the research process further confirmed or disputed some of these concepts.

Box 3.6: Preliminary concepts based on the baseline interviews

- *Relationship, trust, and building capacity as the collaborative process foundations*
- *Commitment to the topic of research, other team members, the research process, the different research activities and communication as well as, commitment as one of many other commitments*
- *Collaborative research practice, interdisciplinarity, and engagement with knowledge users (KU), Knowledge translation (KT) as part of the research process*
- *Communication for transparency and alignment, safe and inclusive environment for learning*
- *Management of expectations, roles*
- *Power and ownership*

Following the preliminary phase, I undertook an iterative analysis, in which, each iteration and each additional data element contributed to advancing the identification and construction of the themes relevant to the collaborative process. There was also a deductive process, in which data were explored against some preliminary categories. Analysis can than fluctuate between

inductive and deductive processes to fully examine the data (Austin, 2008). Through this process, some concepts were consistent in the data and some were not. This entire process required constant reflection on assumptions, procedures, and findings.

3.7.3 FINALIZING THE ANALYSIS AND FINDINGS REPORT

Reporting a case study includes both the description of the case itself and the main issues identified through analysis of the case and interpretation of their meaning (*i.e.,* case themes) (Creswell, 2013). In the analysis process, both semantic and latent approaches were combined, which transformed the analysis from being descriptive to interpretive. Thus, when reporting the case study results, I describe the case (**Chapter 4**) and the resulting themes and their dimensions, which were based on thematic analysis (**Chapter 5**). I then continue with the development and conceptualization of the themes and the relationships among them (**Chapter 6**). In **Chapter 6**, I provide deeper explanations of the different components identified in the analysis and suggest more theoretical and abstract understanding that goes beyond the relevance of the case. Based on the entire analysis, I propose a conceptual framework, which connects the perspectives of participants, my researcher subjectivity, and empirical evidence to inform theory. These stages of finalizing the analysis reflect the ongoing connections between researcher subjectivity, empirical material, and theory (Alvesson & Kärreman, 2014). Theorizing is an explanatory tool (Richards & Morse, 2013) that helps to promote identification of future implications to the research findings and enable readers to draw *naturalistic generalizations* (Stake, 2005) - the relevance to their own cases, and support *transferability* (Denzin & Lincoln, 2005) so readers can learn from the case.

3.8 RIGOUR

Reliability and *validity* are important concepts for attaining rigour, thus establishing integrity and legitimacy of the research findings (Morse, Barrett, Mayan, Olson, & Spiers, 2002). *Validity* refers to the concept of something sound, defensible, and well grounded, or the credibility and accuracy of processes and outcomes associated with the research study. *Reliability* refers to consistency of the findings (Guest, MacQueen, & Namey, 2012). Ensuring validity and reliability is achieved by verification, which is the process that includes checking, confirming, and being certain in the research findings. This is often done by triangulation of data (time, space, and people), investigators, theories, and methodological approaches. Triangulation is the process of using multiple perceptions to clarify and explain complex meanings and the different ways the case is seen with different realities, and in some way support the researcher's responsibility to the readers' interpretations and reduce misinterpretation (Stake, 2005). *Verification* is an incremental self-correcting and iterative process, which requires the researcher to be responsive and flexible, and to constantly check their procedures and stance to achieve reliability and validity of the findings and generalizations (Morse et al., 2002).

Morse et al. (2002) suggest ensuring rigour by several strategies: investigator responsiveness, methodological coherence, theoretical sampling and sampling adequacy, an active analytic stance, and saturation. In pursue of reliability and validity, I have taken the following strategies during my research to support these suggestions:

Investigator Responsiveness implies the need for flexibility and sensitivity to data and analysis as they develop over-time while responding to changes. In my research, I have gone through an iterative process of analysis and data collection/generation. This process required writing and

rewriting, labeling and re-labeling the codes and themes, suggesting new ideas and meanings of the data, developing certain ideas and leaving some behind. Responsiveness was enabled by the research design, different research procedures, and my stance in the research. Thus, attaining rigour during the study was built by moving back and forth between the design and implementation of the research in order to achieve congruence between questions, design, and research procedures and achieve verification. Responsiveness was built on several practices:

- *Reflexivity* refers to constant reflection on analysis procedures and decisions to ensure that known frameworks or assumptions are not imposed on the data throughout different phases of the study and analysis. Each of the data collected and analysis findings were reflected upon while considering new-collected data (*e.g.,* the focus groups).
- *Peer check* included regular debriefings with supervisors to discuss and examine my analytic process and impact on findings including *a priori* assumptions. I have also shared research findings with colleagues to seek for feedback.
- *Member checks* imply sharing results with participants for verification. Member checks as a verification strategy have been questioned, since meanings may change through the analysis and may become abstract and theoretical, which makes those difficult for participants to relate to (Goldblatt, Karnieli-Miller, & Neumann, 2011). Furthermore, member checks do not always ensure the validity of findings (Thomas, 2017). However, my experience showed the benefit of member checks despite potential limitations. I had different opportunities during the five years of the project operation, and in different phases of the analysis to share some of my findings with participants. I received useful feedback, which helped guide analysis, directed future data collection, added clarity to the findings, and contributed to verification. For example, the focus groups with the DoMiNO team members (after the DoMiNO project ended)

were aimed, among others, to get respondent validation (Noble & Smith, 2015), which refers to inviting participants to comment on whether the final themes and concepts created adequately reflect the phenomena being investigated from their perspective. Revisiting the results with the team took place once the themes were constructed from all data and were articulated and defined. Team members were invited to share their thoughts about the collaborative process and comment on the findings presented. Members' input helped to:

- Confirm the significance of the identified components to the collaborative process and outcomes.
- Strengthen the description of the themes by discussing the importance of different concepts to their own perspective. The descriptions of the themes were than further articulated to include details and nuances to reflect the team' s perspectives.
- Affirm that the different components in combination contributed to the growth of the collaborative process.
- Provide additional testing to the significance of the themes identified, overtime (*i.e.,* more than a year after the project ended), assuming that those impressions stayed in their memory because they were meaningful.

Thus, these focus groups strengthened the reliability and validity of the findings and confirmed that the themes and components resonate with the views and perspectives of the team members and not necessarily mine.

- *Negative case analysis*: This part of the analysis refers to pieces of data that differ from expectations or assumptions as part of a real-life story. In fact, it is unlikely that every piece of data will fall exactly in-line with the development of analysis and findings (Brodsky, 2008). Identification of these negative cases helped to illuminate my own biases and motivated me to

seek where and how these data diverge from the rest and provide adequate confirmation of the borders and attributes of the theoretical concepts identified. These negative cases are similar to outliers, they are not ignored, but rather used through active seeking to test and refute the findings so that the findings can be finalized rigorously. For example, a theme I named 'ownership' was refuted by several members who did not feel this was relevant for them, but rather for them, it was 'joint ownership'. Thus, further verification using negative cases helped to better define and establish the domains of each of the themes.

- *Crystallization:* Many noted the importance of triangulation for verification and rigour in case studies in order to achieve accuracy and confirmation (Baxter & Jack, 2008; Patton, 2002; Stake, 1995; Yin, 2003). However, some argue that triangulation is a narrow description of the process that actually occurs to satisfy confirmation and verification and propose the use of *crystallization* instead (Richardson, 2003; Stewart, Gapp, & Harwood, 2017). In the crystallization process the researcher tells the 'story' from different points of view to illustrate the complexity of the analysis process and findings to support the validity of outcomes. Crystallization disputes the concept of triangulation as it creates a two-dimensional triangle and suggests instead the creation of a 'crystal' that combines symmetry, substance, and infinite variations of shapes and angles that can still change and grow. Crystallization implies an interactive analysis process, in which the researcher's immersion, intuition, creativity, and reflection are engaged in the research process and findings. This process provides deep, complex, and thorough understanding of the topic while still recognizing limitations, and that there is more to know (Richardson, 2000). In my study, through a crystallization process, I was looking for consistencies and inconsistences in ideas and perceptions across different types of data from different time points, sources, and methods, weaving the story based on the

combination of different spheres (*e.g.,* data, methodologies, observers) to display the different realities. I examined my own stance in the process and how this too shapes the interactive process. I provide a thick description of the case to illustrate all angles, which in turn contribute to the validity of the research findings and encompass the depth of a multidimensional complex collaborative process.

Methodological Coherence implies congruence between questions, data collection methods, implementation, and analytic methods. It is not a linear process but rather requires flexibility in the implementation of the research process. My research proposal suggested a specific research path. Over-time this path changed and needed to be modified. For example, the research questions that were initially proposed evolved and were refined over time, as well as data collection methods, which were modified from the original proposal. As a result, the research procedures were aligned to achieve methodological congruence.

Appropriate Sampling is required in order to achieve a good representation of participants with the necessary knowledge. In this case, adequate sampling meant that the views of all team members who represent different perspectives were required; therefore, all team members were included as participants. Furthermore, appropriate sampling also implies reaching saturation of codes and categories, and replication of concepts in the new data generated. This was enabled by the prolonged engagement and multiple data collection methods over different time points. An example of adequate sampling was the final focus groups, which contributed to saturation of the analysis in different topics. I invested time in revisiting and testing my findings with data collected to identify replications of generated data and for polishing and constructing the final findings presented in the thesis. Saturation also meant that negative cases were included in the analysis to define dimensions and test assumptions in order to further contribute to the construction and clarity of the findings.

Furthermore, prolonged engagement and persistent observation enabled the development of assertions and generalizations.

Collection and Analysis of Data Concurrently implies that the research process is iterative. It meant labeling and re-labeling of codes, concepts and themes, writing and re-writing, and developing analysis and data collection on the previous data collected and analyzed, to guide both data collection and data analysis. For example, based on my analysis, I developed observation guides and focus group guides and worked with sensitizing concepts to guide the analysis. These processes also helped identify the gaps that needed further investigation. For example, to ensure I was ready for the final focus group, I wrote a draft of my findings thus far. I identified areas that seemed 'weak' and required more data to ensure my analysis was appropriate.

Thinking Theoretically occurs alongside data collection and generation as part of the emerging analysis. It means that ideas emerging from the data are reconfirmed with new data that contribute to credibility. These ideas may inspire new ideas, which would then be verified with the data collected through checking and rechecking. This was essentially done by comparison and crystallization throughout the analysis process. It also occurred though talking with peers about the concepts of interest and how they may be useful, while considering the limitations of my analysis.

Theory Development occurs when the findings move from a micro perspective of the topic to a conceptual and theoretical understanding. Case studies are very helpful in theory building (Alvesson & Kärreman, 2014; Eisenhardt, 1989; Yin, 1992) mostly because they can provide thick description and generate an abundance of empirical material. The development of theory is an inductive process that builds on the intimate contact with empiric material and the frictions that it holds (Eisenhardt, 1989). The theory emerges from empirical settings, which are rooted in different realities. Some argue that the theory is already operationalized and that the empirical evidence act as a compass

keeping theory generation on course; this then facilitates critical thinking and enhances the ability to challenge, refine, and illustrate theory (Alvesson & Kärreman, 2014; Eisenhardt, 1989). Theory then provides insights into the complexities and details of empirical reality and acts as a dialogic tool with the reader (Alvesson & Kärreman, 2014). In my exploratory case study, the development of theory is from the bottom up; theory development was constantly present in the analytical procedures and is reflected in the final presentation of results. I present a conceptual model that illustrates the collaborative process, themes, and the connections between them. Theory was developed as an outcome of this research to inform a hypothesis for future comparison and testing.

3.9 ETHICAL CONSIDERATIONS

Conducting research with participants requires consideration of the core ethical principles (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, & Social Sciences and Humanities Research Council of Canada, 2014). These include *respect for persons* and their autonomy to make decisions about participation in the research; *concern for participants welfare,* which implies ensuring no harm to participants; and *justice* treating participants fairly and equitably. The following procedures were applied to ensure these core principles were considered in the research.

Ethics approval was obtained from the University of Alberta Ethics Board (Study ID Pro00039545).

Consent**:** Initially, in the DoMiNO proposal phase, joining the project as a co-applicant or collaborator meant that members agreed to take part in the evaluation of the IKT process. As the

project began, members gave specific consent to observation and recording of all team activities (through signed consent forms). Participation was voluntary in individual interviews or focus groups; informed consent was obtained from all participants for these activities (written and verbal). Modified consent forms were requested midway of the DoMiNO project (due to the change in the evaluation lead) and consents were obtained from all participants. Team members who joined the project in the middle of the research project provided consent as well. All consent forms included an explanation of procedures, benefits, and risks to enable informed consent of participants. All consent forms were reviewed and approved by the University of Alberta Ethics Board prior to sharing with participants.

***Anonymity*:** Anonymity cannot be ensured in this kind of research. Anonymity within the team could not always be maintained, specifically since data were collected in team activities (*e.g.,* focus groups or meetings). This implied those present on those occasions may be aware of 'who said what'. Participants were informed and provided their consent.

Confidentiality: All data were saved in a secure location (password locked computer or locked cabinet). Raw data had restricted access by supervisors and me (baseline interviews were shared with a former team member). All data will be destroyed five years following the completion of the project. Where possible, keeping the reported results confidential was done by removing identifiers from quotes or descriptions in reports or publications and using codes to de-identify participants (*i.e.,* participants are identified numerically P1, P2, P3 *etc.*). In cases where identifying quotes are used for a publication that might be identified (*i.e.,* those in major roles such as the principal investigators and knowledge users), permission was requested and obtained from individuals.

CHAPTER 4

A COLLABORATIVE RESEARCH EXPLORATION OF POLLUTANT MIXTURES AND ADVERSE BIRTH OUTCOMES BY USING INNOVATIVE SPATIAL DATA MINING METHODS: THE DOMINO PROJECT. CASE REPORT

Osnat Wine, Osmar Zaïane, Alvaro Osornio Vargas, and on behalf of the DoMiNO team

The following chapter is a case report conducted in collaboration with the DoMiNO project members and published in *Challenges*, (2019) 10, 25. The aim of this chapter is to describe the research project that was studied as a case. It provides details on the project's context, applied collaborative framework, team, and the project's different phases and outcomes. The case report reflects some preliminary insights about the collaborative process.

ABSTRACT

Environmental health research is of growing interest due to global concern of environmental factors impacting health. This research is often multifaceted and becomes complex when trying to understand the participation of multiple environmental variables. It requires the combination of innovative research methods as well as the collaboration of diverse disciplines in the research process. The application of collaborative approaches is often challenging for interdisciplinary teams, and much can be learned from in-depth observation of such processes. We share here a case report describing initial observations and reflections on the collaborative research process of the DoMiNO project (2013-2018) that aimed to explore associations between mixtures of air pollutants and other environmental variables with adverse birth outcomes by using an innovative

data mining approach. The project was built on interdisciplinary and knowledge user participation with embedded evaluation framework of its collaborative process. We describe the collaborative process, the benefits and challenges encountered, and provide insights from our experience. We identified that interdisciplinary research requires time and investment in building relationships, continuous learning and engagement to build bridges between disciplines towards co-production, discovery, and knowledge translation. Learning from interdisciplinary collaborative research experiences can facilitate future research in the challenging field of environmental health.

4.1 INTRODUCTION

Environmental risk factors such as air pollution (WHO, 2018a) contribute to the burden of disease in children worldwide, driving a growing interest and need in children's Environmental Health research. This research field is complex as there is a need to study multiple types of environmental exposures, various groups of variables for each type of exposure, and several windows of vulnerability (*e.g., in utero* development, post-natal) in order to understand the role of the exposome in the health of people and planet (Wild, 2012).

An example of the potential environmental impact on health is adverse birth outcomes, such as low birth weight and preterm birth, which are significant public health concerns. Adverse birth outcomes represent a multi-factorial set of conditions that result in significant, immediate, and long-term health consequences (Heaman et al., 2013; Kramer, 2003). Moreover, adverse birth outcomes are increasing problems worldwide as more than 1 in 10 babies is born prematurely (Blencowe et al., 2013; WHO, 2018b).

Current research identifies associations between adverse birth outcomes and various determinants of health, which include: social factors, such as poverty and stress; biological factors, such as diabetes, infection, and maternal age; and environmental pollutants, including metals, PM_{10}, and SO_2 (Kim & Saada, 2013; Shah & Balkhair, 2011; Stieb, Chen, Eshoul, & Judek, 2012). Past research, commonly disregarded combined effects and interaction among multiple environmental stressors mainly due to methodological limitations at the monitoring and analytical level.

Research studies, mainly focusing on monitored urban pollutants, have identified linkages between environmental exposures and fetal and early childhood deleterious effects, along with genetic, physical, social, dietary, and biological factors (Buka, Koranteng, & Osornio Vargas, 2007). However, the contribution of industrial pollution has not been fully explored (Wine et al., 2014), even though some of those chemicals are known to be developmental toxicants. This knowledge gap is even broader when assessing the role of mixtures of chemicals. In that respect, there is good evidence that low-level exposure to multiple, similar-acting, but potentially distinct chemicals demonstrate dose additive mixture effects (Kortenkamp, Faust, Scholze, & Backhaus, 2007). Researchers and funding agencies are calling for the development of new methods, which will explore mixtures that impact human health and different ecosystems (Heys, Shore, Pereira, Jones, & Martin, 2016) in order to advance research on links between environmental pollutants and adverse birth outcomes.

Furthermore, the possible association and influence of multiple environmental factors on adverse birth outcomes must be understood within a geospatial context of co-location, after considering maternal confounders. The complexity of these data requires analytical tools that go beyond conventional statistical and geographical approaches, such as data mining. Data mining is

used in the domain of health sciences for hypothesis development and to explore early diagnosis and prevention of diseases (Norton, Huyn, Hastings, & Heller, 2001). The spatial aspect of data mining is also used in health science applications, such as detection of epidemics and pandemics (Bailey-Kellogg, Ramakrishnan, & Marathe, 2006; Obenshain, 2004). However, the use of advanced spatial data mining for the evaluation of complex geospatial relations between environmental factors (*e.g.,* exposome) and different health outcomes is still in early stages and has good potential for future application in the research on air pollution (Bellinger, Mohomed Jabbar, Zaïane, & Osornio-Vargas, 2017). Considering that this type of research has a unique, complex, and multifaceted context, which requires consideration of time and space, there is a need for interdisciplinary and multisectoral engagement (Briggs, 2008; Fazey et al., 2014; Repko & Szostak, 2017; Van De Ven & Johnson, 2006).

Interdisciplinary research refers to a paradigm of knowledge formation, which implies a process of answering a complex question/problem by drawing on different disciplines' methods and perspectives and by integrating their insights reaching a more comprehensive understanding. The disciplines engaged in the process serve as a means to an end (Repko & Szostak, 2017). The goal of interdisciplinary research is integration - integrating the different insights in order to achieve a holistic understanding to address complex systems (Newell, 2001). To date, interdisciplinarity is becoming an integral part of many research projects and, as described by the Committee on Facilitating Interdisciplinary Research (USA), this is driven by:

> *…the inherent complexity of nature and society, the desire to explore problems and questions that are not confined to a certain discipline, the need to solve societal problems and the power of new technologies* (Committee on Facilitating Interdisciplinary Research, National Academy of Sciences, National Academy of Engineering, & Medicine, 2005)

In the case of environment and health research, interdisciplinarity is both instrumental (problem driven) and critical (society driven) (Repko & Szostak, 2017) due to its potential to support policies, practice and research (Gavidia et al., 2011). Thus, the need for participation of interdisciplinary researchers and stakeholders/knowledge users in a collaborative research process (O'Brien, Marzano, & White, 2013), for the creation of knowledge and its translation (Briggs, 2008). These forms of collaborations can address the complexity and the uncertain and sensitive outcomes intrinsic to the context of EH research (Briggs et al., 2009). Due to the unique characteristics of EH research, the application of interdisciplinary collaborative best practices is often challenging, and much can be learned from in-depth observation of real-life experiences.

We present here the DoMiNO research project (Data Mining & Neonatal Outcomes, 2013-2018) (DoMiNO, 2014), an interdisciplinary research project with knowledge user participation, which investigated co-location of mixtures of environmental pollutants and adverse birth outcomes by using an innovative spatial data mining approach, an embedded collaborative framework and the inclusion of a dedicated evaluation of the collaborative process.

DoMiNO's case illustrates the collaborative approach experience in a complex research context of understanding some aspects of the exposome. We describe the project in its unique context and the opportunities for new knowledge discovery when using an innovative research approach of developing new algorithms to account for spatial co-occurrence of environmental factors and adverse birth outcomes, which was supported by a collaborative approach of experts from different domains. Moreover, we portray the collaborative process, how it benefited the research, and the challenges it created, and share initial insights on the interdisciplinary process based on our experience.

4.2 METHODS

We present an EH research case where we describe its embedded collaborative and interdisciplinary process. We provide a detailed description of the DoMiNO project '*the case'*, including the research context and framework, the research progress and outcomes with an emphasis on the collaborative and interdisciplinary approach.

We studied the case at different points in time aiming to reveal changes in conditions or impacts (Yin, 2003) of team members' in the collaborative and interdisciplinary process. Multiple data sources, including meeting minutes and recordings, project logs and field notes, were used to provide the descriptions.

This case report would hopefully provide enough information about lessons learned so that others who are currently involved or plan to engage in similar research can understand what interdisciplinary and collaborative research entails and draw their own conclusions (Stake, 2005; Stake, 1995).

4.3 THE DOMINO PROJECT

4.3.1 THE RESEARCH FRAMEWORK

The research objective of the DoMiNO project was to discover co-location of adverse birth outcomes with specific mixtures of industrial emissions and social factors as a way to provide insights for postulating new hypotheses.

The study focused on the period between 2006 and 2012 and used data from 1) the National Pollution Release Inventory (>300 chemicals annual emissions); 2) maternal variables (21 variables) and birth data (>300,000 births) from the Alberta Perinatal Health Program and the Canadian Neonatal Network; 3) wind data; 4) socioeconomic status (SES) index (five categories); and 5) urban air pollution models. These databases were chosen for their public availability (NPRI, Wind) and for their comprehensiveness and reliability (neonatal and maternal data). Other data originated from DoMiNO team members (SES Index, urban air pollution modules).

Due to a large number of variables involved in this complex research and the resulting large number of potential combinations, we developed novel data mining approaches based on geographical location. Newly developed algorithms identified associations between adverse birth outcomes and mixtures of chemicals occurring at the same location, after considering wind patterns and maternal mobility. Our approach also included a computer-based visualization tool to identify and present results. Furthermore, ad-hoc maps using geographic information systems (GIS) and traditional statistical approaches provided support to the data mining findings and insights into how complementary traditional research approaches supported the generation of co-location hypothesis and the validation of the findings. Altogether, several associations were selected as the potential hypotheses to relate specific mixtures of pollutants with adverse birth outcomes. **Figure 4.1** illustrates the research framework.

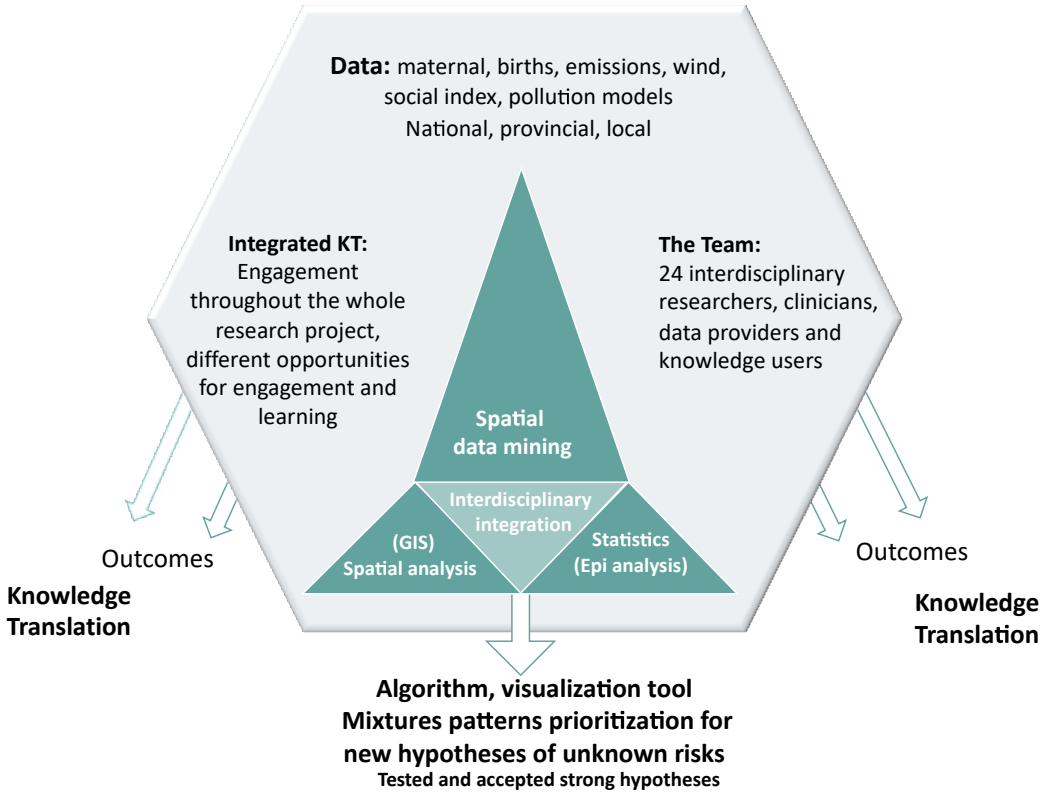

Figure 4.1: The DoMiNO Project research framework

4.3.2 THE TEAM AND COLLABORATIVE APPROACH

The complexity of the DoMiNO project resides in the EH research context and the various methods employed, requiring individuals with diverse expertise engaging in an interdisciplinary research process that also included a partnership with knowledge users.

The DoMiNO research team consisted of over 20 team members. The team included researchers, clinicians, graduate students, and knowledge users. Research members' expertise included EH & public health, computing science (data mining), epidemiology, geography, neonatology, obstetrics and gynecology, pediatrics, and knowledge translation (KT). The team

also included knowledge users from non-government organizations (NGO), government health agencies (science and policy), and data providers. This diverse collective expertise reflects the complexity of the question and the research. Most members of the team resided in one city. The rest of the team was dispersed in different geographical locations and time zones.

Beyond the interdisciplinary methodology, an integrated knowledge (IKT) approach based on participatory principles and engaged scholarship (Bowen & Graham, 2013a) was embedded in the research framework. By definition, IKT promotes the participation of knowledge users from the early stages of the project throughout the whole research process, as well as knowledge translation and exchange phases, and take part in the knowledge creation and steering the research to be more relevant to users (CIHR, 2016b). All team members became involved in the research process from conception and throughout all the research phases. Team members engaged in obtaining, analyzing, and interpreting useful information from large sets of data, and developed KT strategies as the project progressed.

The collaborative framework included: 1) A governance structure in the form of a steering committee (including knowledge users and representatives of the main disciplines involved in the project) whose role was to support project management and decision-making; 2) An engagement plan, which included opportunities to participate in the different phases of the research through annual face-to-face meetings, teleconferences and email updates; 3) An embedded evaluation plan, which informed the research undertaking and addressed the needs of the collaboration as well as enabled scientific learning on the processes of collaboration. Two principal investigators and research coordinator were responsible for the project management and communication and were supported by the steering committee.

4.3.3 THE DOMINO RESEARCH PROCESS

4.3.3.1 Building the project

The first steps of the project involved constructing the research plan, bringing together the team members, designing and writing the proposal, and articulating the project objectives. Once funding was guaranteed, the process focused on obtaining ethics approval and adverse birth outcomes data from local and national sources. These agreements were complex, considering that birth data needed to preserve privacy and confidentiality; therefore, there was need for assurances that no individual identifiers would be compromised.

An important initial step was to build a baseline from which the team could start working together, since most members did not know each other and were unfamiliar with some of the methods planned for the research. At that time, we conducted individual interviews with all team members about their previous experiences with interdisciplinarity and knowledge user-oriented research and advice for this collaborative research. For example, we explored through this baseline interview: the potential challenges related to the interdisciplinary practice of the project, and suggestions on how to address those; what are the best strategies for communication management are; what expectations members have regarding the project and suggestions they may have on what to include in the first meeting. Findings from this interview informed the project planning, and the results were shared with the whole team in the first meeting acknowledging the contribution of these baseline interviews to the planning of the meeting. The meeting agenda reflected the suggestions and needs that team members made in the baseline interviews and inspired the following meeting themes as objectives (Annual meeting 1, Agenda):

- *Getting to know the team*
- *Clarifying and updating the project*

- *Developing a shared team vision*

The team got together for a first kick-off face-to-face meeting (the first of four). For the few who were unable to attend in person, the meeting was selectively broadcasted live for them to join online. The meeting enabled the beginning of building relationships among team members and getting familiarized with the different members' backgrounds and expertise through the development of shared understanding of the different concepts, which were integral to constructing the project. The meeting offered an opportunity to clarify the project's future route, the objectives and expected outcomes, and preliminary discussion on the desired and appropriate knowledge translation goals. The conversation included clarifications about timelines, expectations, roles, and responsibilities. A discussion on communication management also took place to clarify the best strategies for this team, after the baseline interviews presented mixed responses and thus a realization that *"…the project would need multi-prong communication approach"* (Annual meeting 1, Minutes) that will include emails, a website as a repository, newsletters, and individual or sub-team discussions with experts as required.

In response to comments made during this meeting and the baseline interviews, specific individual discussions followed to further clarify the project boundaries of what the project will and will not include, establish the research framework and clarify roles. The steering committee for DoMiNO was formed and took part in planning and decision making of the entire research process through monthly or bimonthly teleconferences.

4.3.3.2 Constructing the building blocks for the research

Once data were available, the entire team met in person for a progress report and for a workshop to plan and design the research path, which was necessary for the data mining process. Content experts decided on inclusion and exclusion criteria for the different variables used to conduct the research and the level of investigation (*e.g.,* geographic areas for the different variables). Once this plan was clarified, members of the team, the principal investigators and students from different disciplines, continued in cleaning and harmonizing the data according to the protocol developed with the assistance of specialists in the team, for the subsequent research processes.

Research activities focused then on developing data exploration approaches based on the three research methods: spatial data mining, statistics, and geographic information systems. Graduate students were mainly engaged in this phase alongside consulting with content experts as needed. Specifically, the data mining team developed a unique, new, and efficient algorithm to discover contrastive motifs (Jabbar, Zaïane, & Osornio-Vargas, 2017) and created a list of association patterns. Concurrently, statistics and geographic information systems, explored urban and rural differences in adverse birth outcomes occurrence. Different maps were developed to identify the geographic distribution of adverse birth outcomes, pollutants, and socioeconomic status indices (Chan et al., 2015), that later served to complement and finalize the analysis. These processes created a preliminary list of colocation patterns when brought together.

Throughout this period, rapport with the whole team was kept using newsletters and emails, in which progress was shared. We also initiated, based on team members suggestion, webinar sessions, which served as learning opportunities and enabled discussion with the entire team on

results, future steps, and follow up with individual or sub-team discussions as required. Through these activities the research progressed.

The team also engaged in reflective discussions and identified difficulties resulting from the interdisciplinary nature of the project, such as different perspectives and vocabularies. In order to address those issues, all future interactions contemplated 'building bridges' between disciplines and getting familiarized with each other's terminologies and meanings. Several different strategies were applied, including continuous learning opportunities, repetition of concepts, methods, and terms. Additionally, a lexicon that included important terms, methods descriptions, and data sources, among others, was shared among all team members. Over time, the team became familiar with the different methods and terminologies used, as was stated by team members "*understanding the different terminologies is getting better…*" (Annual meeting 3, Minutes) and found the lexicon to be helpful "*we have to have a good understanding of all measures and better understanding of the data: the glossary* [lexicon] *is nice*!" (Annual meeting 4, Minutes) so they were able to be meaningfully engaged in the research process.

4.3.3.3 Refining results

Once the first association patterns were identified, with the guidance of the data mining team members, the team jointly supported the design of a visualization tool (VizAR) for identifying data mining patterns (Bellinger et al., 2019; Bellinger, Jabbar, Hojjati, Zaïane, & Osornio-Vargas, 2018). By using this visualization tool, findings were easily presented according to the different pollutants, the birth outcomes and the location where they co-occur.

Team members took part in several face-to-face workshops, webinars, and surveys to first learn about the tool and then brainstorm to provide input regarding issues related to the inclusion of data, design, processes used, prioritization methods, and usability of the tool. This process

helped in shaping the tool itself with new types of analysis and functionalities. As was described by the data mining team, "*Many versions of the tool were produced in response to the team comments and feedback*" (Annual meeting 4, Minutes). Through this iterative process and the joint interdisciplinary effort, the outcome resulted in an interactive tool that enabled users, team members and external users, to explore the different patterns according to their parameters of interest, such as specific chemicals, locations, or birth outcomes. This visualization tool enabled exploration, sorting, prioritizing and identification of mixtures with strong data mining associations with adverse birth outcomes to generate new hypotheses.

4.3.3.4 Prioritization, interpretation, and validation of results

The last stage was to identify new hypotheses based on the data mining findings. Using the visualization tool, the whole team met to discuss, interpret, decide on new hypotheses, identify other project outcomes, and develop a knowledge translation plan.

The expectation was that the team would identify patterns using VizAR to generate hypotheses, as was expressed in the beginning of the meeting by a Principal Investigator: *"…We are making discovery, not causality… VizAR is like a microscope; the microscope cannot interpret the results…we used different methods to rate the patterns; there is no methodology to tell us which is the best way to sort*" (Annual meeting 4, Minutes).

Coming from different disciplines and epistemologies, members had different perspectives on outcomes selection and the ways to claim validity and reproducibility of the results in this discovery-based research. This situation created a challenging discussion for finalizing the results. It was difficult to make a joint decision about which patterns could be considered as strong hypotheses, and which measures could determine what 'strong' meant. Based on the different perspectives in the team, various suggestions were made to move the project forward, such as: "*We*

need a validation process with different health outcomes", "*We need an automation process*", "*This is a good tool to look at mixtures*", "*We need to translate data mining results to epi* [epidemiology] *language*" (Different team members Annual meeting 4 Minutes).

Although this was the official end of the project, one of the more comprehensive propositions for hypotheses prioritization, which was introduced in the meeting, was followed through by several team members. They further developed a validation approach by integrating data mining, geographic information systems, and statistics into an integrative framework that helped the validation of the data mining findings required for the generation of five robust hypotheses. These hypotheses were reviewed and approved by the whole team, and the joint team publication describing these results was published (Serrano-Lomelin et al., 2019).

4.3.4 RESEARCH OUTCOMES AND KNOWLEDGE TRANSLATION

Over the five operational years of the project, the outcomes included: development of a new algorithm; creation of an interactive visualization tool to visualize data mining results; identification of an initial list of potential hypotheses; and a secondary list of robust hypotheses linking specific chemical pollutants mixtures with adverse birth outcomes. Additionally, the project had other 'side outcomes', such as new classification methods in data mining (Li & Zaïane, 2015), adverse birth outcomes, and industrial pollutants maps (Nielsen, Amrhein, & Osornio-Vargas, 2017), description of adverse birth outcomes, and related risk factors prevalence (Serrano Lomelin, 2018), testing the usefulness of existing publicly available data, learning about the collaborative process, and training a new generation of interdisciplinary researchers in environmental health. (A detailed list of outcomes is available on **Appendix 4.1**)

The project's framework contemplated, from the very start, knowledge translation and exchange as part of the research process. Thus, sharing the gained knowledge to contribute to research practice and policy that may advance and optimize children's health was central to the project. Many discussions and planning sessions took place during the project's process on what this knowledge translation exchange would look like considering the complexity of communicating about air pollution (Wartenberg, 2009). This included what the impact of the research could be, who the users would be, how and what to share, and how to best connect with stakeholders. As the KT plan developed alongside the project, the resulting knowledge exchange activities included different forms of engagement. The team initiated targeted and interactive activities with varying stakeholders with clinical, research, and policy interests. Engagement activities included hands-on workshops, presentations, and webinars to our team members' organizations (medical departments and agencies) and other stakeholders' organizations. The team engaged in traditional dissemination of results, including scientific publications and presentations in local, national, and international conferences. To date, some KT activities are still in progress and members of the team continue to collaborate on different spheres.

4.3.5 FACILITATORS AND CHALLENGES

A complex context and the research scope challenged the DoMiNO project. It involved discovery research in a poorly explored territory, aiming to identify associations between adverse birth outcomes and mixtures of pollutants, some of which have unknown toxic potential. Challenges also included the development and application of a new methodology for identifying mixtures, working with data limitations, such as lack of details or need for aggregation and the constant expectation of proving causality.

However, the collaborative and interdisciplinary nature of the project and the team's commitment provided the conditions to develop and support such an innovative project. As was noted in one of the field notes:

> *It was very helpful to have team members with different familiarities (a data analyst, a medical expert, people familiar with the databases and what they do and do not offer, familiar with the chemical release reporting systems). Also, helpful to have a group who uses a variety of research techniques. The discussion would not have gone anywhere without the combined expertise and diversity of the group.* (Observation, Meeting 3)

Moreover, the inclusion of data providers/custodians and NGO representative as team members supported all the phases of the research including the knowledge translation. The diverse and comprehensive input from all members enabled the progression of the project, which would not have been possible otherwise; thus, the inclusion of all team members in the different activities of the project was imperative. It was an iterative process of learning and production, collectively and individually at times (*e.g.,* only the data miners could develop the algorithm). Hence, the data mining process could not have progressed into developing a meaningful algorithm without understanding the different considerations imposed by the context and why these mattered. Moreover, data mining findings could not have been interpreted and validated without the assistance of the rest of the team.

Different channels of communication facilitated rapport, dialogue, engagement, participation, and learning to support the ongoing collaboration. Among those, face-to-face meetings were the most efficient manners of communication, which included frequent small/sub team meetings and four annual two-day meetings for the whole team. Those interdisciplinary sessions and interactions promoted continuous learning and participation of different perspectives and at different times and were essential for progression and development. Annual full team meetings were designed by the principal investigators, research coordinator, and the meetings facilitator to respond to the project

needs. Planning of format and content were based on consultation and feedback received from the team: the steering committee, previous meeting evaluations, webinars, small /sub-team meetings, and individual discussions. Annual face-to-face meetings usually involved formal and informal sessions, presentations and progress updates, interactive workshops designed for brainstorming on results, methods, challenges, interpretations, improvements, and future steps in large forum discussions and smaller groups. The team also engaged evaluation surveys and in reflective sessions discussing the collaborative process to identify strengths and weaknesses as well as opportunities and challenges. Participation in the face-to-face meetings was almost always close to the maximum.

Webinars and newsletters were other channels for communication. Newsletters focused on providing updates on progress, outcomes, logistics, short-term plans, and summaries of team activities and decisions. Webinars (online seminars) were professional platforms for deliberations on details on methods and interim research outcomes from all arms of the project and an opportunity to discuss future steps. In most cases, approximately 15 (3/4 of the team) members joined the webinars. All webinars were recorded and shared on the DoMiNO website to benefit those who may have missed the sessions.

The project faced logistic challenges, such as having the right personnel to address all aspects of the research, team members who had competing priorities, and geographic distances. However, this partnership supported and grounded the research and steered the research towards exciting and meaningful outcomes as well as dissemination, and application in different domains. **Figure 4.2** illustrates the DoMiNO's project main milestones, the different elements that supported the promotion of the interdisciplinary and collaborative practice, and the contribution of the different disciplines during the years of operation.

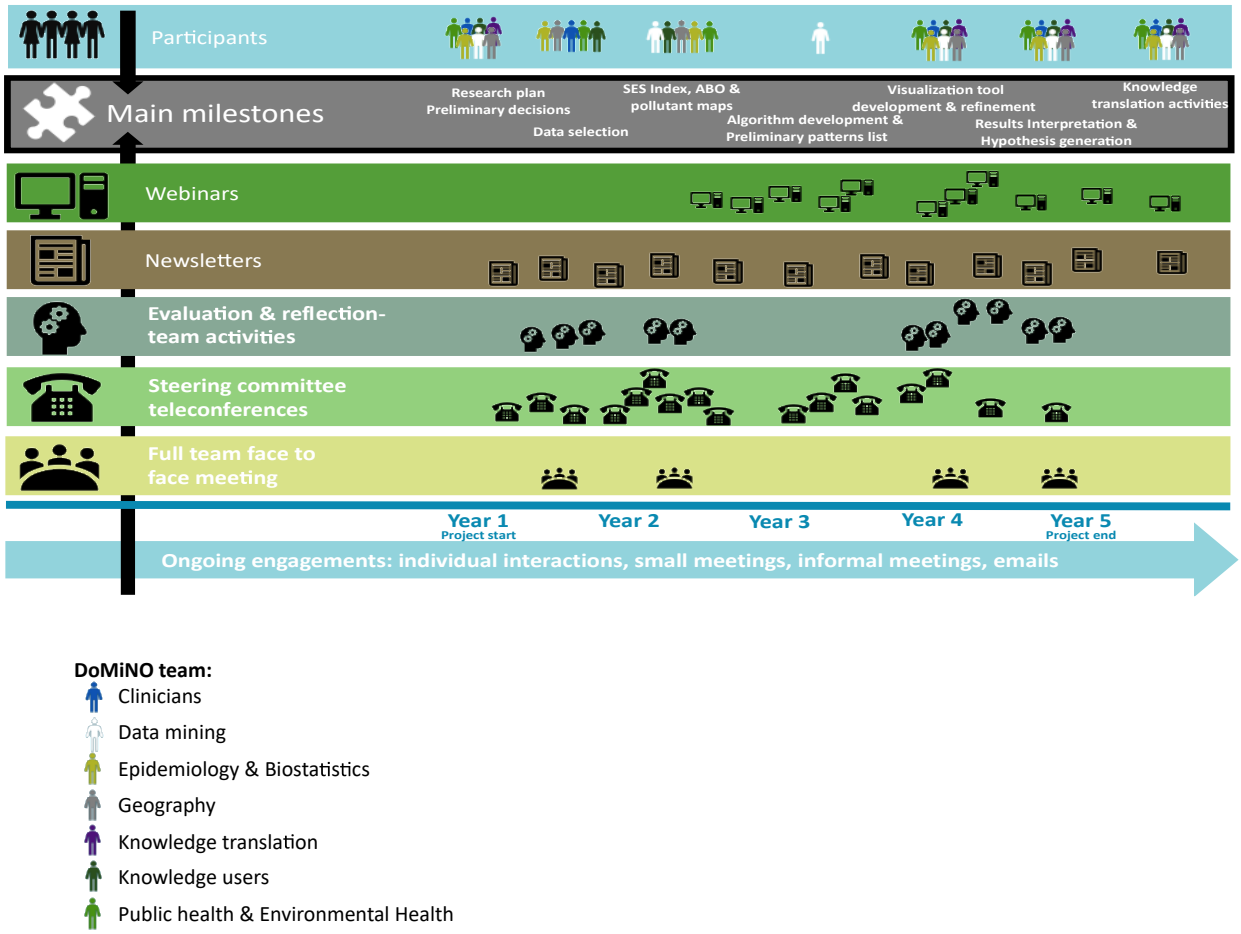

Figure 4.2: DoMiNO project milestones and the elements promoting collaborative practice

4.4 Discussion

In an attempt to understand the environment and how it impacts the health of the people and the planet, complex research is required to capture all the participating elements and understand how they connect [*e.g.,* exposure to multi-pollutants in the air impacting different systems (Dominici et al., 2010; Mauderly et al., 2010)]. New research approaches are required along with diverse disciplines, collaborating to support this type of research as the scientific exploration

moves to be more holistic and includes different aspects of the problem (Ledford, 2015) [*e.g.,* EWAS approach (Agier et al., 2019), One Health approach (Conrad et al., 2013)]. Wild (2014) called for interdisciplinary research of the exposome, a collaboration across disciplines that use different paradigms, tools, and even languages (Wild, 2012). Dagnino (2019) further emphasizes the significance of the collaboration of epidemiologists and statisticians with other experts to ensure proper study design, methodologies, and analysis in exposome research, and provide examples of projects and centers devoted to the research of the exposome. Thus, the DoMiNO project described in this dissertation is an example of how a collaborative and interdisciplinary approach including an array of specialists and expertise can contribute to a novel research approach to address this complex context of the human exposome.

In a previous exploration of the literature on collaborative research in the EH context (Wine et al., 2017) we identified several approaches embracing interdisciplinary research in collaboration with knowledge users or stakeholders among them are transdisciplinary research and community based participatory research. Additionally, we identified key components of the collaborative research process that negatively or positively impact the collaborative process, among them the significance of allocating time and resources, addressing disciplinary and sectoral issues, building relationships, ensuring representation, embedding participation in the research, supporting ongoing collaboration, and developing knowledge translation (KT) and exchange. The literature review findings, and those obtained from the DoMiNO collaborative process experience, highlight several aspects that are of significance to interdisciplinary and collaborative research projects.

The interdisciplinary research process requires sufficient time and efforts to enable the building and maintenance of the collaborative process in order to optimize the partnership and achieve goals. Although it may seem at times that interdisciplinarity can create obstacles for

progression, it actually pushes the work forward in a way that benefits the project to be more relevant and useable (Campbell et al., 2015; Reed, 2008). We have learned that collaboration is an evolving process, which starts from planning and writing the proposal and goes on to the next phases, in which relationship among team members evolve and strengthen over time, through formal and informal activities. The research progresses thanks to the integration of different perspectives, methods, and experiences (Annerstedt, 2010; Podestá et al., 2013) and the team's commitment.

The interdisciplinary and stakeholder engagement process can only occur in a supportive environment that promotes learning and sharing ideas. Learning is especially essential, considering that members have different backgrounds, perspectives, and concepts. In order to achieve effective learning, the team needs to build bridges to guarantee the progression of the research by learning, thinking, and employing different methods and harmonizing discipline-specific terms or word meaning. The team needs to embrace different epistemologies, theories, and methods, challenge their own beliefs, and engage in reflexivity and self-awareness of one's own epistemology bias as part of the research process and the interpretation of results (Repko & Szostak, 2017). Moreover, this type of research requires a team to think in 'discovery mode' for generating hypotheses, where logic, rigour, and objectivity are insufficient at times. At the same time, there is a need to ask for creativity and intuition. Times for disagreement and epistemologies breakdown may happen (Mengis, Nicolini, & Swan, 2018). The integration, interpretation, assessment, and agreement on results is a difficult test and challenge for interdisciplinary practice. Different measures were suggested to overcome those challenges and facilitate best practices such as evaluation, reflection, and deliberations (Hovelynck, Dewulf, Francois, & Taillieu, 2010; Nancarrow et al., 2013; Podestá et al., 2013; Roux, Stirzaker, Breen, Lefroy, & Cresswell, 2010; Wine et al., 2017).

Furthermore, supporting the process of collaboration may help in overcoming discipline-related challenges as described above, as well as technical challenges due to team members geographical distances (Rekers & Hansen, 2015; Stokols et al., 2008). Facilitating different communication channels can address different needs and availabilities. Evaluation and reflection can support the collaborative process as well (Roux et al., 2010). It enables rapport and can help identify different needs of the collaborative process, such as modifications to support systems employed to inform the process and to support learning and capacity building. In order to optimize future collaborative initiatives, research teams may want to consider including a specialist to support the collaborative aspects of the research including formative evaluation (Meadow et al., 2015; Ramirez-Andreotta et al., 2014). Another approach would be to promote training in interdisciplinary and collaborative research for those involved (Repko & Szostak, 2017; Wild, 2012).

The case described here provided insights into the collaborative process within the complex context of EH research from real-life experience. It highlights not only the need for innovative research approach and the participation of an array of specialists working together to promote a comprehensive understanding of the exposome and its impact on human health, but also the process of establishing and maintaining these types of partnerships supportive of building research capacity and knowledge translation, in this evolving area of research.

Those engaged in collaborative research would probably find some similarities between this case and those emerging from their own experiences. Research teams often have diverse expertise participating in their endeavors. However, we do not often spend time thinking about what aspects optimize research partnership practice. While we move forward with more complex research to explore the environmental impact, stories like the one presented here provide insights to the kind

of encounters teams may face in light of the complexity of both the research itself and the collaborative process, and how to overcome those.

Interdisciplinary experiences provide interesting new research outcomes but are not exempt from challenges as the ones discussed above. Team members and leaders need to embrace a collaborative culture, acknowledge the challenges, and address them in their research process.

Building a team requires the investment of time towards building relationship and trust, building bridges between disciplines, and supporting an inclusive learning environment to help strengthen a successful collaborative project. Nonetheless, it is the team's commitment of both management and members to the collaborative process that makes the difference.

This case represents an example of a collaborative process in the complex context of the research of the exposome and is part of our ongoing exploration to understand the essential components and mechanisms necessary for collaborative teams' growth and performance. Future research should continue and promote more opportunities to learn from real-life stories in order to improve interdisciplinary collaborative practice.

CHAPTER 5

FINDINGS (1): THEMES, AS THE ESSENTIAL COMPONENTS OF THE IKT COLLABORATIVE RESEARCH PROCESS

In the previous chapter I presented the DoMiNO project's story that served as the case of study and provided preliminary insights on the collaborative process. This chapter includes the case study analysis findings, based on data generated over the five years of the DoMiNO project operation. Using thematic analysis procedures described in **Chapter 3**, I identified eight themes that represent the essential components of the DoMiNO project's IKT's collaborative process. The first six themes refer to processes that are dynamic in nature: *building relationships, advancing individual growth, building team capacity, maintaining alignment, establishing trust, and developing shared ownership.* Another two themes referred to as enabling conditions and include a collection of elements essential for day-to-day operations of the project called *operative elements,* and for those inherent to the team members named *individual attitudes*. Short definitions and supporting quotes of the themes and subthemes are provided in **Table 5.1**.

Table 5.1: Themes, subthemes, definitions, and supporting quotes

	Themes & Subthemes	Definition	Supporting Quotes
1.	**Building relationships**	Building professional and personal alliance and bonds between team members	"*It is fun to get together and work with people*"
2.	**Advancing individual growth**	Advancing individuals' new academic skills, knowledge, capacity, and competency in aspects of the DoMiNO project	"*People are developing through the course of the project*"
3.	**Building team capacity**	Building of collective knowledge, competency, and ability to jointly perform and contribute to the common goals	"*Different disciplines, different focus –putting this together*"
4.	**Maintaining Alignment**	Achieving and maintaining collective consensus and individual orientation. Alignment of the project progress, project-specific knowledge, and expectations	"*Making sure everyone is on the same page*"
	4.1 **Project progress**		
	4.2 **Project - specific knowledge**		
	4.3 **Expectations**		
5.	**Establishing trust**	Establishing confidence among team members and in project procedures and outcomes	"*We trust each other as individuals and the work we do"*
6.	**Developing shared ownership**	Developing a sense of individual and shared ownership and responsibility	"You feel a responsibility, that you are contributing, and part of the scene"
7.	**Operative elements**	Elements that facilitate rapport engagement, reflection, learning and inclusion	"*Sustaining the project momentum*"
	7.1 **Maintaining communication channels**	Maintaining different communication channels between team members	"*Setting the Stage*"
	7.2 **Supporting a learning environment**	Supporting knowledge sharing strategies to facilitate learning of project knowledge specific	"*Getting those hard concepts engrained*"
	7.3 **Sustaining an inclusive setting**	Sustaining the inclusion of all members	"*Your voice matters*"

	7.4	**Embracing an attentive leadership style**	A leadership style that promotes and supports a collaborative culture	"*Setting the Tone*"
8.	**Individual attitudes**		Individual position, will, and ability to act as contributing team members	"*It is me, I needed to step forward, it is not the project that needs to come to me*"
	8.1	**Commitment**	Individuals' ongoing commitment and dedication of time and attention to the project and its different activities	"*Devoting uninterrupted time both physically and emotionally*"
	8.2	**Engaging in dialogue**	Active engagement in two-way communication between members to support dialogue, feedback, and reflection	"*Exchanging ideas, or bouncing things of each other*"
	8.3	**Keeping an open mind**	Willingness and ability to learn, accept and practice different epistemologies	"*Going beyond our own domains*"

The eight themes contributed to building a constructive, collaborative climate towards individual and team *performance*, *productivity*, *outcomes,* and *KT*. *Performance* refers to an action or process of taking out and accomplishing actions and tasks; it includes the different phases of production, co-production, and KT planning and utilization of KT activities as a team or as individuals within the team. *Productivity* refers to the outcomes and achievements resulting from individuals and the team's joint generation and creation [e.g., achieving milestones, objectives, outputs (actions or items), and KT activities]. *Outcomes* refer to the tangible and intangible results of the project. *Knowledge Translation* refers to knowledge exchange, outreach, and dissemination (active and passive) of new knowledge and outputs produced. Knowledge exchange can occur during and at the end of the project for different audiences, for different purposes, and by using different strategies.

Below, I present each of the themes' and subthemes' descriptions and meanings, why team members felt it was important, how it manifested in the different phases of the DoMiNO project,

and how each theme contributed to the collaborative process, performance, and productivity. The themes and the concepts they represent in relation to performance and productivity are illustrated in **Figure 5.1.** The first theme I present is '*building relationships'*, which is considered a significant building block for beginning collaboration.

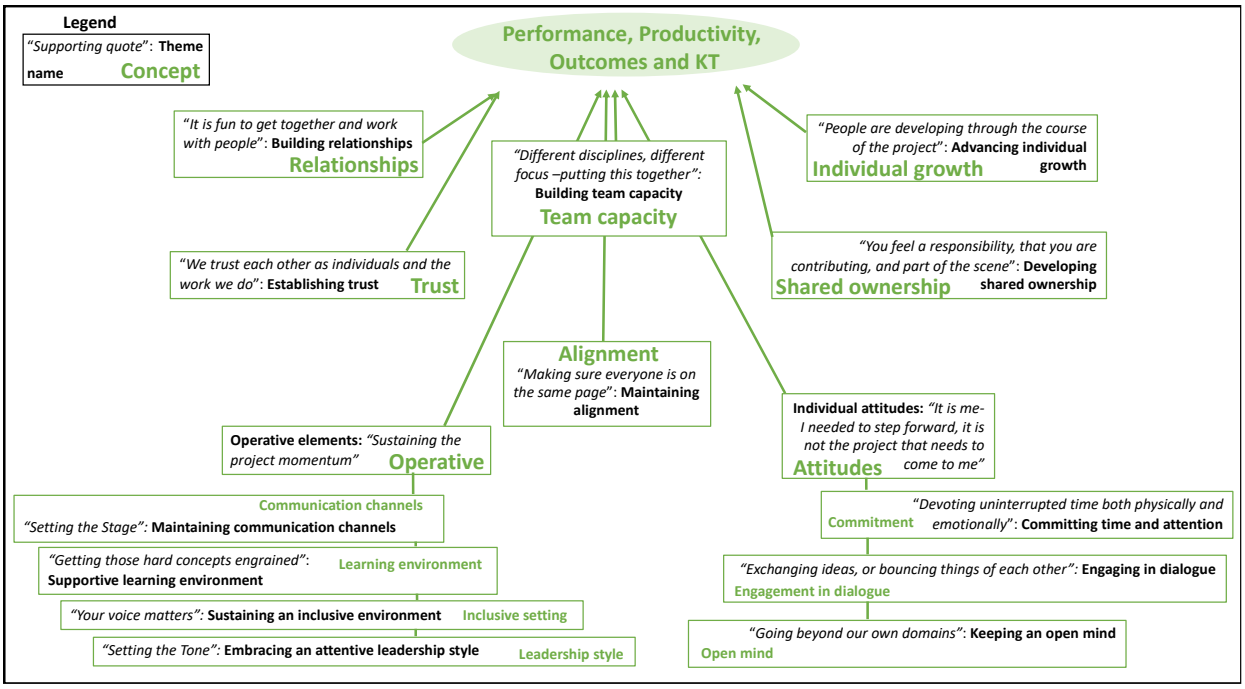

Figure 5.1: Themes, subthemes and concepts that contribute to the team's performance productivity, outcomes and KT. The identified themes and subthemes, which contributed to the DoMiNO IKT process towards performance, outcomes and KT. Each of the themes is presented by supporting quotes (*italics*) a short theme description (**bold**), and their conceptual underpinning (**Green**)

5.1 BUILDING RELATIONSHIPS

"*It is fun to get together and work with people*"

	Themes	Definition
1	**Building relationships**	Building collegial and personal alliance and bonds between team members
2	**Advancing individual growth**	Advancing individuals' new academic skills, knowledge, capacity, and competency in aspects of the DoMiNO project
3	**Building team capacity**	Building of collective knowledge, competency, ability to jointly perform and contribute to the common goals
4	**Maintaining alignment**	Achieving and maintaining collective consensus and individual orientation of the project progress, project specific knowledge, and expectations
5	**Establishing trust**	Establishing confidence among team members and in project procedures and outcomes
6	**Developing shared ownership**	Developing a sense of individual and shared ownership and responsibility
7	**Operative elements**	Elements which facilitate rapport engagement, reflection, learning and inclusion (Communication channels, Learning environment, Inclusive environment, Leadership style)
8	**Individual attitudes**	Individual position, will and ability to act as contributing team members (Commitment, Engagement in dialogue, Open mind)

The first theme was building of collegial and friendly *relationships* among team members. It refers to creating a kind of connection, alliance, or bond between team members, either professional and/or personal. In DoMiNO, some of the team members were acquainted prior to the project's launch and some joined later. Before the project commenced, team members recognized the importance of getting to know each other personally. They considered introductions of team members to be an essential component of the first phase for building the project: *"…to what extent are the investigators already acquainted with each other? So, if they are not, then obviously that is … the first order of business*" (P11, baseline interviews).

Exploration of data from initial stages of the project suggests that members of the team recognized building relationships as means to improve communication among team members, understand their different perspectives, and help them familiarize themselves with members'

backgrounds. Through these relationships they would communicate, work better with each other, and support the team's performance, as demonstrated in the following quotes:

> *For me it will be really good to get to know all the team members…but also getting to know the people helps you to understand personalities and where they are coming from, and how to work better with each other.* (P1, baseline interviews)

> *…give the opportunity for everybody to meet, because so far, most of the communication has been over the phone or by emails ... to me that is important. We need to meet people and communicate, putting a face to a name, or a body language to a name…and that will happen because we are meeting in the same physical place.* (P12, baseline interviews)

As the project progressed, relationships evolved and strengthened. Indication of the attainment of friendly and collegial relationships over time was obtained from observational data and team members' perspectives (*e.g.,* focus groups, insights, evaluation forms, field notes). Indications for the friendly bonds made include informal conversations and a positive atmosphere in face-to-face meetings (*e.g.,* chatting, social mix of locals and non-locals, seniors, and juniors). Team member reflections confirmed these observations. For example, members described that: "*relationships have been built – it feels like some* [kind of a] *family*" (P1, Insights) and that "*everybody knows each other very well, everybody is comfortable sharing ideas, everybody enjoys* [the project]" (P3, Insights).

Records in the DoMiNO logbook demonstrate that collegial working relationships were also built. Throughout the project members had continuous professional engagement with the DoMiNO project. They connected with each other and shared responsibility of the various parts of the research process (*e.g.,* contributions of time, skills, products) that contributed to the collective effort and progression of the project. Relationships were built on respect as one member noted: "*my interaction with* [another team member] *was always very respectful, from the very beginning, and I think that allowed me to build trust in whatever followed*" (P13, FFG).

Members identified the significance of relationships to the project's performance and productivity and the time they take to develop, as noted by team members: *"…it takes time to develop relationships, and 2-3 meetings to get to optimal team performance…*" (P6, Insights), and in the evaluation forms of the annual meeting indicated that "*The meeting really was useful, and to observe how long it takes to build relationships, which lead to good productivity*" (Anonymous, Evaluation form 3). Members also described their appreciation to the built professional relationships. When asked what aspects of the annual meetings felt most like teamwork they noted: "*Open discussion in a very collegial manner"*, and *"the cooperative spirit of the team members*" (Anonymous, Evaluation form 4).

After the project ended, team members indicated the importance of professional interactions and the positive social element, as both being vital to building the collaborative atmosphere and contributing to the project's success, as documented in the final focus group (FFG):

> *I think it was absolutely critical* [the social atmosphere]. *Everybody was pleasant to be around … it was like having a 'little social thing' before the actual meetings … get socialized and become friendly …or personable ….it was a really fun group to be around.* (P3, FFG)

> *For me, it was interesting to see different methods and have a group of people that have a lot of different expertise try to apply it to a problem. So, these workshops were actually pretty fun … they were very different than what…traditionally happens at a scientific meeting. So that was really my main interest of being involved. And it is a really small community, we know most people and it is fun to get together and work with people.* (P14, FFG)

In summary, friendly, and professional relationships evolved along the progression of the project, and as described were a fundamental component of the collaborative process.

5.2 ADVANCING INDIVIDUAL GROWTH

"*People are developing through the course of the project*"

	Themes	Definition
1	**Building relationships**	Building collegial and personal alliance and bonds between team members
2	**Advancing individual growth**	Advancing individuals' new academic skills, knowledge, capacity, and competency in aspects of the DoMiNO project
3	**Building team capacity**	Building of collective knowledge, competency, ability to jointly perform and contribute to the common goals
4	**Maintaining alignment**	Achieving and maintaining collective consensus and individual orientation of the project progress, project specific knowledge, and expectations
5	**Establishing trust**	Establishing confidence among team members and in project procedures and outcomes
6	**Developing shared ownership**	Developing a sense of individual and shared ownership and responsibility
7	**Operative elements**	Elements which facilitate rapport engagement, reflection, learning and inclusion (Communication channels, Learning environment, Inclusive environment, Leadership style)
8	**Individual attitudes**	Individual position, will and ability to act as contributing team members (Commitment, Engagement in dialogue, Open mind)

Another element that was important for the progression of the collaborative process was *advancing individual growth*. It refers to the advancement of individuals' capacity, intellectual growth, competency, and knowledge through the participation in the research project. Members felt that the new experiences and roles played in the process enabled further individual development besides their previously obtained capacities. As described by team members, individual growth is reflected by the individual outcomes from the project; these include both tangible (*e.g.,* publications, specific skills, degrees) and intangible outcomes (*e.g.,* knowledge, connections, experience).

Members described that the possibility of gaining new knowledge was a motivator for joining the project and for staying engaged throughout. Team members acknowledged the strong potential for learning from each other about different and new methods, approaches, and perspectives, and learning from the project outputs. As was described by team members: "*…one thing that kept me*

interested is that I am here to learn from this project. If you do not learn anything new, it is just painful!" (P14, Insights).

Team members appreciated the learning opportunity and intellectual challenge that the project's interdisciplinary nature provided. As described by the team members: *"…this is an opportunity, to try and move in different knowledge domains… and it opened my mind to try and understand different concepts*" (P9, FG).

However, developing individual growth manifested differently for different team members. For some members it was about developing competencies and skills while for others it was an intellectual growth, as noted by one member, who did not necessarily feel they gained new skills, but rather experienced a change in their understanding and thinking of new procedures:

> *I look at building individual capacity, for myself- I do not see that I have built a lot of capacity coming to this new area; I think I know a little bit more about what data mining is and how it works. But I would not say I came with a whole new skillset or new capacity to do a different type of research … I think maybe shaping some individual attitudes about new techniques and you know how different skills could come together.* (P4, FFG)

Attaining knowledge specific to the project was necessary in order to deploy the research, or parts of it, and gaining this capacity led to different achievements. Member comments on the meeting evaluation forms continuously confirmed that learning was a significant part of the overall project. Individual growth, through learning, led to increasing competency and stimulated some members towards collective progression and team performance: "*I learned a ton today, and… it got me more excited … I have seen the progression, and it's like 'ok!' now there is all this cool stuff that we can do*" (P4, FG). Some members described how learning and gaining new

understanding was a necessary process to engage and contribute to the discussions, as described in the following quote:

> *I saw it like a learning curve for me, in the sense that I enjoyed listening to people who were experts at data mining and putting those in context … we were bringing it into medicine from a data analysis perspective, for hypothesis generation …I certainly learned something new. I have seen data mining in a very different way previous to being involved in this project, and then I saw the matrix of data mining and the development into patterns, and that was certainly a new learning, and I was able to contribute to it once I understood what is happening.* (P18, FFG)

Members perceived that learning evolved over time as part of a journey taken by the team. At the start of the project it was unclear what each member needed to learn from each other and this needed to be adjusted to the project and team needs to support the project's outputs at the end, as described by one member: "*In the beginning you may not know all that you need to learn; this is a journey, and we didn't know in the beginning where we end up, and what we needed to learn from each other*" (P3, FG).

Another example of building individual growth is demonstrated by building students' individual capacity. It includes acquiring the skills and knowledge for conducting the research, the production of outcomes, graduating, publishing, and maturing as independent interdisciplinary researchers. Building student capacity was a significant aspect for several reasons: graduating students was one of DoMiNO's objectives and was an expected outcome of the granting agencies; but moreover, training students as part of the research project is an academic legacy (productivity) and was a central goal for senior team members; it was regarded to as part of the productivity of the project. Throughout the project, members saw student capacity building and progression as a specific strength of the project: "*What was really nice about this project is, you could see the trainee component of the students, and see the students' progression, with students coming in and*

out, and I think that was a distinct strength of the project" (P4, FG). Students themselves indicated the immense learning experience and excitement about interdisciplinary and collaborative research as one student noted:

> *This was the first time I dealt with researchers outside of my discipline and that was a really good experience… that helped develop my perspective on different angles and to be open to this kind of research. I would love to continue with this kind of research.* (Student, FFG*)*

Furthermore, graduate students were the engine of the project as part of the core team. They were involved in central aspects of the research work (*e.g.,* harmonizing data, analysis); thus, building their capacity, meant that they were able to bring their new gained competencies and knowledge to the collective research effort. In fact, their research work was fundamental to the project's progression. As seen in the logbook, discussions in annual meetings were based on the students' research findings and much of the project outputs (e.g., publications) were the direct result of their research work. An indication of the built individual capacity of the students was evident by the end of the project, as I observed in the 4th face-to-face meeting "*junior researchers/students were taking the lead in small discussion groups and different meeting activities, in comparison to earlier meetings in which senior researchers were the leads*" (Observation notes, Meeting 4).

After the project ended team members and students identified additional aspects of individual growth. They indicated that capacity and knowledge growth included not only academic proficiencies but also intangible skills like project management, KT, and the significance and practical lessons on interdisciplinary research and practice:

> *I was interested in the method, and also I feel that I probably learned a lot of intangible skills of seeing the process, of running the meetings, of how-the leadership roles of the*

principal investigators within the project [were undertaken]*, and then also around the KT* [development] *process as well…those were in addition to the ultimate outcome of the* [Project] *… that had me, buy-in.* (P3, FFG)

As described above, advancing individual growth was a significant component for the collaboration. Team members viewed individual development as a motivator for participating in the project and described how they increased their competencies, skills, and knowledge, which contributed to their own growth as well as fostered discussion and the building of joint capacity of the team.

5.3 BUILDING TEAM CAPACITY

"*Different disciplines, different focus –putting this together*"

	Themes	Definition
1	**Building relationships**	Building collegial and personal alliance and bonds between team members
2	**Advancing individual growth**	Advancing individuals' new academic skills, knowledge, capacity, and competency in aspects of the DoMiNO project
3	**Building team capacity**	Building of collective knowledge, competency, ability to jointly perform and contribute to the common goals
4	**Maintaining alignment**	Achieving and maintaining collective consensus and individual orientation of the project progress, project specific knowledge, and expectations
5	**Establishing trust**	Establishing confidence among team members and in project procedures and outcomes
6	**Developing shared ownership**	Developing a sense of individual and shared ownership and responsibility
7	**Operative elements**	Elements which facilitate rapport engagement, reflection, learning and inclusion (Communication channels, Learning environment, Inclusive environment, Leadership style)
8	**Individual attitudes**	Individual position, will and ability to act as contributing team members (Commitment, Engagement in dialogue, Open mind)

Building team capacity refers to the development of collective competence and the ability to perform and deploy the different parts of the research. It contributes to *performance* and

productivity by addressing common goals, the co-creation of new knowledge, and joint planning and utilization of knowledge translation activities. Team capacity was built on the integration of different perspectives. Members explained, before the project started, that an interdisciplinary approach, which combines different angles, was essential to address complex research questions that aim for discovery, such as the ones the DoMiNO project was exploring.

> *The only way these projects get done is to bring together people with different backgrounds and specialties... it's very unusual to find all of the skills required in one lead person…nobody knows everything… bringing people together with different viewpoints often helps discover new ways of looking at things.* (P15, baseline interviews)

Building team capacity also refers to the team being capable of navigating interdisciplinarity to support collective progress and enhance the breadth and depth of the research. An indication of the significance of team capacity for the progression of the project is reflected in one of the Principal Investigator's (PI) words, emphasizing the need for contributions from different perspectives: "*Data mining needs the assistance of the group in working on the input*" (PIs, Minutes Meeting 2). This meant that joint discovery needed to be constructed on bringing different research paradigms together, as explained by another team member at the end of the project:

> ...[there were] *investigators coming from different backgrounds: the traditional epidemiology way of doing things - the traditional ways of quantifying facts - versus what was coming out of the data mining. And so, there was a real sort of sense that we were jointly discovering what the best way was to bring those two paradigms together*. (P11, FFG)

Members realized that building team capacity could happen if members get involved from the very beginning of the research process and throughout its different phases, so they can meaningfully engage in the final stages of exploring and interpreting the result, as was described

in the FFG: "*I think the exploratory phase is best understood if you're informed by the previous phases because you know the strengths and weaknesses of the data, so it is important for the team members to understand those* [previous] *pieces*" (P2, FFG)

Observation of different activities throughout the research process (as documented in the logbook, and meeting evaluations) identified performance and outcomes as the result of team capacity; the ability to work and produce as a team. For example, in workshops: "*different disciplines, different focus – but putting this together gave a broad view, build a team through the process of discussion*" (Observer 5, Meeting 2). Team members engaged in brainstorming, contributed different perspectives for one goal, and participated in decision-making processes (*e.g.,* the steering committee, team meetings or in workgroups). Members' engagement was compared to a dance by one of the team members: "*Everyone knew when to join in if needed: It was a nice dance, everybody knew when to get on the floor and do their little dance and then go back to their chairs*" (P12, FFG). Team capacity was also reflected in the productivity of the research processes [*e.g.,* the achievement of milestones and other building blocks to subsequent phases, integration of methods, and co-production of new knowledge (*e.g.,* new hypothesis), and products (*e.g.,* visualization tool, maps)].

Another example in which the built capacity manifested was the team's ability to reflect on their collaborative practice. During the project, there were designated opportunities for reflection on the collaborative practice. Reflection also became a 'spontaneous' practice. For example, members identified their research practice as progressing from being discipline-specific to an interdisciplinary practice integrating methods for a joint product (Minutes, small meeting February 2017).

Team capacity also related to the joint planning and utilization of KT activities. KT was considered as a subset of the project's outcomes. The development of the KT plans and KT activities transpired during and at the end of the project as an integral part of the project's progress. Dedicated discussions and informal conversations on KT development occurred during all phases of the DoMiNO project. Jointly developed KT activities took place at different time points of the project, while the end-of-project KT plans were developed by the team alongside the project progression.

During the final focus group, several team members discussed the role of building team capacity as a significant factor for the project success, which even exceeded expectations: "*I think it* [the project] *did a great job of building team capacity and bringing together people*" (P4, FFG); *"…the way the leadership and all the team worked closely together... I feel it was very good, for me it was beyond expectations*" (P9, FFG).

Building team capacity was an essential process for the project progression within the IKT framework. It was imperative for bringing together the different perspectives to a state of joint performance and productivity.

5.4 MAINTAINING ALIGNMENT

"*Making sure everyone is on the same page*"

	Themes	Definition
1	**Building relationships**	Building collegial and personal alliance and bonds between team members
2	**Advancing individual growth**	Advancing individuals' new academic skills, knowledge, capacity, and competency in aspects of the DoMiNO project
3	**Building team capacity**	Building of collective knowledge, competency, ability to jointly perform and contribute to the common goals

4	**Maintaining alignment**	Achieving and maintaining collective consensus and individual orientation of the project progress, project specific knowledge, and expectations
5	**Establishing trust**	Establishing confidence among team members and in project procedures and outcomes
6	**Developing shared ownership**	Developing a sense of individual and shared ownership and responsibility
7	**Operative elements**	Elements which facilitate rapport engagement, reflection, learning and inclusion (Communication channels, Learning environment, Inclusive environment, Leadership style)
8	**Individual attitudes**	Individual position, will and ability to act as contributing team members (Commitment, Engagement in dialogue, Open mind)

Building relationships, and individual and team capacity, were instrumental for DoMiNO's collaborative effort. *Maintaining alignment* was an essential component of the collaborative process. Alignment needed to be achieved and maintained among team members with regards to the project progress, the project-specific knowledge, and the different individual expectations. Alignment refers to forming collective and individual orientation with these aspects, and being, more or less, on the same page. The data indicated that alignment between members of the team needed to occur on different spheres: first, between the main 'doers' and the rest of the team, by keeping everyone up-to-date about the *project's progress*; second, between members from different backgrounds and disciplines regarding the *project-specific knowledge* (such as terminologies, concepts, and background), and; third, between members with regards to *expectations* about individual roles and expectations related to the project objectives, outcomes, and possible impact of the research.

As noted by team members, alignment of all levels needed to be a continuous process maintained through all phases of the research and required members involvement in order to be maintained. Detailed descriptions of the avenues for alignment of progress, knowledge, and expectations, are described below.

Alignment of Progress

The *Alignment of progress* refers to team members being on track with regards to the happenings and progress made in DoMiNO. This was achieved by sharing constant updates among team members related to activities, procedures, and outputs, so members (especially those not part of the core of doers) could understand the big picture, the possible outcomes, and are kept up to speed regarding to progress made and plans. This meant keeping others informed and staying informed in a manner that enabled progression.

On many occasions, different team members indicated that the alignment of progress made was crucial for the operation and progression from start to end of the research process. Members described at the beginning of the project what this alignment would look like in terms of meeting and sharing progress:

> *…not only we meet and discuss but also have presentations: This is what I've done so far, and here are the issues that I have, and this is how, I plan to do it…and then the year after: 'We promised this, this is what we've done so far, and we couldn't do this because it was a problem here'—and explain the problem—'and we went this way instead of that way'. And continue to do that – until - we all remain aligned together, towards the same goal, and because we have to put the pieces together as well. The pieces are—each one's working on something. (P13, baseline interviews)*

Once all team members were up-to-date on the progress made and the issues that needed consideration (*e.g.,* in workshops), members were able to provide input on work done and direct the research and planning to the next phases of the research; as one of the PIs noted, it was critical for progression: "*Sometimes felt blind … am I doing something useful? These workshops helped me to make things clear which direction to go"* (PIs, Insights). Other members described how

applying different check-up measures at different time points (*e.g.,* workshops in face-to-face meetings, email updates) supported the formation of alignment and helped keeping the momentum:

> *Have regular check-ins of different magnitudes: emails… webinars… and then annual face-to-face meetings… and so just keep the momentum going, and keep everybody on… even though we are all doing our own thing, we kind of get back together, it will take a couple of hours to* [figure out]*: 'this is what we are doing', and then nearly at the end of the meeting, we start to know what we really need to be doing and then… let's just keep going…* (P3, FG)

Maintaining alignment with the progress made was described by team members as both a need and a challenge. Members emphasized the need for constant alignment as registered in the members' response to the following question in the evaluation forms: '*What did you find useful in the meeting?*': "*Getting updates or status of the project from the presenters*"; "*Review of current status*"; "*Presentations and updates on where the project is and what the questions and decisions points are*"; and "*…would like more information on the stage of the project*" (Anonymous participants, Evaluation form 2). On the other hand, when asked about challenges, team members indicated that it was difficult to stay informed and aligned: "*Catching up on what has been done over the last year"* and *"Following what other team members had been involved with*" (Anonymous participants, Evaluation form 4).

Team members indicated the significance of the process of alignment of the project progress to the collaborative process. They noted that it was especially important for those not part of the 'doers' or core team, who needed to catch up, and indicated that the geographical dispersion of team members also made it difficult to stay informed:

> *Making sure that everybody knows the work that we're doing…or where we're trying to head with, and everybody's involvement maintains an alignment... it was just making sure everyone is on the same page- what are we trying to do together… because it's very easy… in a team like this, especially for those… who are not geographically in* [the same city]*, to*

> *lose track of it, because some of the trainees and some other researchers, are working ahead and doing all this great stuff, and coming back in at the annual meeting, or the occasional webinar, and just trying to get back up to speed. There is a continual sort of loop to catch up and engage together and then… you have to do it again.* (P6, FFG)

Considering that alignment of progress developed over time, most members noted that they felt they had a good sense of the project's status, which improved as the project progressed, *i.e.,* after meetings 3 and 4, as registered in the closed questions of the written evaluations of the face-to-face meetings.

Alignment of Knowledge

The *Alignment of knowledge* refers to acquiring project-specific knowledge. Knowledge specific to the project refers to aspects that were relevant to the operation of the research: the different disciplines' background and context, concepts, and terminologies, as well as interim knowledge developed in each of the project's phases. Members acknowledged that in this interdisciplinary context a baseline of knowledge needed to be built through alignment, which meant learning from each other and about each other's field: *"…making sure that everybody has a clear understanding, or at least, appreciation of the backgrounds of where people are coming from*" (P3, FG). The alignment of knowledge was also required to promote appreciation among the different disciplines, which took some time to form, as described by one of the team members: "*It's just that I did not quite appreciate the intensity of each group's work, the amount of… work computing science did, I hadn't quite appreciated it until I started to see the results*" (P4, FG).

Team members described that alignment of knowledge required all team members to be involved as a team, to learn and understand the different perspectives and progress towards a common goal:

> *This was a learning process for everybody when we got together, and heard the nuances from other co-investigators, and learned from their perspectives as to what they want to do, and how they want to do it; it was very important, and it gave perspective where everybody was sitting in that room… and this is how we learned, which maybe everybody knew but I did not, and started to learn, and there was a lot of it… It was very lively and collaborative… it was just, reinforcing everybody's learning at every meeting … in order to hone down our process of thinking towards a common goal.* (P7, FFG)

Similar to the alignment of progress, members indicated that the alignment of knowledge also needed to be maintained throughout the project by sharing individual aspects of the project, as indicated at the focus group (FG):

> *P4: Maybe each person, will bring different knowledge, which other people don't understand, or not necessarily understand, so if we each had 3 minutes sound bite of our part of the project, that would be the permanent record of where we were, and actually we could change it half way through… and that might have been a good way of logging or recording where we were.*
>
> *P3: … and have that… repeated across time.*
>
> (FG)

Maintaining alignment of knowledge was recognized as both a need and a challenge. For example, the challenge of achieving a shared understanding of different vocabularies and terms came up at different time points during the DoMiNO project. Specifically, difficulties with the different terms used were flagged by team members. This motivated development of different strategies to address the challenge (See **Chapter 4**).

An alignment of knowledge relevant to various parts of the project was not straightforward and took time to form. Maintaining this alignment and exchanging discipline-specific knowledge was identified to be challenging not only for those who learned from others' but also for those who shared their background and discipline perspective with others. Intra-team translation challenges were mentioned by some participants after the annual meetings: "*a challenge as an individual was: understanding the research of others… but it is getting better*" (Anonymous, Evaluation form 3) and, "*a challenge as an individual was: to make people from other disciplines understand something from mine…*" (Anonymous, Evaluation form 4). An example of such intra-team communication challenge was how to best visualize the findings for other team members to understand and use. Members realized that this challenge is part of the interdisciplinary nature of the project, and that it took some time to work these things out:

> *I think one of the challenges that I witnessed, was trying to get the visualization software to be helpful. We were trying to understand how the data mining results should be presented in an effective way. I think that took some time, just to nail down even the metrics how we are going to evaluate what is working. I guess that is standard struggles of interdisciplinary work. That took time to work out.* (P25, FFG)

At the end of the project, members recognized that the alignment of knowledge resided in learning from each other. They described it as an 'internal knowledge translation process' within the team and among the members. This was a necessary process for the interdisciplinary practice and a strong feature of the project, as was described by one of the team members:

> *There was a whole lot of knowledge translation happening within the team and that speaks to the diverse interdisciplinary nature of the work. Team members learning from other team members on an ongoing basis, is … really a strong feature of the project. (P6, FFG)*

Alignment of Expectations

Alignment of expectations refers to the mutual understanding of expectations about the project's objectives and outcomes. Also, the expectations related to each other's knowledge, capabilities, and roles. Considering the exploratory nature of the project, the expectations about the boundaries of the project needed to be aligned. As explained by one of the team members, at times, expectations about the possible outcomes of the project drifted away from the original objectives and feasible outcomes. Constant repetition of the original objectives, as charted in the research plan, helped in keeping focused on the joint goals:

> *At some point, people were thinking about different goals. For example, looking at the relationship between the chemicals and adverse birth outcomes…* [they] *were thinking about causality and that wasn't the aim of the project, the project was exploratory- building hypotheses. So, the workshops were very important, to again clarify the objectives of the project.* (P9, FFG)

Many activities were applied to enable communication between members and support rapport, engagement, reflection, inclusion, and learning, which in turn helped to form alignment. However, the analysis and observations show that it was not always simple. Members of the team discussed these challenges in the final focus group and acknowledged that it took time to get everyone on the same page because of the complexity of the data and analysis. However, alignment was eventually achieved when members understood the different aspects and considerations required for the development of the research and the overall goals became clear:

> *It was challenging* [to get people on the same page]*, but slowly, slowly, it came together, and people started to understand. I am not sure everybody has gotten the complete picture… and how many assumptions went in, and how many assumptions had confidence. (not that great confidence around them). I am not sure everyone is completely clear, that everyone understands everything, but what we were trying to do was evident in the meetings* (P7, FFG)

The complex context of the project and its exploratory nature meant that alignment needed to occur with the development of the KT plans as well. This alignment was necessary in order to ensure that potential users would not misinterpret the findings. For example, some members expected that the project outcomes would inform a broad level of users and felt there were messages from the project to audiences from the public or industry "*we just need to identify these messages…*" (Minutes, meeting 4). Others thought messages should be limited because of the level of the findings (*i.e.,* generation of hypothesis), and therefore recommended that KT should be dealt with caution. Members of the team realized that the project outcomes and KT plans needed to be aligned, and that meant that articulation of the KT for this project could only occur alongside the evolution of the project, as explained by one of the team members:

> *When we started, at the beginning of the five years, I am not sure we really knew what those KT outputs would be and what that would look like. I think it was a process of evolution along the way…and an alignment between the work we were doing and the* [KT] *objectives.* (P6, FFG)

Another aspect of the alignment of expectations referred to the different roles each of the team members had within the project, for example, the knowledge users. Since this role was a relatively new concept, and not well defined for this type of research, it was not clear what was expected from knowledge users, as was described by one of the knowledge users in the project:

> *One of the issues that may arise is that sometimes that role* [of a knowledge user] *is not all that clearly defined: exactly what the expectations are? … What does that mean? What is the lead investigator looking for, in terms of contributions from a knowledge user?* (Knowledge User, baseline interviews)

In the first face-to-face meeting, the DoMiNO team decided that in order to fulfill the research aims, all researchers would be regarded as knowledge users. In this case, there was the expectation

that the team members would act as knowledge users taking part in the interpretation of results and the KT. For example, one of the PIs requested the team to validate the findings, and to focus on how to communicate the findings explicitly: "*I need the users* [other researchers] *to tell me if these* [findings] *are valid? Do they answer what the users wants? … how to communicate these patterns, so they are actionable, but also identify if they are valid or not?"* (PIs, Minutes Meeting 3). This expectation of team members to act as knowledge users (reaching alignment) was manifested, as members engaged in conversations and provided valuable input towards the progression and development of a tool and initiated and engaged in different KT activities. However, it was not always simple. Members were challenged by the interpretation of the findings, their possible use, and impact (as discussed in the next chapter).

For the knowledge users, their roles became more clearly defined over time, which implies that the alignment occurred as the project progressed. Knowledge users acknowledged that defining the role of a knowledge user needed to evolve alongside the project progression; thus, by the third meeting, clarification of the role of a knowledge user became more evident:

> *This is a novel initiative, I don' t think we knew before, as knowledge users, how to use it… there is a lot of knowledge… we may misuse it – jump to conclusions… Only yesterday understood how exactly we want to use the knowledge… It was not clear to me until I saw the combinations…* (Knowledge User, Insights)

The alignment of expectations also included individuals' expectations about their own roles in the project and how this role would be determined. The alignment of role expectations was critical since some members indicated that role allocation had a direct impact on individuals' engagement. Team discussions identified that unclarity about roles in the team may alter engagement and, directly and indirectly, performance and productivity. This was indicated by one

of the team members in response to a question on what the collaborative process challenges are: "*being actively engaged, not sure what is my role, without active role or tasks, hard to stay engaged… without something to contribute, hard to actively stay engaged… will miss webinars*" (P14, Insights).

Identifying individuals' roles in the project was addressed at different time points during the research process, as documented in the logbook. In every face-to-face meeting, efforts were made to clarify the roles that everyone would take, and members had opportunities to identify a distinct role. Some did, and some did not. Some members were happy with an 'as needed' role and felt it was just implied: "*I think the trust was always there, and that's why I was just happy with whatever I was contacted for … I think it was more implicit*" (P18, FFG). For some members, the identification of roles was vague, as captured in the evaluation forms from different meetings. Responses to the question about 'aspects of the meeting that has been challenging for you' addressed the issue of roles expectations. Some of those responses included the following: "*Knowing what is/will be expected of me as a non-core member of the team and how to contribute moving ahead*" and "*would have been nice to more clearly define timelines and responsibilities*" (Anonymous participants, Evaluation form 3).

On the other hand, there were other members who expected team members to initiate and identify, on their own, their contribution to the project- as indicated in the same evaluation form of Meeting 3: "*…have meeting attendants identify how they see their roles in the project, and what they think they can do*" (Anonymous, Evaluation form 3).

The alignment of the individuals' expectations about their roles and the conceptualization of role meanings within the project evolved and became coherent at different times. As described by one member:

At the start, I had no idea how I was going to contribute, and then... (Others in the background: yes)... *when it went on, that was more clear…* (Others in the background: yes, it became clearer)... *really only in the last year or two…* (P3, FG)

The evolution of roles is further discussed below under ownership.

As described, establishing familiarity with the different aspects of the project was essential to foster discussion between members. Alignment on different spheres was critical for the progression of the project. It was about the attempt to stay updated, have common goals and shared understanding of the different approaches, identify, and address different expectations. This required continuous alignment of progress, knowledge specific to the project (*e.g.,* background, methods of the different disciplines involved) and alignment of expectations while contemplating the diversity among team members.

5.5 ESTABLISHING TRUST

"*We trust each other as individuals and the work we do"*

	Themes	Definition
1	**Building relationships**	Building collegial and personal alliance and bonds between team members
2	**Advancing individual growth**	Advancing individuals' new academic skills, knowledge, capacity, and competency in aspects of the DoMiNO project
3	**Building team capacity**	Building of collective knowledge, competency, ability to jointly perform and contribute to the common goals
4	**Maintaining alignment**	Achieving and maintaining collective consensus and individual orientation of the project progress, project specific knowledge, and expectations
5	**Establishing trust**	Establishing confidence among team members and in project procedures and outcomes
6	**Developing shared ownership**	Developing a sense of individual and shared ownership and responsibility
7	**Operative elements**	Elements which facilitate rapport engagement, reflection, learning and inclusion (Communication channels, Learning environment, Inclusive environment, Leadership style)
8	**Individual attitudes**	Individual position, will and ability to act as contributing team members (Commitment, Engagement in dialogue, Open mind)

Alignment was a significant process in supporting team consolidation and was one of the contributors to *establishing trust*. Trust refers to confidence in the integrity, ability, and surety, of team members in each other and in actions and outcomes. In DoMiNO, my analysis of the data indicated that establishing trust was among people with different professions and expertise, different working circles in the project (*e.g.,* team and data providers, team and core doers, seniors and students), as well as trust in each other's actions, procedures and outputs.

Trust in the research work that members conducted was identified as a condition for researchers to work with other researchers and with knowledge users and move forward the project including the KT aspects and help crossing hurdles. This was described by one of the team members in the baseline interviews:

> *I think we need to establish trust between all the participants… then that trust needs to become a trust in the work we do—probably we trust each other as individuals or based on our reputation… the trust that you will be working with somebody and trusting their methods—their way of thinking, that only can be achieved when you work with them. That is really, really important…and that trust and confidence will permeate into the knowledge users. So, if we are able to transmit trust of the completions then the knowledge users will trust those, and therefore, their work will be easier. So, if we trust in each other, the obstacles would be easier.* (P12, baseline interviews)

In some cases, trust was already established thanks to previous acquaintances. One participant indicated that trust originated from physical proximity: *"… I had full trust - there is that physical element - if I was in* [a different city]*, there's a different type of bonding… but at the same time, I feel trust was always there*" (P18, FFG). Establishing trust in each other meant that members felt confident in their work relationships and felt they would be called to contribute when needed, as described by one team member: "*I had a role, and when I wasn't needed, I didn't need to be there. That's a trust issue. And when I was needed I was approached, and I could contribute*" (P2, FFG).

Members also explained that the established trust in members' capability (*i.e.,* by the assignment of specific tasks) increased the level of responsibility and motivation to contribute to the progress of the project as was noted:

> *I have been assigned this responsibility… of tasks or delivering certain outcomes… these responsibilities mean that the team trusts me, or the PI and my teammates trust me. That reinforces the idea of trust and increases responsibility. That was helpful moving us forward* (P5, FFG)

Another member described the need to build trust between the members of the core group and the other members of the team in a satisfactory manner for them to stay involved and contribute to the project, because the nature of the work implied that not all would be engaged in the continuous work:

> *In a study like this, who are the core group who need to understand everything? And how did that group engage people who are not* [core] *but are engaged in part of it? … Did that group gel, and then did that group engage the people in a trusting relationship? Because in a big project like this you do not need everybody to be engaged all the time. It should not be a good use of resources, but you need them to be sufficiently engaged that they feel ownership of their piece or that they can contribute their piece.* (P2, FFG)

Trust was further built and maintained by having various deliverables of the project at different phases as information, data, results, and products were shared or co-produced. The building of trust in the outcomes and procedures was necessary for the project's progression, producing new knowledge and enabling KT. Team members explained that previous relationships contributed to trust but moreover that trust was gained through a process of presenting and achieving deliverables and a buy-in process by peripheral members:

> *I had some relationships with some other people involved, so there was initial trust of knowing that these are all highly regarded individuals. But I think the trust came when often the deliverables were delivered-on time. It was initially, getting the grant accepted on the second run, and that was a big accomplishment, and then meeting the deadlines for certain*

> *deliverables. For me, that was showing that this team was dedicated, and we are moving ahead quite well… For me it was* [about] *buy-in and buy-in sort of came out after the second into the third meeting, where I bought into the idea and the vision of where the project was going and thought that it had legs to make that happen.* (P3, FFG)

Another member described the need to trust others' work as part of the interdisciplinary nature of the research in which experts from one discipline have knowledge that others do not: *"at the end of the day, there's a level of trust, and there's a level of confidence, and also the part of - I'm not an expert in that, I'm just going to have to believe they know what they're doing"* (P4, FFG). Over time, established trust manifested in different outcomes, such as members feeling comfortable with others to ask questions and share data and ideas; buy-in and acceptance of methods, procedures outcomes and results; confidence in other epistemologies – other members' ways of research practice; work relationships, and the progression of the research.

An example of how trust manifested towards performance was the data sharing process. Two maternal and birth outcomes data sources were used in the project. These types of data on individuals are usually not readily available and need to go through several steps of agreements for data release, mainly because of confidentiality issues. Data providers of both these data sources were also team members. Trust was a condition to enable the use of confidential data on adverse birth outcomes. It was crucial that trust would be built with those handling the sensitive data to ensure confidentiality of the information and data shared. One of the team members described the significance of building that trust to support the partnership progression:

> *We need to be in a partnership of trust, and the trust will be based around confidentiality we need people to be able to express themselves and give information that they know will be held very confidentially. So, I'd like at the very first meeting to have that discussion about confidentiality, trust—sharing information that doesn't leave the four walls and isn't recorded anywhere, even other than in our own minds, so that we can move forward and on the right direction.* (P10, baseline interviews)

Trust between data providers and the rest of the team was necessary for the progression of the project. Data sharing was assured by the various agreements made in the beginning and suggestions for supervision of the early research procedures. Overtime trust was gained because data providers took part in the project and witnessed the research process and outcomes. In the third meeting, the data providers acknowledged that the project's success was reflected by establishing trust in the team. Trust ensued once they saw the rigour and the thought process that went into attaining results: "*for me success is building trust within an interdisciplinary team in the way the process is done, use of the data and the way we assess the results*" (Data provider, Minutes meeting 3).

This example of data sharing shows how trust was built in the team. Data providers showed their trust by supporting the confidential data sharing, and use for the research process, and by applying KT in their own organizations (*e.g.,* presentations, workshops). This observation of the trust built with data providers was shared with the team in meeting 4 and was verified by the team members and specifically, data providers.

In summary, the significance of establishing trust in each other and in the procedures and outcomes was exhibited when members of the team (especially non-core), endorsed the outcomes, which resulted in the initiation of different KT activities by the team members. A team scientific publication also demonstrated buy-in overtime of the project outcomes by the entire team at the end of the project.

5.6 DEVELOPING SHARED OWNERSHIP

"*You feel a responsibility, that you are contributing, and part of the scene*"

	Themes	Definition
1	**Building relationships**	Building collegial and personal alliance and bonds between team members
2	**Advancing individual growth**	Advancing individuals' new academic skills, knowledge, capacity, and competency in aspects of the DoMiNO project
3	**Building team capacity**	Building of collective knowledge, competency, ability to jointly perform and contribute to the common goals
4	**Maintaining alignment**	Achieving and maintaining collective consensus and individual orientation of the project progress, project specific knowledge, and expectations
5	**Establishing trust**	Establishing confidence among team members and in project procedures and outcomes
6	**Developing shared ownership**	Developing a sense of individual and shared ownership and responsibility
7	**Operative elements**	Elements which facilitate rapport engagement, reflection, learning and inclusion (Communication channels, Learning environment, Inclusive environment, Leadership style)
8	**Individual attitudes**	Individual position, will and ability to act as contributing team members (Commitment, Engagement in dialogue, Open mind)

The progression towards outcomes and KT also meant the need for the development of individual and *shared ownership*. In the context of the DoMiNO project, the concept of developing ownership refers to fulfilling a role or task, conducting own part, or taking part in the collective work, and ongoing joint activities. It is about team members' individual contributions overtime to the joint effort and the sense of partnership, belonging, and responsibility of the collective effort. I used the logbook and minutes to capture how ownership manifested in DoMiNO. Members showed willingness and commitment to contribute with ideas, specific tasks, supervision of students, data sharing, and consultations as needed. They took part in joint discovery and reflection, recognized their own part, took pride in the joint work, initiated, and promoted the project and its outcomes (*i.e.,* KT activities).

To further demonstrate what ownership meant in this context one team member explained how ownership could be conceptually described:

> *I think ownership can be viewed in many different ways. Ownership could be you manage… Ownership could be that you feel engaged and that you feel that there is an ongoing relationship, and if you are engaged it could mean you feel a responsibility that you are contributing. Ownership could mean that you are part of generating ideas, or that you are part of the scene, of critiquing the process.* (P2, FFG)

Some articulated in the final focus group that ownership did not mean individual ownership, but rather joint ownership, or shared roles where individuals contributed input or guidance:

> *I never really saw my role was to take a certain piece of this and claim responsibility. So, I… try and be a resource, and try to help, and to provide guidance, and to run input. There could be some ownership in terms of helping with training of students, providing input on some types of analysis. As I look at my contribution to all aspects of this project it is really a shared role for a lot of it.* (P4, FFG)

Many of the team members acknowledged the development of a sense of joint or shared ownership as contributions that supported *performance* and *productivity*. They noted that the project belonged to everyone and that taking ownership was necessary in order to make progress in the project, as described by one of the team members "*I think that we are all in this together… if somebody is not taking ownership, things do not move, or progress*" (P7, FFG).

The sense of ownership was consistent for some (*e.g.,* core members) or fluctuating for others, resulting in different levels of individual and joint involvement in the research and KT activities at different times. An example of how these different levels of engagement and responsibility can impact the level of ownership was evident by a comparison between the core and non-core members' sense of ownership. Members of the team described this difference before the project began as a potential challenge for research collaboration: while the project was the primary practice for the core members it was remote for others, which may impact the sense of ownership:

> *I guess often what happens with a project like this, is that there is a core group that is doing most of the technical work and interpretation, and writing manuscripts and that sort of thing… and then others who aren't necessarily involved on a day-to-day basis may—may not feel like they have as much ownership in the project.* (P11, baseline interviews)

Ownership levels were different for different people, depending on role, geographic location, specialty, and expectations, and it occurred at different phases of the project. One of the team members explained that in this kind of a research project, not everyone needs to be involved all the time, but members need to be sufficiently engaged so that they can contribute to the project. They also explained that similarly to a coordinated dance as mentioned previously (under building team capacity), different phases of the project required different levels of engagement and ownership:

> *Because in a big project like this, you do not need everybody to be engaged all the time. It should not be a good use of resources, but you need them to be sufficiently engaged that they feel ownership of their piece, or that they can contribute their piece...I think because of transitions* [in the project] *ownership changed throughout, and it seemed to me right from the beginning, we had these three phases… and during some of the phases there might have been less buy-in, ownership, involvement or engagement by different team members.* (P2, FFG)

It was recognized by the members that although there were distinctions in the level of contributions by different members of the team, ownership, and contribution developed in unexpected ways and times:

> *Some members were making major contributions* [students] *and some in parallel trying to contribute. Some projects were* [pre] *defined and some grew out of it, like the project I lead now- it was not planned, it has organically grew out, this was a satisfaction for me as part of the team, because I was able to contribute to the knowledge equation of things.* (P17, FFG)

Ownership was also determined by the clarity of roles for some team members in the project. Participants interviewed in this study suggested that unclarity about roles might impact the sense

of ownership and the level of individual engagement, commitment, and contribution to the DoMiNO project, and its activities. The issue of identifying a specific role and the need for role clarification was raised several times during the project by members of the team. One member explained this connection between ownership and role allocation. This team member perceived that ownership could be achieved once the project matched members' own perceptions of fulfilling the assigned roles: "*Ownership is only satisfactory when my perception of ownership matches what the project perceives is the assignment that I have, a role I am actually fulfilling, then I would feel ownership*" (P2, FFG).

Some members indicated that ownership was developed in the early stages of the project while being involved in writing the proposal: "*I was involved, before the project started, in writing the grant and facilitating the submission of the grant, and worked with* [the PIs]*, before it all started, and we had a lot of interaction. So, I was feeling 'in' from day one*" (P7, FFG).

For others, the sense of ownership progressed over time; for example, understanding what part you play, and your contribution, which may not have been clear at the beginning became clearer as the project progressed, as discussed earlier when referring to the alignment of expectations of roles. Development of a sense of ownership articulated over time, to a point in which team members felt they jointly own knowledge and could present it as their own, as was described by another member:

> *I did not, for a lot of the time, feel like I know this* [project] *so well, that I could go out and present it confidently, as I would with my own work. So that feeling, of finally getting to the point where we could all present <u>our</u> collective work, and <u>collectively own</u> knowledge… is developing a sense of ownership or collective ownership.* (P6, FFG)

The evolution of ownership was also observed in the way knowledge users (KU) saw their roles. For some of the initially identified knowledge users in the team, the realization and clarification of what their roles would be, progressed over time. While in the beginning, knowledge users noted a lack of clarity about their role; it became clearer as the project progressed:

> *This project… it is a really different animal because the KT… its internal, it is cross-disciplinary, it is not like the classic: let's get it out to patients or practitioners. It is hypothesis generation, to inform future discovery and future research, so it is a little bit different… and I found that really mind-boggling because it really stretched me in terms of what my role could possibly be on the team… it was not clear to me at the beginning… but* [became clearer]. (knowledge user, FG)

Knowledge users acknowledged that defining the role of a knowledge user needs to evolve. Thus, the progression of the project supported clarification of their role and resulted in articulation of applicable KT for the project. One example is the identification of potential audiences and users: "*It was not clear to me* [how to use the findings] *until I saw the combinations… I can now think of five more knowledge users, as it becomes clearer*" (Knowledge user, Insights).

By the end of the project, knowledge users' roles materialized. They described this role to include steering of the project, the development of possible implications of the project and the consequent KT, and the planning and application of KT activities:

> *Over time, I felt* [I contributed] *more, partly because towards the end of the project I had more actual work to do. We began to organize sessions. So, then I started actually feeling helpful. In the research and analysis, I did not have a role really, except of asking questions from time to time, and help the group think through the implications of the research for either other researchers or the general society.* (Knowledge user, FFG)

The sense of ownership in this project meant that everyone had a shared responsibility and equal opportunity to participate, unlike projects where few do the work, and everyone gets the credit. In this project, they felt there was a true partnership, as explained by one team member:

> *The things that resonated for me are… making… sure that everybody is actually engaged in the work, because the other end of the spectrum is a research team where the principle investigator, few trainees, and a few people very close to the center, do the work and then everyone else get their name on the publication that isn't actually theirs. But in the end, this project specifically, because there was such diverse expertise and sort of equally weighted environment… there really was a partnership all the way from the top PIs, all the way down through all the trainees and so forth.* (P6, FFG)

For some, ownership and responsibility lasted even beyond the time course of the project or their official obligation. For example, students continued to be involved in the project after they graduated, and after the project related funding period ended, in order to complete the research needed (*i.e.,* conducted additional analysis and engaged in end-of-project KT activities). One student described how they did not want to leave the project half-way; they felt responsible and wanted to take part all the way to the end of the project, and therefore, stayed engaged even after their official commitment ended:

> *I graduated and worked for the project for the next six months. That was motivated by the fact that we had the workshops and other deadlines… I liked the work we have done. I wanted to see the end of it, so, pushed towards that final goal.* (Student, FFG)

At the end of the project, members continued to be involved and initiated or supported KT activities. In the FFG, members acknowledged how this involvement of members with KT activities implied that a sense of ownership was developed: "… [members helped] *bring it* [the project findings] *to the government people… to me that was a good sign for ownership*" (FFG). They also described a sense of pride, *e.g.,* being part of the project and contributing to the end products. As one of the principle investigators described the reaction of team members to the joint publication of the DoMiNO project findings: "*When we had this paper accepted, they were so*

proud to be part of this group that got this paper out. So, they feel ownership… They gave something to the problem" (PIs, FFG).

Development of shared ownership was a vital component of the collaborative process. It resulted in performance and progression of the project and KT during and at the end of the project.

To summarize, so far, team growth was built on themes represented by dynamic processes, as I presented above, which were *building relationship, advancing individual growth, building team capacity, maintaining alignment, establishing trust,* and *developing shared ownership*. The following two themes were identified as those enabling the conditions for the evolution of the collaborative process and the collaborative environment: *operative elements* and *individual attitudes*.

5.7 OPERATIVE ELEMENTS

"*Sustaining the project momentum*"

	Themes	Definition
1	**Building relationships**	Building collegial and personal alliance and bonds between team members
2	**Advancing individual growth**	Advancing individuals' new academic skills, knowledge, capacity, and competency in aspects of the DoMiNO project
3	**Building team capacity**	Building of collective knowledge, competency, ability to jointly perform and contribute to the common goals
4	**Maintaining alignment**	Achieving and maintaining collective consensus and individual orientation of the project progress, project specific knowledge, and expectations
5	**Establishing trust**	Establishing confidence among team members and in project procedures and outcomes
6	**Developing shared ownership**	Developing a sense of individual and shared ownership and responsibility
7	**Operative elements**	Elements which facilitate rapport engagement, reflection, Learning, and inclusion (Communication channels, Learning environment, Inclusive environment, Leadership style)
8	**Individual attitudes**	Individual position, will and ability to act as contributing team members (Commitment, Engagement in dialogue, Open mind)

Operative elements supported the creation of a collaborative climate that enabled rapport, engagement, learning, reflection, and inclusion. *Elements* refer to a part, or aspect, of something abstract, especially one that is essential or characteristic of the project operation. These elements were under the mandate, control, ability, and will of management to initiate, facilitate, and apply. The operative elements were of distinct types and are considered as subthemes, which include: *1) maintaining communication channels; 2) supporting a learning environment; 3) sustaining an inclusive setting; 4) embracing an attentive leadership style*. Team members suggested, as described below, that the operative elements were significant in supporting the creation of a collaborative process. They set the stage and tone for collaborative work, as was described by one of the team members: "*bringing together people, and setting the stage and the tone, with the meetings at the very beginning was a good thing, and that helped set the tone for the collaborative work*" (P4, FFG).

These elements were initially being driven by design, as presented in the collaborative framework of the proposal. However, as the project progressed, informed by evaluation and measures to attain those were adjusted according to the team's input, dynamics, and needs.

5.7.1 MAINTAINING COMMUNICATION CHANNELS

"*Setting the Stage*"

Maintaining communication channels refers to the facilitation of different means for team members to communicate with each other, to enable rapport, engagement, learning, and reflection. As was discussed by team members, these channels included meetings in person (*e.g.,* full team face-to-face meetings, small meetings); through teleconferences, email updates, newsletters,

project's website, webinars, and by informal engagements, such as unstructured social engagements.

The project initially proposed several channels of communication: Four face-to-face meetings, email updates, different evaluation and reflection activities, and teleconferences. Over time, communication channels used for the DoMiNO project were extended, refined, and adjusted according to the team's needs and suggestions, as was identified in evaluations (*e.g.,* meetings evaluation forms), reflections, and discussions (*e.g.,* collaborative exercise, insights) throughout the project. Additions to the initial communication channels included: online participation in all face-to-face meetings, online webinars, website serving as a repository (including online shared accounts, *e.g.,* virtual clouds to store and share project documents), small meetings in person or as teleconferences, newsletters, extension of opportunities for evaluation and reflection (*e.g.,* focus groups), and informal engagements. These communication channels were illustrated in **Figure 4.2** in **Chapter 4.**

Team members acknowledged that the different channels of communication were imperative for sustaining the ongoing partnership throughout the research project. Preferred communication management strategies to keep the team engaged were suggested in order to check in with team members and for ongoing communication of updates to keep rapport and support research progression.

Notably, members of the team appreciated the opportunities the annual face-to-face meetings offered. Project logs indicate high attendance in all four full team annual meetings. As acknowledged by team members, the meetings were an essential mechanism for building the team: "*Make sure you have regular face-to-face meetings because it really helps to build a team*" (P1,

Insights). They indicated that investing the time and resources in team meetings was necessary in order to reach ideal performance:

> *…investing resources and time in face-to-face meetings, not every project allows the time to build relationships and learning. It takes time to develop relationships and 2-3 meetings to get to optimal team performance. From other experiences- do not always invest the time… worth investing!* (P6, Insights)

These face-to-face meetings were pivotal jumping stones for the research process. Members articulated that face-to-face meetings were important for productivity. This was achieved by reaching mutual understanding and integration of ideas, among other things. Moreover, having annual face-to-face meetings was a key take away from the DoMiNO project experience for future collaborations:

> *…definitely do these in-person workshops. That really had a large component that was demonstrating the different approaches. I think that, at least for this project, that was really key for trying to get everyone to a common understanding, and a common language before we could move forward, and trying to integrate and create something new. And, that did take a couple of iterations, in terms of 'let's run through that tool again', presentations on air pollution exposure assessment, and in time that felt a little bit slow, but it was definitely needed to get everyone on an even starting point.* (P14, FFG)

Additionally, evaluation forms from all the face-to-face team meetings indicate that the team members were pleased with the small discussion groups included, as well as full team discussions. They appreciated the learning opportunity, and the opportunity to hear all voices in the different meeting formats, and valued the progress made in the meetings. Meeting evaluations illuminate the significance of these face-to-face meetings as team members noted that the meetings was an: "*excellent opportunity for interacting with each other*", for "*Building relationships*", "*Learning*", "*Sharing progress and results*", "*Discussion*", and that the meeting promoted "*Interdisciplinary brainstorming and progressing the project*" (Different evaluation forms).

The significance of the small meetings was also mentioned. 'Small meetings' refers to a smaller group of members from the same discipline or different disciplines meeting to discuss a specific aspect of the project at any time of the project, in contrast to the entire team meeting. While in the full team meetings, members may have felt lost, small group discussions, within those face-to-face meetings or outside of those, provided an opportunity for members to have a voice and feel they contribute in a more meaningful way to the project, as one member described:

> *I think sometimes being in a large group… at the beginning; I found it a little hard to understand where I could fit in…. I felt like when we had our individual small groups sessions, like we did with* [one of the team members] *on the adverse birth outcomes, that's where I had a better idea of my role and, where I could contribute - in a small group setting.* (P8, FG)

Team members indicated the importance of other channels of communications had on staying (*e.g.,* webinars, email updates) updated and being able to connect which enabled rapport and learning:

> *P2: The web connectivity was nice… I look forward to the emails. When I get an email, I open it eagerly wanting to know what are the next pieces… I like the email updates!*
>
> *P6: I was going to say that too… those proactive email updates, unlike having some website where on some spare moment I am actually going to go there, (yes, in background) that spare moment never really happens (yes, in background)… when something comes to me on email and* [it] *is saying: here is what's happening, then I will read it... so, taking the time to do those team updates that's really helpful. The more the better!* (FG)

As part of the integrated KT framework, there were also different opportunities designed to enable communication via reflections on the collaborative process and the research process through dedicated sessions (*e.g.,* focus groups, evaluation forms), as well as through other sessions, like the follow-up calls, teleconferences, small meetings, and surveys. The evaluation process and spontaneous reflection (*i.e.,* not structured), which occurred throughout the research project,

informed management, and helped to respond and adapt for the next steps of the collaborative process according to the team's needs. As described by a team member: *"…it was very beneficial to have this analysis* [the IKT evaluation] *running alongside everything else and reflecting on what worked and what not*" (P25, FFG). Another member denoted that the reflective practice as part of the IKT framework had a significant impact on the maturation and productivity of the team: "*I feel, because we have the IKT, because we have been asked to talk about it: what we feel about it, the challenges, expectations, etc., it helped us in the process of becoming a team and influenced the products*" (P10, Minutes Meeting 4).

5.7.2 SUPPORTING A LEARNING ENVIRONMENT

"*Getting those hard concepts engrained*"

Supporting a learning environment refers to elements that supported learning, which was an essential aspect for the project progression. Learning was identified by the team, early on, as a vital aspect of the DoMiNO research process, because of the project's interdisciplinary and exploratory nature. Learning was imperative so the team could "*hone down our process of thinking towards a common goal*" (P7, FFG). Members identified that it was about learning from each other and about each other's background, methods, processes, and approaches relevant to the research project, as well as learning from the project outcomes, as was described in the baseline interviews. Furthermore, learning contributed to both individual and team capacity, as demonstrated above.

There were different channels of communication to support the learning process throughout the project (*e.g.,* webinars, workshops, presentations). However, it was also essential to create a learning environment, in which members could share and learn from each other. The learning environment needed to enable learning in a manner that all could follow. One member specifically noted the importance of having a good learning environment for all team members: "*The talks*

were targeted to all levels of team members, so that was great; everyone was very collaborative and encouraging about asking questions" (Anonymous, evaluation form 3). The learning environment was also vital because it supported a comfortable and safe place to ask questions: "*I feel… comfortable with the people so don't mind asking questions or expose naivety*" (P20, Insights).

Repetition of concepts and backgrounds was another essential element identified to support learning. This practice helped ingrain the different concepts and was helpful for understanding complex and new information, such as data mining. It resulted in building both individual and team capacities, as members were able to learn to a level that facilitated team discussion and progression. This aspect was described by members of the team in the focus group (FG) at the end of the project:

> *P3: I would say that the repetition of not just results, but the repetition of language and methods, helped cement, specifically the hard concepts. Specifically, the first few times. For the first few years, the data mining procedures were repeated, and that was repeated, and that was repeated a couple of times, and we saw those presentations a couple of times, then it would become more complex and, then we could start seeing* [where] *it headed, and how we would be using it with the data, so that repetition helped get those hard concepts ingrained to start thinking of this novel method.*
>
> *P6: … and I join you at that, I was always so grateful when* [the PIs] *would start from the beginning and… because it has been a year since we heard it… (Agreement in the background) for those who come from a far, and are not here on-site more actively involved, I really appreciated the repetition and the building of the knowledge.*
>
> (FG)

Other ways of facilitating a learning environment were by supporting team members to get familiarized with backgrounds, vocabularies, and terms that were specific to different disciplines and could be used differently in each discipline. In earlier stages of the project, on a few occasions,

the issue and challenge of terms and definitions for DoMiNO were raised by the team. Vocabularies were a source of misunderstanding among team members in different stages of the project. Over-time, there was a feeling that common ground was built. As was mentioned in the third meeting, regarding the challenge of interdisciplinary practice: "*different vocabularies for often the same things, I am more familiar, but it is still challenging*" (P14, insights). As the logbook indicates, different efforts were made to address misunderstandings: *e.g.,* explaining discipline-specific terms in every meeting and preparing background material that included discipline-specific explanations of terms, methods, and data of the different terms used by different disciplines (as described in **Chapter 4**).

5.7.3 SUSTAINING AN INCLUSIVE SETTING

"*Your voice matters*"

Sustaining an Inclusive Setting refers to elements that enabled the inclusion of all team members. For example, this meant that resources were allocated for travel and accommodation in order to include remote team members in all full team meetings. One member shared reflections form their previous experience, suggesting that it would be a good practice to support the participation of members and that this could contribute to progression and performance: *"*[when] *everyone had an opportunity to attend all of the meetings and partake in all of the discussion, I found that to be a lot more rewarding, and we were able to move the project forward in a timely fashion"* (P20, baseline interviews). The logbook records indicate that resources were invested in enabling all members to take part in the project activities.

Another element was the enablement of remote participation in face-to-face meetings or webinars from anywhere. Members who joined remotely appreciated the opportunity to take part in those meetings, as was described by different team members:

> *When I was* [outside of North America]*... being able to listen, even if I could not be involved… be able to watch the slides and see presentations that was very helpful.* (P2, FG)

> *The remote connection was just fine. The audio was clear. And for the times when my microphone did not work, the chat box for comments/questions was just fine. A very fine option for those outside of [the project site] to consider – that's for sure, and yet, to still feel involved and part of the meeting just as much as being there.* (Anonymous, Evaluation form 3)

An inclusive environment was created, as was noted by different team members and demonstrated in the following examples from face-to-face meetings evaluation forms and the FFG: *"…never been involved in such a variety of researchers and expertise… felt comfortable and welcome*" (P8, Minutes Meeting 1 follow up calls). Members also indicated the annual face-to-face meetings were useful for: "*Hearing from every participant*", "*comfortable for everyone to participate*" (Anonymous, evaluation forms 2,3), and that "*everybody's perspective was valuable*" (P11, FFG).

One member explained that inclusion also meant respect to each other's discipline, different points of view and each other's goals, as part of the general objective, and also recognizing that everyone's contributions were essential:

> *…we respect the goals of the others and we know that they all feed into this main goal that is common to everybody, even though we have our own goals….respect is also important because everybody felt important in the team… nobody is just in the corner, we are all as important as anybody else, and that helps the synergy of the team.* (P12, FFG)

After the project ended another observation about a key to success of the collaborative process was having the patience and determination to include, engage, and care for all team members and their growth as a significant part of collaborative research culture:

> *It is pretty obvious to me that we had super competent people… I think really… it is probably quicker and easier sometimes to just do the stuff yourself and then call it a team, and it's not really a team, right? So, having the patience and determination to really make sure that people are engaged, and that a lot of people are developing through the course of the project was that sort of take away from me.* (P6, FFG)

5.7.4 Embracing an attentive leadership Style

"Setting the Tone"

Team members identified that *embracing an attentive leadership style* was a central contributing factor to supporting the collaborative process and team growth. Leadership refers essentially to the two principal investigators (PIs) of the DoMiNO project, who were responsible for the managerial and research aspects. Team members acknowledged that their leadership style was vital to the project's success by setting the tone for collaborative work from the start, and keeping the momentum and the team together, as described in the following quotes:

> *The leadership styles of* [the PIs] *are really key to starting things off in the right manner and with the right tone, and continuing through some of the technical challenges and challenges related to the multidisciplinary aspect of the project.* (P11, FFG)

> *The leadership style is really important and was quite exemplary. I thought that was part of the magic of fire the project sustained with such momentum.* (P6, FFG)

Analysis of the data suggests that embracing this attentive leadership style was the factor that enabled the other operative elements, such as ensuring channels of communication for rapport,

engagement, and reflection, supporting a learning environment, and ensuring ongoing inclusiveness described above.

The leadership style was thoughtful to ensure that *communication* between the team members was available for everybody's needs and was continuous. This could be exemplified by the detailed planning of each of the annual meetings to ensure learning, rapport, engagement, and inclusion, as well as the ongoing management of the project, which allocated time and resources for the different continuous communications (from the logbook). As team members describe, communication among members was essential. Leadership ensured good communications in a challenging, large interdisciplinary and dispersed group: "*I think leadership was a real key… to keeping this going... without that leadership, it would be very easy for such a large interdisciplinary group to kind of break along the lines, or maybe not communicate as well*" (P19, FFG).

The Leadership style ensured a supportive *learning environment* by providing the means of learning and setting the tone with patience to enable the learning that needed to occur. As described by team members: "*they did a good job teaching us*". Leadership worked on building bridges between the different disciplines, either by teaching (repetition) or by being role models and encouraging others to be open-minded and practice interdisciplinarity. Additionally, the PIs supported advancement of individual's capacity and knowledge growth.

> [The PIs] *were able to set the tone and be patient when we ask the same questions over again and again… it was the patience to… repeatedly explain what the data mining is doing, especially at the start, for the first two years, a kind of summary of the different processes.* (P3, FFG)

Leadership made sure *inclusion* was happening on a technical level but also established inclusion as a team culture, in which everyone had the opportunity to engage and their perspective considered. One of the PIs described this as one of their strategies: "*I think in our advantage is that we knew to call them [team members] to participate, and that was part of keeping them engaged*" (PIs, FFG). Members indicated that leadership inspired an inclusive work culture based on respect in which everyone's perspective mattered as one member describes, *"the leaders were… encouraging respect between people and encouraging people to listen*" (P19, FFG). Members also noted that leadership emphasized that this research project was the team's project versus someone's own (our project vs. mine), which led to a sense of true partnership as several members described:

> *It was really* [the PIs] *who set the tone… approaching this with a sort of humility. This was an exploratory project, we didn't really know where it was going to go, but everybody's perspective was valuable.* (P11, FFG)

> *The leaders were very generous and very sincere in wanting this to be a team effort and wanting to spread the resources out to encourage people to bring trainees in from different disciplines… when you were in the group you felt like we were all part of this together and even deciding upon how we would support people, and doing things like that, I felt like it really made it a good team effort. So, I was very appreciative of that.* (P19, FFG)

The attentive style of the leadership set the tone and stage for collaborative practice. The leadership also set the tone by their personal attributes such as being a role model for interdisciplinary and collaborative practice exhibiting an open mind approach. The PIs inspired the team to conduct joint discovery research by continuously providing support and motivators to the team members, such as the promotion and encouragement of interdisciplinary practice, support and feedback on an interpersonal level, and supporting members' individual growth. Several team

members discussed these leadership attributes during Meeting 4 and in the focus group (FG): "*encouraging and trying to get us to explore outside our traditional thought*", "*interdisciplinary in thought*", "*very good appreciation for the policy dimension and the big picture of things*", "*could very fluently engage with any person on the team*", "*is open to suggestions, kept an open mind*" (Different members, FG). These perceptions were further articulated in the final focus group a year after the project ended. One member noted how determination drove the project and the collaborative work: "*I saw the PIs leadership,* [the] *tenacity- the project got done… and* [how] *many people contributed*" (P3, FFG). Others described a feeling of warmth, generosity, informality, and encouragement to support interdisciplinary work culture:

> *I felt like there was a lot of warmth from the leadership… there was a real welcoming attitude that I felt from the leadership, and a real attempt to make you feel personally welcome that I felt very good about… I've been inside of competently led groups before, but I thought this was a particularly nicely led group because of the personal characteristics of the folks involved, but also because of, I think a real generous attitude.* (P19, FFG)

> [The PIs] *were sort of the perfect leaders for this project… they bring people together. They want people to be very open. So, I think they did a really good job of just making sure that everyone could bring their own ideas, and that everyone was sort of open to new ideas. Because you really needed that with a project that was this interdisciplinary, and they had enough knowledge to be able to try to pull them* [the different disciplines] *together as well.* (P14, FFG)

To summarize, operative elements were identified to contribute to the shaping and creation of a collaborative climate for IKT by enabling communication and rapport among team members, learning, engagement, reflection, and inclusion, which contributed to the project performance and outcomes, as illustrated in **Figure 5.2**.

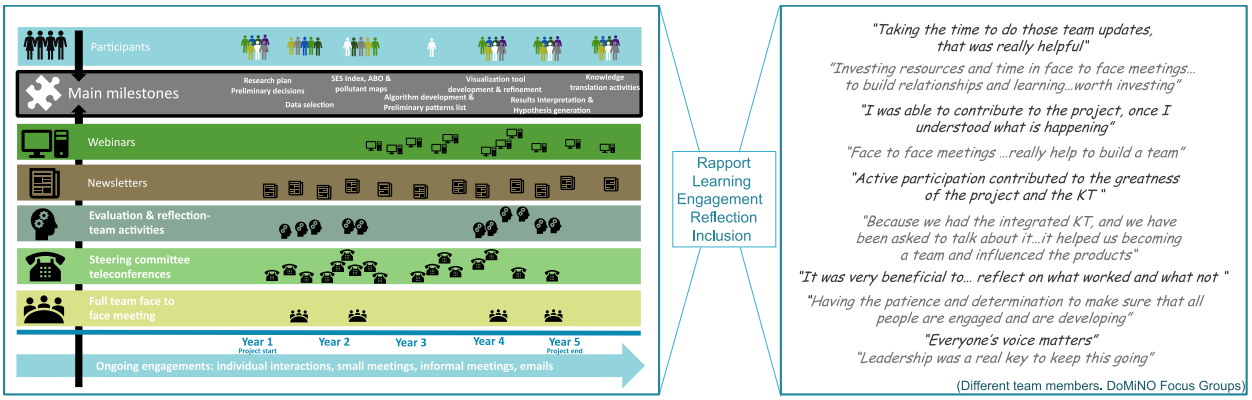

Figure 5.2: The contribution of DoMiNO's different activities to rapport, learning, engagement, and inclusion. DoMiNO's different activities, participants, and milestones, over five years of operation, which supported rapport, leaning, engagement, and inclusion, as reflected in members' quotes, helped shape the collaborative process for IKT.

5.8 INDIVIDUAL ATTITUDES

"*It is me - I needed to step forward; it is not the project that needs to come to me*"

	Themes	Definition
1	**Building relationships**	Building collegial and personal alliance and bonds between team members
2	**Advancing individual growth**	Advancing individuals' new academic skills, knowledge, capacity, and competency in aspects of the DoMiNO project
3	**Building team capacity**	Building of collective knowledge, competency, ability to jointly perform and contribute to the common goals
4	**Maintaining alignment**	Achieving and maintaining collective consensus and individual orientation of the project progress, project specific knowledge, and expectations
5	**Establishing trust**	Establishing confidence among team members and in project procedures and outcomes
6	**Developing shared ownership**	Developing a sense of individual and shared ownership and responsibility
7	**Operative elements**	Elements which facilitate rapport engagement, reflection, Learning, and inclusion (Communication channels, Learning environment, Inclusive environment, Leadership style)
8	**Individual attitudes**	Individual position, will and ability to act as contributing team members (Commitment, Engagement in dialogue, Open mind)

The operative elements described in the previous section helped set the stage throughout the project. However, *individual attitudes* were required for those operative elements to be utilized and to optimize the collaborative process. The component *Individual attitudes* refers to an individual's settled way of thinking or feeling about something that impacts a person's behavior. Individual attitudes are under the individual's control, will, and ability to apply and, in a way, define what 'being a team member' means, in any role (*e.g.,* PI, student, co-investigator, knowledge user).

Team members noted that the involvement in the project and the responsibility for being engaged and contribute originates from the team member's attitudes: "*It is me, I needed to step forward, it is not the project that needs to come to me*" (P17, FFG). They also explained that it was crucial that everyone is involved and taking an active part in the research process: "*In these collaborations, to keep enough of the momentum, and involvement… everybody is actually realizing they have a role to play, and need to step up and throw in their ideas or pull some of the weight*" (P6, baseline interviews)

The individual attitudes theme includes the following subthemes: 1) *commitment of time and attention; 2) engaging in dialogue and reflection;* and*, 3) keeping an open mind towards other epistemologies.*

5.8.1 COMMITMENT OF TIME AND ATTENTION

"*Devoting uninterrupted time both physically and emotionally*"

Team members indicated the importance of the *commitment of time and attention* to the project and its activities, as part of the collaborative work culture. The team members' commitment to the project included participation in the project's activities, research, and KT, by contributing time, ideas, work, responsiveness, taking initiatives, and supporting others in the team. Different members described 'optimal' commitment in the baseline interviews, as "*I think the main suggestion that I would have, is to have an expectation that people commit to be able to attend the meetings on a regular basis…*" (P20, baseline interviews), and "*Being able to set aside stresses, worries, and concerns when we come into the project and come into it with a fresh mind and a fresh resolve, and being able to devote uninterrupted time both physically and emotionally*" (P10, baseline interviews).

Some examples of this commitment occurred during the face-to-face meetings. It was reflected by the high attendance and the engagement of all members in all activities of the two-day meetings. This was noted in the meeting evaluation, in which members were asked about what they liked about the meeting; one of the responses was: "*Commitment of participants during the meeting*" (Anonymous, Evaluation form 3). This notion of commitment during the meeting is further supported by my own observation during the last annual meeting:

> *Members contribute full attention and are all engaged in discussion… the discussion is very lively, and many participate or show active listening. I have not noticed distracted people, like working on laptops… During the meeting members were willing to take responsibilities and engage in all activities… and were willing to participate and take the lead in small group discussions.* (Observation, Meeting 4)

Further examples of willingness and commitment were the participation in the collaborative evaluation and voluntary reflection activities embedded in the project (baseline interviews, evaluation forms, FG, FFG), as well as in other activities, such as webinars and teleconferences,

and participation in specific tasks as needed or requested. All these activities had almost full participation of all team members.

As with all the other themes described previously, commitment manifested in different ways at different times for different people. For some, the enthusiasm in the project grew over time, changing the level of commitment of time and contribution, as was reflected by one team member: "*Building the project occurs because of the enthusiasm about the project topic. For me, it built over time. In the beginning, I did not know much on environment and adverse birth outcomes, learning more about it increased my enthusiasm*" (P17, FFG).

Members also discussed how commitment of time to the project was challenged by other professional commitments, which I further describe below.

By the end of the project, the PIs indicated in the last annual meeting, most of the team stayed engaged throughout the project (a few left because they changed position or graduated and one that 'faded' out). Members of the team also commented that the commitment of the team throughout the project went beyond expectations:

> *I think that at the end, the commitment of all of the team members was very, very high. The commitment, I think, went beyond expectations, because I worked previously in very large teams, and it's very easy to lose some things... this project was very long, with a large number of participants… and the way the leadership, and all the team worked close together... I feel it was very good. To me, it was beyond expectations.* (P9, FFG)

5.8.2 ENGAGING IN DIALOGUE

"*Exchanging ideas, or bouncing things of each other*"

Engagement in dialogue meant active two-way communication between team members to support dialogue, feedback, and reflection. Team members identified the significance of giving and receiving input or opinions as part of the collaborative practice. As noted, at the beginning

of the project, feedback and two-way interaction should be part of the work culture to jointly progress the different aspects of the project, as was expressed by team members:

> *People should be able to draw on the members of the team when they are looking for help, or looking to exchange ideas, or bounce things off each other.* (P21, baseline interviews)

> *The most important thing is just to ensure that information is shared on a regular basis and, sort of in an active way… so, the idea of having regular teleconferences and meetings should help to get around sort of just inseminating information electronically… and make sure that people continue to be actively engaged in the project.* (P11, baseline interviews)

As the project advanced, team members acknowledged that feedback was a critical factor for progression: *"…Were there enough meetings for you guys* [the core] *to get enough feedback, and enough time to work with what you have been given?*" (P3, FG). The following quote demonstrates how feedback supported progress for the development of the data mining tool: "*I think the workshops and feedback really helped... the meetings and webinars we have conducted helped us improve the software over time*" (P5, FFG). As indicated later by one of the PIs, the feedback was necessary: "*I really appreciate the session* [workshop], *I heard different comments for improving. I am very excited about this. This has been a success!*" (PIs, Minutes Meeting 3).

At the end of the project, one of the team members reflected that the input from the team was available when needed: "*I think the research team was very supportive over time; when we had problems, and we had to discuss something more specific, they were always there*" (P9, FFG).

The importance of feedback was described as a motivator for improvement and required an open mind to accept the feedback and address this input in future work:

> ... [it is important to] *be flexible and keep an open mind. I got a lot of feedback, so I* [apply the analysis] *this way, because I showed it to someone, and he had a lot of different ideas: 'we should try this, we should try that, this is wrong, I don't understand this'... so, I try to improve upon the feedback, try to get feedback and improve again.* (P5, FG)

As the project progressed, members noted that the project's environment was encouraging and motivating to contribute, as described by a member who joined the project midway "*it was my first workshop… the team dynamics were in place, so it was clear to me at that point... it was an open and welcoming group, interested, and engaged, so I was motivated to work*" (P25, FFG).

Another aspect of active engagement was willing to reflect and participate in a meaningful manner in the reflective process. As part of the research framework, team members were asked to participate in reflection on the collaborative process and research progress at different opportunities formal or informal. They included reflections on different parts of the collaborative process (*e.g.,* the strengths and challenges, areas to improve). Most of the reflective activities were voluntary, and DoMiNO members choose to participate, demonstrating willingness to take part in that. Reflections informed the project leadership and management and enabled adjustment according to needs. At the end of the project, the FG facilitator described the team members' participation and engagement in the reflection process "*this group acted like a team; participants felt comfortable with each other, they were immersed in the context and able to reflect*" (FG Debrief).

5.8.3 KEEPING AN OPEN MIND TOWARDS OTHER EPISTEMOLOGIES

"*Going beyond our own domains*"

Keeping an open mind towards other epistemologies refers to the willingness and ability to learn, accept, and practice different ways of thinking as well as different ways of conducting and approaching research - going beyond one's limits. It requires the ability to balance perspectives, being flexible in one's own thinking, and having an appreciation of other's work. Team members described their previous experiences of being open-minded. They described attitudes towards different parts of the project and the ability to communicate and accept comments from others, as

noted by one of the team members: "*I think that it is important to have a good attitude about the project and be open… to communicate with everyone… we have to be open-minded, to accept any kind of comment from anyone"* (P9, baseline interviews). Being open-minded also referred to the willingness to think beyond one's own discipline (comfort zone) and accept other views:

> *If you are willing to do that, get out of your discipline, then you have to be open-minded, then it doesn't work if people feel that their view is the only view, and they would pretty much stick with their own group… everyone involved need to have patience and understand the different perspectives* (P16, baseline interviews)

Members also described their own experience and perception of what the opposite of being open-minded would look like when people are not engaging or accepting other expertise:

> *Part of the problem is when you get people who think they know more about disciplines that aren't their own than the experts in the area… it can get to a situation where people don't recognize each other's expertise and the consequence of that is that they will make decisions or judgments by thinking on their own approaches of their own field rather than actually trying to engage and take on board the expertise of other people. Particularly when you are dealing with large egos.* (P21, baseline interviews)

These were the team perceptions of what being open-minded was or was not before the project began. As the project progressed, it was acknowledged that integrating established discipline epistemologies and accommodating other methods might be challenging. This was observed in one of the team meetings: "*The* [small] *teams work together, but it is mostly a group of people trained to think in a certain way, who need more direction in other ways to think*" (Observer 2, Meeting 3). During its operation, there were times when the issue of established discipline epistemologies challenged progression of the DoMiNO project as I further describe below.

In the FFG, members further described the issue of being open-minded and noted that it required compromises: "*Everybody was open-minded, everyone has that experience… knowing that you do have to make compromises on how to interpret, or how to work with the different analysis*" (P1, FFG). They also suggested how to address the issue of different ways of thinking and how to benefit from it by trying to use the best from the different perspectives:

> *The open-mindedness - it is like a 'big deal'. Computing sciences and statistics can have opposing views. There is no wrong in it, the idea is that you're open to accept an opposing view… we try to say 'okay, what are the advantages… and how can we utilize them to do the research'... trying to use the best of both worlds, that's one of the best outcomes of being open-minded.* (P5, FFG)

At the end of the project, some members of the team reflected that despite the challenges encountered, they managed to overcome them. This perception suggests that, like other themes described previously, being open minded was a dynamic and evolving process. It may have been awkward or uncomfortable at the beginning, but changed over time:

> *…open mind is an important point- have the capacity to go beyond our own limits, because we are in three different knowledge domains. Sometimes in the group, epidemiologists say, 'do it this way' and data mining is trying to solve it in 'that way'. So, at the beginning, maybe you feel uncomfortable with hearing different people who are trying to solve the problem in a different way. So, I think that we have to have an open mind, ability, and capacity to go beyond our own domain. It's important to build trust to move forward in this kind of interdisciplinary project. Eventually, I think we reached that point, I think the project was not only multidisciplinary but really interdisciplinary.* (P9, FFG)

To summarize, this chapter described eight themes and subthemes that were constructed through the thematic analysis. Each of the themes was represented by different dimensions and the manner by which they manifested in DoMiNO. The themes reveal essential *components* as those that are significant for the progression of the collaborative process. Thus, *components* refer to the

key parts of the project, which constitute the collaborative climate and process, and were identified as essential towards progression performance and productivity. As presented, the components evolved over the five years and were achieved at different time points for different team members. I use the conceptual underpinning of the themes to describe the components, as illustrated in **Figure 5.3**.

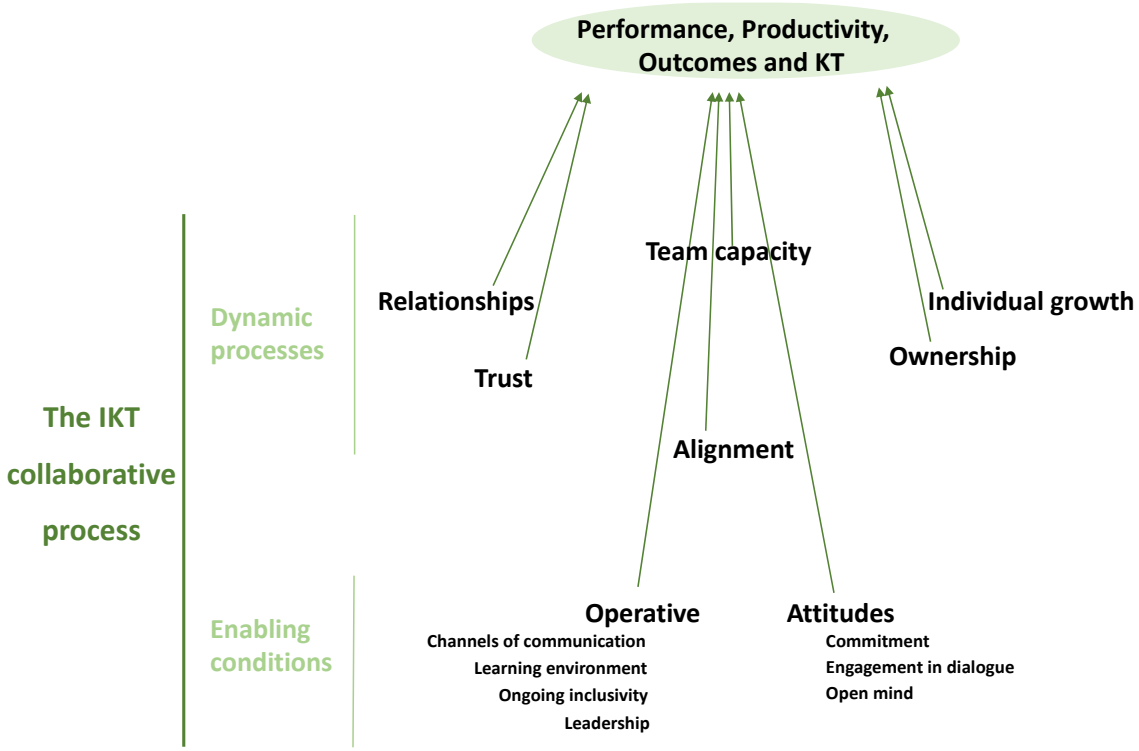

Figure 5.3: The components of the IKT collaborative process. The **i**dentified components contribute directly to performance, and productivity, outcomes and KT. Their conceptual underpinning denotes the components. They are divided into components representing dynamic processes (relationship, trust, alignment, team

capacity, individual growth, and ownership) and enabling conditions (operative and attitudes).

There were times over the years when these components were more challenging to attain. Additionally, although I describe each of the components as a separate dimension, there is much overlap among them. I further discuss these observations in the next chapter, as I continued exploring the components.

CHAPTER 6

FINDINGS (2): EXPANDING THE CONCEPTUALIZATION OF THE ESSENTIAL COMPONENTS OF THE IKT COLLABORATIVE RESEARCH PROCESS

In the previous chapter, I identified and described the different components as those responding to the question: what are the essential components that contribute to the team's collaborative progress and growth in IKT? The essential components of the collaborative process included the following *building relationships, advancing individual growth, building team capacity, maintaining alignment, establishing trust, developing shared ownership, operative elements,* and *individual attitudes*. I presented and provided definitions of the components and how they manifested throughout the project and contributed to performance, productivity, outcomes, and KT in the DoMiNO project. This was the first step in recognizing the components that were essential for the IKT collaborative process.

In this Chapter, I undertake another level of exploration of the components identified. The aim of this analysis is to further confirm the essence of the collaborative components to the IKT process, extend the articulation of the components, and explain how they developed, and what contributed to their evolution and maintenance. The analysis is done by shifting from descriptions to interpretations of the case and findings, theorizing and conceptualizing the components role by further exploring the components in different situations and times and in relation to one another.

This chapter includes four sections. In the first section, I revisit different settings and situations over time to explore the significance of the components identified and their role and effect on performance and productivity (*i.e.,* progression and delays) in those situations. The second section explores the evolution of the components independently and with each other by examining the relationships among them. In the third section, I examine how team members have perceived the collaborative process in retrospect. Section four concludes this findings chapter and situates the findings in a conceptual framework for the IKT collaborative process.

6.1 THE COMPONENTS IN DIFFERENT RESEARCH SETTINGS

This section explores how the components identified play out in the different research settings of the DoMiNO project. *Research settings* refer to three levels:

1) Context: the project's research focus and exploratory nature

2) Team: the interdisciplinary practice of the team

3) Individual: the team members' states.

I examine the role of the components previously identified in various situations and articulate their significance and impact on the collaborative process and outcomes. The analysis also contributes to the components' conceptualization: how and when were they attained (or not)? What was the impact of these settings on the components' evolution and the project's progression? Furthermore, the analysis provides insights into the implications of these research settings for IKT.

6.1.1 THE EXPLORATORY CONTEXT OF THE PROJECT AND THE COLLABORATIVE PROCESS

Environmental health research offers an opportunity to contribute to societal change and improve human health by enhancing our understanding of the impact of the environment on health. The DoMiNO project undertook an exploration of the relationship between adverse birth outcomes and emissions. As part of its discovery nature, DoMiNO used a novel method to explore mixtures of chemicals. As described by one of the team members, this research project was filling a significant knowledge gap by discovering combinations of chemicals with unknown impact:

> *We study certain chemicals to death, and then just kind of 'squeeze our eyes' and ignore the others, especially when it comes to combinations of chemicals. So, that is a big gap in our ability to grasp the environmental health implications of the chemicals that we use.* (P6, FG)

For the DoMiNO team, the research topic and interdisciplinary approach introduced an exciting and innovative project, in which members could apply their skills and contribute to research outcomes that respond to a societal need. These factors motivated team members to take part in this complex project from beginning to end. However, as described in detail in the introductions to **Chapters 2** and **4**, this is a complex and challenging research topic as a result of sophisticated interdisciplinary methods of inquiry, the exploration of multiple variables, data limitations, uncertainties, and context-sensitive outcomes (due to risk implications). Furthermore, these characteristics may have implications on the research process and the production of new knowledge and the consequent KT.

In DoMiNO, team members indicated that one of the challenges for innovation and discovery in this context was the limited availability of previous evidence. These aspects created difficulties for the finalization and endorsement of the research findings. Members explained that often, scientific findings are confirmed by comparison to other previous evidence. However, it was

difficult to make decisions and establish trust with regards to the project outcomes, because of the lack of previous evidence on the relationship between health outcomes and the chemicals explored, and especially chemical combinations. As described by one of the members:

> *Somebody raised the issue that we have to validate the results... It is like, how far can we go without validation. There is nothing to compare it to! When you see patients, and when you do clinical research, and when you do laboratory research, there is always something to build on, compare to. We did not have anything… We chose the chemicals that we know have certain health effects. But we know that, and we are not trying to prove those health effects occurred in this geographical area. That is a different study. We are trying to show combinations of chemicals, and therefore, this is completely new! Completely new!* (P10, FFG)

Members explained that some of the outcomes of this project included new hypotheses to direct future research on the environment and adverse birth outcomes, which were different from providing evidence to confirm or extend established health research. There was also a need for team members to align their own expectations of the project with the original aims of the project, which simply was to generate knowledge for hypotheses. For example, the project outcomes could not imply policy changes of chemical regulation, as some members had hoped at the beginning of the project. As indicated by one of the team members at the end of the project: "*as long as they* [the rest of the team] *understood that it is for hypotheses generation, I was at peace with it. I would not go and put a policy based on the data that would come out of this analysis."* (P18, FFG)

The novelty of the findings, on the one hand, and uncertainty, on the other, created a challenge for developing end-of-project KT plans for team members and knowledge users "*because it was so exploratory, making that link to the stakeholders was fairly challenging*" (P14, FFG). This also implied difficulties in the alignment of knowledge user roles (how could knowledge users contribute). As described by one of the KU:

> *The knowledge translation in this project… is a really different animal… it is not like the classic: 'let's get it out to patients or practitioners,' It is hypothesis generation to inform future discovery and future research. So, it is a little bit different, and I found that really mind-boggling because it really stretched me in terms of what my role* [as KU] *could possibly be on the team* (Knowledge user, FG)

Other considerations for knowledge users emerged from the need for KT planning to ensure that the findings will not be misinterpreted and create health alarms within and outside the team:

> *Thinking about how do we make this a value to researchers- because this wasn't sort of stuff off-the-shelf that an individual could make use of, and… there was some cautionary work around that, so that people wouldn't misinterpret what we were trying to generate: just the hypothesis generation nature of the work. So that was all pretty new* (Knowledge user, FFG)

Thus, the complex research context provided an exciting research opportunity that sustained the project and ongoing team engagement. However, the discovery nature of the project also contributed to a complex and challenging phase of the articulation of findings that impacted the project finalization and subsequent KT development. At these times, the essence of several components was acknowledged. Establishing trust in the outcomes and the alignment of expectations about outcomes and findings were significant components for the project progression and challenged the consequential development of appropriate KT plans. As I further describe below, the team's commitment and re-alignment were vital components that steered the team to overcome these challenges, finalize the complex findings, and develop feasible KT activities.

6.1.2 THE INTERDISCIPLINARY PRACTICE AND THE COLLABORATIVE PROCESS

As presented earlier, applying an interdisciplinary practice benefited the overall project goals, the team, and individuals. For example, in the previous chapter I described the contribution of

interdisciplinary practice to individual growth, in which members learned, expanded their skills, and were intellectually challenged. This, in turn, sustained motivation and the ongoing engagement and commitment of the team members and led to building team capacity to address the research goals. The interdisciplinary practice is a complex research setting, and team members anticipated that there might be some challenges as a result. In previous chapters (**2, 4, 5**), I described this complexity (*e.g.,* maintaining alignment of knowledge) and the measures taken to address those (*e.g.,* lexicon, repetition). In this section, I explore situations resulting from the interdisciplinary nature of the DoMiNO project. As I discussed above, the discovery nature of the project created challenges for an agreement on the findings in a newly explored territory and the utility of a new exploration approach (*i.e.,* data mining). The last phase of the project provides an example of a complex situation resulting not only from the context but also from the interdisciplinary nature of the project, in which different components can shift the focus and hinder the advancement of the project or help to overcome challenges and bring the project back to course.

After a process of identifying a list of chemical combinations associated with adverse birth outcomes, the data mining team used a significance measure named 'lift' to identify and prioritize chemical patterns for hypothesis generation. The term 'lift' is commonly used by computing scientists but was novel to most members from other disciplines. As previously discussed, one of the common challenges of interdisciplinary research practice is the use of discipline-specific terminology, concepts and the building of common understanding to establish familiarity at a level that will foster discussion and progression. In this instance, team members had difficulty reaching collective understanding and agreement about this measure, and the meaning of the results when using 'lift'. The following comments provide a glimpse into the discussion that took place at that meeting:

> *…what is lift? We don't know- a lift of 20 means- what? We don't have a sense…*
>
> *…everyone seems to struggle with interpretation: how can lifts be related to traditional measures like odds ratios and relative risk…?*
>
> *We have a translation problem in the team… we need to translate data mining results to epi* [epidemiology] *language.*
>
> (Different members, Minutes Meeting 4)

Team members, who were not familiar with the term 'lift', asked to make sense of this term, wanted to see the results using metrics more familiar to them (*e.g.,* odds ratio and relative risk). It was difficult to achieve alignment that would foster discussion and agreement. Moreover, it created an obstacle for trusting the outcomes, as some members asked: "*how do you know you can trust the system? Need to prove the system is working and is meaningful*" (Minutes, Meeting 4). Members requested additional research measures in order to be able to understand the outputs. This was further exemplified in the meeting evaluation form, as one of the members described the gaps remaining as "*Trusting the output by the majority of participants*" (Anonymous, Evaluation 4). In the FFG, one member described the difficulty with using 'lift' and the consequent limited trust in the novel outcomes for some members at that time:

> *I think there was good trust until we got into that last meeting, and we had to trust those 'lifts'. That is when people start getting... 'ehhhhh?' It is nothing like I have ever seen before, and somebody raised the issue that we have to validate the results...* (P10, FFG)

The PIs seemed genuinely surprised by the challenges of coming to an understanding and reaching consensus about the metrics used for the analytic procedure (lift). In the following quotes, one of the PIs indicated that they did not expect that the continuing education would have a limited effect when pivotal decisions about lift were required; differences of opinion and understanding of the value and utility of lift were debated:

> *We had many, many presentations about what are these patterns that we are discovering… I think those who attended these workshops did not foresee the end… the metric that says this pattern is better than that pattern. That is where the disagreement was set. Even though we presented it early on. They* [team members] *did not realize that this is what we will use in the end… I did not foresee it because I did not realize how people were actually understanding what we presented* (PIs, FFG)

This example demonstrated that reaching alignment about this approach was more difficult than expected. It was an indication that there was a misalignment on the members' expectations about what outcomes the project and the data mining process could or could not achieve. Reviewing the DoMiNO history (logbooks) identified that misaligned views and expectations about the original outcomes and objectives of the project were present throughout the research project. Team members reminded themselves about the exploratory nature of the research, which did not necessarily fit an epidemiology research approach: "*looks like we are drawn to the epi* [epidemiology] *road with the perfect data, this is an exploratory road*" (Minutes Meeting 2). The assertion that the project was not designed to test the hypothesis generated, prove causality, or assess risk was discussed in every face-to-face meeting. Nevertheless, some team members expected that the hypotheses would be tested and connected to risk ratios.

During the last meeting, a request to apply traditional measures, was perceived by the PIs as a different level of exploration that responds to a different research question, which was not part of the original project objectives, as was discussed by the PIs:

> PIx: *The big difficulty came at the end… in the last meeting when people started challenging the metric of 'lift'…*
>
> PIz: *There was a sense of misunderstanding…*
>
> PIx: *…and we started with that old discussion, and the* [project] *objective started to be distorted among the* [members]*… and, it was* [almost] *the end of the project…* (FFG)

These final stages of the project also revealed another interdisciplinary difficulty: the ability to work with and accommodate different methods and research strategies. Team members discussed in the FG the need to accommodate different perspectives and of that being a challenge: different disciplines have different ways of looking at the world. They sometimes needed to put aside traditional ways of 'doing research', keep an open mind, and accommodate other ways of 'doing research' to let discovery happen as was discussed in the focus group:

> P6: *The data miners have a certain way to organize the world than the epidemiologists, and it was just so interesting to see these conversations happening across those two disciplines, and sometimes I got the sense that* [some members] *couldn't break outside of their* [discipline] --*you know what I mean? -- just let it go, let it go! Let it just be data mining, just for a moment… and we can go to the 'epi stuff' after we have done this discovery.*
>
> P1: *Yeah, you need to go into it with an open mind…*
>
> *(Agreement in background)* (FG)

On the other hand, some members felt that a traditional approach was absolutely necessary for the validity of the findings as one member stated: "*The way I looked at it was, I was kind of anchoring people from flying too high, saying if you're getting that many associations be careful what you're finding*" (P18, FFG).

The lack of agreement on results and difficulty reaching alignment of knowledge and expected outcomes delayed the project's progression and finalization. It also impacted the consequent KT by delaying KT planning and the application of KT activities. Knowledge users emphasized that they realized that KT needed to evolve and align with the project outcomes in order to be articulated and formalized, as described by one of the knowledge users:

> *I guess the one thing that I struggled with, is my role as knowledge user and the whole idea of knowledge translation… I guess I had an evolving and sometimes tenuous grasp on what I was supposed to do to help launch this knowledge that was being generated out into practical use,... and I think when we started at the beginning of the five years, I'm not sure we really knew what those KT outputs would be and what that would look like. I think it was a process of evolution along the way.* (Knowledge user, FG)

Despite this complex and challenging conversation that took place in meeting 4, the team was able to overcome these interdisciplinary challenges and completed the project. A collective examination of the original project objectives identified that all the original objectives were accomplished. One team member acknowledged a collective reflection that regardless of the different possibilities, the project findings may have had, the original research objectives were fulfilled: "*The slide on project objectives showed seven objectives. I feel* <u>*we fulfilled all seven*</u>!" (Minutes, Meeting 4). This inferred that there was an alignment of everyone's perceptions of the project goals. The next steps taken were aimed at addressing the research procedures that members of the team felt were absolutely necessary in order to finalize the findings. A validation plan was developed by an innovative process that integrated the different research approaches and epistemologies used in the project. The PIs described this final phase as a bit of a compromise. The final product was achieved by the enthusiasm and work of the students, which led to finding a solution that was accepted by all members: "*the students took over, and I think we solved the problem, but it took some convincing: talking back to the team, presenting findings, again. So, it was not simple; it was almost one extra year of work*." (PIs, FFG)

Under these circumstances, the completion of discovery as the aim of the project in a satisfactory manner for the team was achieved at the end, despite the delays. In this challenging phase of the project several components, such as maintaining alignment around terms and methods, establishing trust in the outcomes, and accepting other ways of 'doing' research, were difficult to

achieve and had an impact on decisions and progression. However, members' commitment to the project, attentive leadership, and strong built relationships helped overcome obstacles and shift the project's course back to progression. Overcoming the final challenging phase, resulting from the projects' interdisciplinary nature, was possible through re-gaining a level of alignment, establishing trust in the outcomes, keeping an open mind to other epistemologies, and finding ways to integrate them through building a bridge between the different perspectives. Together, these components brought the project to a satisfying end for all disciplines involved. Furthermore, engaging in reflective practice and being attentive and responsive to the team's needs helped find a solution.

This example also demonstrates that, at times, good things can evolve from conflicts. In the end, the conflict drove forward performance and productivity. This 'conflict' was addressed by the developing an innovative and integrative framework, (*i.e.,* the compromise) which 'transformed' the data mining findings to traditional measures of risk, which went beyond the original goals of the project. A publication presented the research processes utilized throughout the research project, including the validation process and concluded with the generation of new hypotheses. These last findings were endorsed and co-authored by all team members. They were published in a high-impact journal (Serrano-Lomelin et al., 2019), which was a pleasing ending for the team members. Collaboration of team members in future research is planned based on these findings.

6.1.3 Individuals as members within the IKT collaborative process

The research field context and the interdisciplinary nature of the project had an impact on the components identified and on the project's performance and progression. Individual circumstances within the collaboration had a role as well. The identified components in this

thesis place individuals' attributes as an important aspect of the collaborative process; *i.e.,* the process relies on individuals' commitment and will to be actively involved in two-sided engagement and the individuals' openness to accept work in different ways. Moreover, individuals' enthusiasm, curiosity, and commitment drive the collaborative process, and basically, all components identified as essential for the collaborative process are built on the individuals' participation.

However, team members may find it challenging, at times, to stay involved, participate, and engage with the project. Team members indicated different individual challenges for their participation. For some, it was due to communication issues resulting from the interdisciplinary nature of the project and for others, it was the lack of clarity about their specific responsibility or geographical distance challenging their participation.

On several occasions, members of the team also discussed difficulties in finding the balance between dedicating the time for the project, while having many other professional commitments. Multiple obligations were the nature of work and research practice for many of the team members. They described what a busy work practice with many responsibilities could be. For example, one member described busy email boxes: "*I think one of the challenges is, making sure that it gets through the 'borage' of other hundreds of emails that everybody gets every day*" (P11, Baseline interviews). Another member added that it was about finding the balance between sharing updates without overloading with information: "*a lot of people have a lot of other commitments, so I think there needs to be a balance between engaging people and, not overwhelming them either*" (P4, Baseline interviews). Team members recognized that opportunities for engagement needed to be used by the members in order to be effective: "*everybody's involvement maintains an alignment*". Some members expressed that they wanted

more communication about different aspects of the project, while others found it challenging to catch up. Further demonstration of this continuous challenge is presented by the following quotes from team members' reflections. They describe navigating their participation in the project along with multiple professional commitments, and the difficulty for them to be active in all communication and learning activities of the project:

> P2: *It is difficult for someone… in fact for all of us… it is the same: this is the commitment in this building in this room, but in that building, there are three rooms with commitments, and that building has three rooms of commitments, and there are all these streets we have to navigate in between on the day-to-day bases.*
>
> P4: *I found it hard because, I have so many other commitments, and the distance, and I would have liked to spend more time, but I just couldn't…*
>
> *(Agreement in background)*
>
> P7: ... [There are] *competing priorities... we have full interest!*
>
> *(Agreement around)*
>
> P2: *... and that is true for all of us!* (FG)

Analysis of my observational data indicates that members gave their full attention to the project and were totally immersed in the project progression during face-to-face meetings. This provided big jumping stones for the project's progress. At the same time, members also recognized that they had limited time to commit to the research process outside those dedicated time slots for meetings (despite the different opportunities available). One of the team members indicated in one of the face-to-face meetings that: "*It will be very difficult for people to go home and work on it* [aspects of the project] *...!*" (Minutes, Meeting 4). However, limited participation at other times delayed the project's progression. For example, a questionnaire that was shared with the whole team, but received minimal responses from the team members, was thought to have impacted the discussion in the meeting that followed, as described by one member: "*the jury was still out at that point on what the final product was going to be*" (P11, FFG). This may have been the result of the

challenging context ("*nothing to compare to*"), the complex interpretation and integration, or personal circumstances, such as the lack of time. The PIs perceived that some of the difficulties were due to under-preparation prior to the discussion, which impacted readiness for discussion. At the same time, they felt that additional time would have helped the team to better prepare for an extensive discussion:

> PIx: *Before the meeting, we were expecting the team members to 'play' more with the tool. That did not happen… they came unprepared to the meeting… and…* [the team members] *were introduced to make a decision with lack of readiness and forced us to lead the direction of the findings, without them having the opportunity to digest it... it was premature for them…*
>
> PIz: *I think if we had more time it would have been okay, but we were getting closer to the deadline to finish, we had to do something.*
>
> PIy: *I think we were missing discussion. So, I guess we solved it, but it would have been better if we had a chance to discuss it more extensively.* (FFG)

Despite the delay, a solution was developed that led to the finalization of the project in a satisfactory manner for the team members, as described above.

This description of individuals as members of a team demonstrates how, the role of components such as the commitment of time, active engagement in the project activities, and alignment, can progress but at the same time may hamper the collaboration and the project progression. Members of the team realized that "... [the research project] *is longer and messier than you think*" (P8, FG). Through the alignment of expectations, along with the team members' commitment, members of the team found the time to commit and contribute, despite the individual challenges. Additionally, the social environment and sense of responsibility helped overcome these challenges. Both team members' and the leaders' personal attributes, patience, perseverance,

commitment to the project, and their will to accept delays and find solutions helped overcome the challenges encountered and complete the project.

In summary, I described different situations encountered during the collaborative process at the contextual, team, and individual levels. Those situations featured the role of the components at different times. In some instances, attaining specific components was more difficult and resulted in delayed or slowed progression, while other instances demonstrate that accomplishing other components helped overcome challenges encountered through a complex series of processes and events. This exploration extends the breadth and depth of each of the components. It provides additional insights into understanding the components and exemplifies their impact on the collaborative process. Thus, the components can facilitate or hinder progression, as well as help overcome challenges. This analysis reinforces the significance of the components identified as essential to the research progression, productivity, and performance and suggests possible implications to the collaborative process.

Additionally, this exploration provided a preliminary indication of the components' evolution during the DoMiNO project and their joint involvement in the collaborative process, which are the focus of the next section.

6.2 THE EVOLUTION OF COMPONENTS AND CONNECTIONS BETWEEN THEM

In the last section, I undertook a different angle of exploring the components. I examined different situations, which provided additional understanding of the components' domains and

conceptualization and reaffirmed the significance and validity of the components. This section of the analysis extends the articulation of the components to explain how they developed and came to be, and what contributed to their evolution and maintenance. Specifically, I explore the interplay between the components and their combined connection and contribution to performance, productivity, and ultimately to the project's outcomes and KT.

In order to understand how the components were attained (for example, how capacity was built, or what contributed to building relationships, establishing trust, and developing a sense of shared ownership), I revisited the data collected and examined the evolution of the components. I identified that there were several 'assets' with which the project began and was built upon. As previously indicated, some level of relationships already existed when the project started. Several members had known and worked with each other previously, which motivated them to continue working together and committing to the project. Many members indicated that they were driven to join the project because of its topic, which was exciting and innovative and had the potential to contribute to science and society. The project was built on the individual competencies, expertise, and experiences of the team members, as well as their expectations, attitudes, interest, curiosity, and desire to engage with this partnership. This list of assets implies that the project began with a basic level of the components (*e.g.,* relationships, individual attitudes, and capacity). However, how did the identified components evolve and were achieved.

In **Chapter 5,** I presented the components that constructed the collaborative process and the direct role they had in the achievement of outcomes and KT; however, as I will describe below, the evolution and contribution of the components to the process also occurred indirectly, by having an impact on each other's evolution. The data include, in many instances, several components that were involved in a specific scenario, and other occurrences, where the dimensions of the different

components overlap. This implies that components did not evolve independently but instead had a complex intertwined and dynamic evolution.

To demonstrate these connections among the components, I reviewed the team members' perspectives over time, on the essentials for the collaborative process from their experience in the DoMiNO Project. There were many instances in which members attributed the progression of the collaborative process to a combination of several components. Moreover, as this analysis demonstrates, the evolution of the components was facilitated by influencing each other (for example, maintaining alignment led to establishing trust, establishing trust led to developing ownership). These connections among the components were sometimes implicit and became more evident in later discussions on the collaborative process, as the project progressed. In the next paragraphs, I provide a few examples from verbatim data that were revisited, to demonstrate not only one component but the connections between the components and their impact on the collaborative process and outcomes, directly and indirectly.

My analysis of the data identified that one of the more explicit connections was among the operative elements and individual attitudes, which interplayed with each other and some other components. There were several examples in which members described that communication channels helped to build relationships**,** supported learning and alignment**,** and helped build team capacity, performance, and productivity, as demonstrated in the following quotes:

> *3rd time face-to-face meeting, relationships have been built – feel like some family. Make sure you have regular face-to-face meetings because it really helps to build a team* (P1, Insights)

> *Investing resources and time in face-to-face meetings… to build relationships and learning. It takes… 2-3 meetings to get to optimal team performance.* (P6, Insights)

> *The meeting really was useful, and to observe how long it takes to build relationships, which lead to good productivity* (Anonymous, Evaluation Form 3)

In another example, members described the significance of everyone's involvement in the project. In this example, they linked individual attitudes of commitment and engagement with the alignment of common goals:

> *"…making sure that everybody knows: the work that we're doing… or where we're trying to head with, and everybody's involvement maintains an alignment"* (P6, FFG)

The analysis also helped identify that when components, such as alignment, capacity building, trust, ownership, and relationships showed were linked; they created together a dynamic process. For example, team members described how the updates on progress made and the results contributed to their own knowledge and motivated them to plan what the team could do with the research results:

> *What I would also say, is that the more interesting stuff come towards the end right?... (Background agreement) I learned a ton today and… it got me more excited… I have seen the progression and it's like ok, now there is all this cool stuff that we can do* (P4, FG)

To explain this quote, I identify parts of the text that relate to different components and examine how the components relate to each other: The alignment of progress, knowledge, and project outcomes ("*interesting stuff*") led to individual knowledge growth ("*I learned a ton*"), motivating individual attitudes ("*got me more excited*"), and resulting in ownership and performance ("*all the cool stuff we can do*").

Another example that connects alignment, trust, relationships, individual attitudes and operative elements, engagement, and ownership progression was recorded in the final focus group when one member reflected on the essentials for the collaborative process:

> *In a study like this, who are the core group who needs to understand everything? and then, how did that group engage people who are not… but are engaged in parts of it?… Did that group gel? and then, did that group engage the people in a trusting relationship? Because in a big project like this you do not need everybody to be engaged all the time. It would not be a good use of resources, but you need them* [team members] *to be sufficiently engaged that they feel ownership of their piece or that they can contribute their piece. I think from our point of view we did not get involved in certain things because we trusted the people who were in that realm to look after it just as [others] didn't get involved in our [area of specialty]. They trust us to do that. Yeah, I do not think there was any question of trust in those areas.* (P2, FFG)

In this quote, the team member discussed the relationships between the core team and others, and the concept of ownership. They indicated a need for operative and individual attitudes and alignment, to build a sense of ownership and establish trust.

My analysis also identified connections between components in instances when the members felt it was difficult to attain one of the components. In the following example, one member described difficulty at the beginning of the project, identifying where they can fit in, and take part in the project (ownership). They explained that participation in small discussion groups (operative elements-inclusive environment, channels of communication) helped to articulate their role (alignment) and their possible contribution to the project (ownership).

> *I think sometimes, being in a large group, at the beginning, I found it a little hard to understand where I could fit in…. I felt like when we had our individual small group sessions like we did with* [one of the team members] *... that is where I had a better idea of my role and where I could contribute* (P8, FG)

The examples provided above from verbatim data demonstrated how components manifested and evolved through the connections among components. Observation over time provided insights from a different angle to the contribution of the components to each other's growth, evolution, and maintenance. The following is an example based on observational data (minutes, logbook,

observation), which illustrates the significance of alignment in establishing a level of trust between disciplines and the participation of other components in the collaborative process.

The term 'black box' was used in the first annual meeting by computer scientists in the team to describe the analysis procedures used in data mining. Although 'black box' is commonly used when describing data mining processes, it may have had a different connotation for others. In a reflective exercise at the second annual meeting, a few members requested that there will be "*no black box*!" in the project, meaning that this concept implied for them unknown, or even hidden aspects of the research process and that this contradicts the interdisciplinary practice of the project. They wanted to learn about these research processes that would be applied and asked for the procedures to be explained and transparent. Engagement in reflection (active engagement) was a critical activity to identify there was an issue with the 'black box' term and address the team's concern for future interactions. From that point onward, moving away from the 'black box' allegory, the data mining conceptual approach and procedures were shared and described (alignment) repeatedly in the next meetings and webinars (supportive learning environment). This enabled an increased understanding of the procedures that went into data mining, and as members indicated, the hard concepts engrained over time. One member specifically noted in the final focus group the progress of getting familiarized with the new concepts and their difficulty with the term: "*I felt I understood a little bit more each time than before - when it was in the black box*" (P10, FFG). Familiarizing with it helped in achieving a level of alignment that enabled members to take part in the discussions that followed, so they could "*try and contribute*", "*raise questions*", and "*critique it*". As one member phrased it, "*I had to learn and listen, before I could provide feedback*" (P18, FFG). Familiarizing with data mining procedures (alignment of knowledge) also helped build transparency of these methods, and thus, the trust in the procedures was gradually built. This

alignment of knowledge was enabled by building individual capacity and learning and having the operative elements, such as the channels of communication (*e.g.,* meetings, workshops), which provided opportunities to learn in a supportive learning environment. This learning process was also enabled by individual attitudes (the will to learn and keep an open mind), which supported this alignment and active engagement; this further contributed to the team's capacity to achieve the project's goals.

These examples from observational and verbatim data suggest that the progression of the DoMiNO project IKT relied on a complex web of combinations and connections among the components. They impacted each other in reciprocal, sequential, and ultimately, cumulative interactions that drove the collaborative process's evolution. A list of examples in **Table 6.1** using verbatim data provides additional examples that further reaffirm and demonstrate a variety of connections among the components. Based on these patterns, the following is a description of the collaborative process evolution through the progress of the different components.

The Operative elements are used as the starting point for the descriptive summary of the collaborative process evolution. They ensured different channels of communication among members of the team. These were formal and informal interaction opportunities that were invaluable in building the collaborative process and supporting productivity and performance. These opportunities promoted friendly and professional relationships built on respect and trust among the members, similar to what one would find in some families. Annual meetings (and webinars) enabled learning about progress made in the project, and the project's different aspects, which kept the team aligned with regards to the research progression and helped establish trust in the outcomes. Learning needed to occur, in an inclusive, friendly, trustworthy, and safe environment built over time (operative elements). Different activities supported individual growth

and learning together, which helped achieve continuous alignment of the projects' specific knowledge, reach common ground, and facilitate concrete discussion among members. Thus, learning and alignment were instrumental in building the team's capacity, creating momentum, and focusing the research route. The alignment was enabled by engaging in reflective practice, in which members identified what worked and what did not for the collaboration. This then informed the project's management, which was then able to make the necessary adjustments.

Moreover, engaging in a two-way active and respectful engagement, providing and responding to feedback, helped establish the trust in procedures and outcomes. Additionally, supporting individual learning, contributing to alignment and developing a sense of ownership in which everyone's opinion mattered, were instrumental. On the other hand, lack of alignment, for example, in expectations about roles or objectives, impacted progression and resulted in less engagement. However, once alignment, relationships, and individual growth were established, it was easier for team members to identify where they could contribute and helped develop a sense of shared ownership. Members' individual attitudes, *i.e.,* their will, commitment, active engagement, and enthusiasm about outcomes of the project and its prospects, contributed to a sense of mutual belonging and responsibility to the project as team members (*i.e.,* shared ownership), and ultimately to team capacity. The development of team capacity, in which different views were considered and integrated, also required an open mind to develop appreciation and respect to different approaches and perspectives. Finally, in this collaborative process, an attentive leadership style was essential to building, sustaining, and nurturing the different components of the collaborative process, and the ongoing members' commitment, which enabled the joint achievements of the DoMiNO project. Thus, together, all components contributed directly and indirectly to the evolution of the IKT process.

Table 6.1: Additional examples from verbatim data of combinations and connections among the components

Components	Quotes
Operative (communication), alignment, trust in the outputs	"*The workshops that were held in terms of the exercises on data mining and things like that, where people could sort of get familiarized with some of the techniques and trust the outputs that were coming*" (P4, FFG)
Operative (communication) alignment	*"People were thinking about causality and that wasn't the aim of the project, the project was exploratory to build hypotheses, so the workshops were very important to again clarify the objectives of the project"* (P9, FFG)
Operative (communication channels) alignment, team capacity, collective performance	*"Have regular check-ins of different magnitudes, so you would have emails, monthly emails, or a webinar every 4 months, or you can get online, and then annual face-to-face, and so just keep the momentum going, and keep everybody on… even though we are all doing our own thing, we kind of get back together, it will take a couple of hours to 'ok so this is what we are doing'… and then nearly at the end of the meeting, we start to really know what we really need to be doing… and then: we need more time … let's just keep going*" (P3, FG)
Operative (Learning environment, inclusive) individual growth and capacity	"*The talks were targeted to all levels of team members, so that was great; everyone was very collaborative and encouraging about asking questions*" (Anonymous, evaluation form 3)
Alignment, Operative	"*It was very beneficial to have this analysis* [IKT evaluation] *running alongside everything else and reflecting on what worked and what not*" (P25, FFG)
Relationship, individual growth / capacity, and trust in each other	"O*ne of the things that helps me feel better, I still have difficulties, but comfortable with the people so don't mind asking questions or expose naivety*" (P20, Insights)
Attitudes (Open mind), trust, individual capacity	**"***Being open minded helps building of trust over time, trust that your opinions are valued over time, which is a huge deal*" (P5, FFG)
Attitudes (active engagement, feedback loop) trust	"*I think responding to feedback … with respect to the visualization tool and other products, was important in terms of trust*" (P11, FFG)

Attitudes (active engagement) operative inclusion), ownership	*"When we were developing the tool and we had these workshops to present the tool, [team members] used it and they gave feedback. Then we had another workshop after, and they see that their recommendations were implemented. So, they see that we are listening to them, so they have that sense of ownership: 'Well, that [change in the tool] is thanks to me.' The fact that we ask questions and we listen to the answers makes them feel that they're part of the group. Your opinion matters!"* (PIs, FFG)
Operative (Leadership inclusive environment) attitudes, joint ownership, individual capacity, and growth	*"The leadership style* [of] *having the patience, and making the time to make sure that everybody is actually engaged in their work, because the other end of the spectrum is the research team is where the PI and a few maybe trainees and a few people very close to the center do the work, and then everyone else gets their name on the publication that isn't actually theirs. But in the end, this project, specifically because there was such diverse expertise and sort of equally weighted environment… There really was a partnership all the way from the top-the PIs all the way down through all the trainees and so forth. So that was pretty inspiring, and they brought so much enthusiasm... We had super competent people, so that I think it's probably quicker and easier sometimes to just do the stuff yourself and then call it a team and it's not really a team right? So, having the patience and determination to really make sure that people are engaged and that a lot of people are developing through the course of the project was a takeaway for me"* (P6, FFG)
Operative (leadership), attitudes (commitment, inclusive, team capacity and performance	*"The leaders were very generous and very sincere in wanting this to be a team effort and wanting to spread the resources out to encourage people to bring trainees in from different disciplines and encouraging respect between people and encouraging people to listen. I felt like there was a lot of warmth from the leadership… there was a real welcoming attitude that I felt from the leadership and a real attempt to make you feel personally welcome that I felt very good about. …I realize it's necessary at times that the leadership has to safeguard the resources… but it didn't feel like it when you were in the group… you felt like we were all part of this together and even deciding upon how we would support people and things like that. I felt like it really made it a good team effort"* (P19, FFG)
Attitudes, relationships, trust	"I*t is actually really about human beings and affinity, and so forth, and trust, and interest, and enthusiasm, I think they are actually vital facts. Someone told me… the secret to be a successful researcher is always to work with people that you like*" (P6, FFG)
Relationships, individual attitudes (commitment)	"*…that's where human relationships come in… I certainly have a sense of admiration and loyalty to* [the PI]*, I have known him for decades actually and* [the coordinator/ researcher] *I have known before… because I value their work, you know, them as individuals and the work*

	that they were trying to do and wanting to… to not drop-off for that reason." (P6, FFG)
Individual and team capacity	"*In the beginning you may not know all that you need to learn, this is a journey, and we didn't know in the beginning where we end up and what we need to learn from each other*" (P3, FG)
Individual capacity, alignment enthusiasm, ownership, individual attitudes	*"I learned things, and certainly it increased my understanding of data mining that I don't think I had a full grasp of. I do not expect to get a full grasp when I go through these things, but still it was great. I also felt like at the same time as I was learning, that I was given the ability to contribute, and so that was good because it never felt one way, and it really did increase my enthusiasm about the overall project"* (P19, FFG)
Individual capacity, alignment Individual attitudes (commitment) ownership (responsibility) and team capacity	*"Coming into this team, the learning curve for me was pretty steep when it comes to data mining… all of the learning and re-learning, I needed to do. Because we would meet once a year… So, it was the process of: 'what are we talking about, and how does this data mining work and, what are its implications'. I found it fascinating, but an important part of it for me was just building my capacity to… stay in the game, and follow, and hopefully try to contribute to what was happening"* (P6, FFG)
Operative (Leadership inclusion), joint ownership	*"I have been in projects where I felt that at some point you're going to drift back to just thinking 'well I'm just an advisor' but they [leadership] are really like 'no, no', this is your project, we're all on this', encouraging people to get as involved as they felt like they could, and as they wanted to… I felt like there was a lot of encouragement. It was actually an internal dynamic to encourage the ownership among everybody*" (P19, FFG)
Alignment, individual capacity individual attitudes (active engagement), team capacity	*"I think it was okay to get the big picture even if I wasn't needed in some phases. I enjoyed knowing the members. I may not have contributed too much to some of those sessions, but I still was learning based on which I could raise questions… I tried to just learn, I came to this field, which I wasn't aware of, so I had to learn before I could critique it"* (P18, FFG)
Trust, ownership	*"I feel that I had a role and when I wasn't needed, I didn't need to be there. That is a trust issue. And when I was needed, I was approached, and I could contribute"* (P2, FFG)
Lack of ownership, less individual attitudes (active engagement and	"[What are our challenges?] *Being actively engaged, not sure what is my role, without active role or tasks hard to stay engaged… without*

participation in activities) *Implied: (less individual growth and alignment)	*something to contribute hard to actively stay engaged… will miss webinars…*" (P14, Insights)

The analysis presented above extends the understanding of the components to unpack and further conceptualize their dimensions and contribution to the IKT's collaborative process. This analysis further affirms the components' essence to the collaborative process, articulates the evolution of the components, alone and together, and expends their domains. I described the evolution of the IKT process through a description of connections between components. I identify a web of connections and interdependency among the components, which contributed to their achievement and construction, to build directly and indirectly the IKT collaborative process. In the next section, I explore another angle of the collaborative process essentials, as perceived in retrospect.

6.3 DoMiNO's IKT process - Team reflections in retrospect

To finalize my study, I conducted several final focus groups (FFG), more than a year after the project had ended, to confirm the findings among study participants (*i.e.,* DoMiNO team members). Members' insights helped articulate and conceptualize the components and their evolution in the collaborative process and were included in the findings shared so far. These discussions were also an opportunity to learn about *a posteriori* about members' perspectives; what they considered, in retrospect, as most significant for the collaborative process and for achieving the project's goals. In this section, I present a description based on the members'

perspectives on lessons learned on research collaborations from their collaborative experience with DoMiNO.

Reflecting on the DoMiNO experience, members recognized that the collaborative process and team growth were complex processes that required sufficient time to evolve. It was the evolution of developing complex research in unknown territory: "*it was exploratory, and we didn't really know where it was going to go*" (P11). Members described that the project aimed to develop a novel approach for generating new hypotheses and figure out, in this age of huge data, the abilities and the challenges in interpretations of such an approach. Members noted that participating in the research project was like a journey that began with diverse expectations and unknown outputs. They felt the project "*was an ambitious plan, and where it ended up was highly impressive!"* (P3).

The research partnership also needed to evolve, since the team's growth was reliant on the different components' progression over time and their impact on each other. Members indicated that the strength of the project was due to its interdisciplinary nature. In particular, they emphasized the ability to utilize and integrate all expertise in an inclusive environment and have a sense of true partnership and shared ownership, in which members felt that it was our project (vs. my/their project). The sense of shared ownership was deemed to be the way to overcome challenges. In this shared setting, members felt that they could bring forward their own ideas, open to new ideas, and valued other's ideas. At the same time, they described how this environment inspired enthusiasm and motivation, which grew over time.

Members of the team discussed the essence of alignment, especially in this interdisciplinary context. They emphasized that it was important to work towards the same goal by applying many iterations to the product developed and building mutual understanding through an action cycle.

This includes active participation, input, deliberations, and response with deliverables. These actions enabled the integration of the different perspectives throughout the project and, although they may have slowed the process, they were definitely needed.

Many members discussed the good social atmosphere in the project, which created an enjoyable work setting. They appreciated the different opportunities to engage (especially in face-to-face meetings), and other formal and informal interactions, which created a 'fun' climate. They valued the atmosphere in which everyone's voice mattered, and they felt connected and had opportunities for individual development, learning, and gaining experience. Some members perceived the need for more discussion on expectations, and individual measures of success. As well, more explicit communication about roles could have helped support the assignment of responsibilities in this large team. However, they also acknowledged that predefined decisions on roles might be too rigid and could restrict the progression of the project.

A collective agreement among members was that sufficient time for these evolving processes was of necessity. Members recommended ensuring enough time for such research projects. They suggested that at least five years are required to facilitate the success of this type of research project. Members acknowledged that time was required to develop a complex project like DoMiNO to support internal knowledge translation, alongside the building of a strong team, which can perform and produce jointly: "*It was important having a long period of time to work through this, get the work done, and have trainees through…you would lose that group process when you try to rush things too much*" (P19).

Members indicated that the leadership style played a key role in the project by setting the stage and the tone to develop and sustain the collaboration, promote joint discovery, and overcome interdisciplinary and other challenges the team faced. The team engagement with the project, in

which everyone was an essential part of a team and had a part to play, and members' commitment to the project were also considered as imperative to the evolution of the collaborative process in the project as noted: "*the active participation of the team contributed to the greatness of the project and the KT*" (P17).

The development and utilization of KT were part of the evolution within the project, as well. Throughout the project, different KT activities took place. However, much of the KT planning (especially, the end-of-project KT) evolved alongside the project: "*When we started, at the beginning of the five years, I'm not sure we really knew what those KT outputs would be, and what they would they look like. It was a process of evolution along the way"* (Knowledge user). Members noted that KT needed to align with the members' expectations because when the project started, there were many expectations about what the project could achieve. Some expectations were beyond the boundaries of the project. As the project evolved, the KT plan was repeatedly articulated to identify the audiences and avenues in which the outcomes would best fit, and this is how KT activities were utilized.

Overall, members were happy with the applied KT. Few members indicated that they expected additional development of the outputs and more KT and outreach. At the same time, they acknowledged that additional time would have enabled the discussion required for further joint development of the outputs and, ultimately, the KT. One member indicated that the project made a significant contribution that they felt was happening in the backstage of policy and decision-makers. At the end of the project, many members described their participation in the project as a positive and satisfactory experience, even beyond their own expectations and were pleased to see what came out of the project.

In this section, I provided a descriptive summary of the team reflections on the project a year after it has ended and provided insights on take-away lessons from this project. This helped articulate the collaborative process from a different angle, further affirming the essence of the components identified and the evolution of the IKT process. The next section is the last level of abstraction, which ties together all findings.

6.4 A CONCEPTUAL FRAMEWORK OF THE IKT COLLABORATIVE PROCESS

This section concludes this chapter, situating the findings in a conceptual framework for the IKT collaborative process as an evolutionary process of the different components and their relations towards performance and productivity of outcomes and KT.

The case study findings present the evolution of IKT collaborative process through intra-team and individual processes. I identified different components that shaped the collaborative process directly and indirectly. These components include *building relationships, advancing individual growth, building team capacity, maintaining alignment, establishing trust, developing shared ownership, operative elements,* and *individual attitudes*. In the DoMiNO project, these components were interdependent and contributed together to shape the collaborative climate and process. Together, all components supported performance, productivity, helped overcome challenges, and played a key role in achieving the project outcomes and KT. Based on this case analysis and findings, I developed a conceptual framework to illustrate the IKT collaborative process (**Figure 6.1**).

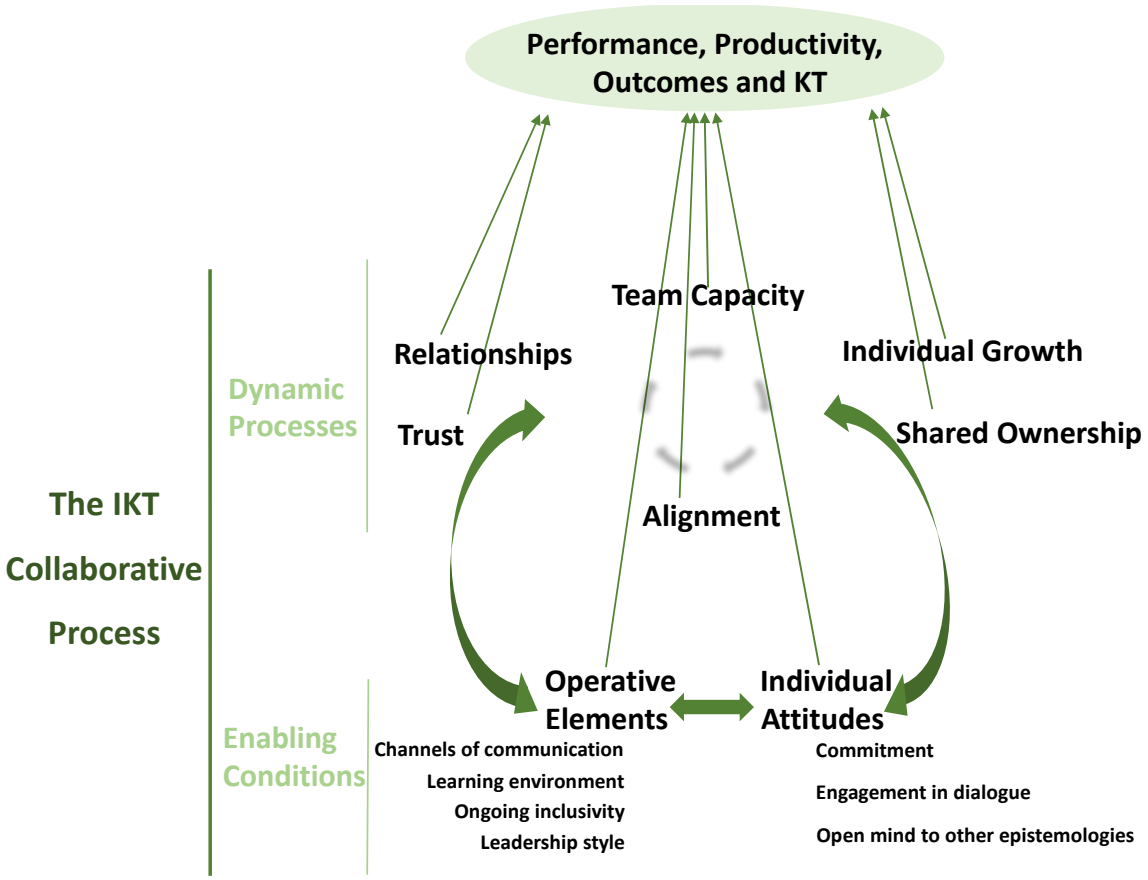

Figure 6.1: The collaborative process in IKT. An illustration of the IKT collaborative process as a conceptual framework that integrates all the concepts of relationships, trust, alignment, team capacity, individual growth, ownership, operative elements, and individual attitudes. The framework illustrates how they interact to contribute to IKT and, ultimately to performance, productivity, outcomes, and KT.

CHAPTER 7

DISCUSSION

Research projects that respond to complex research questions, such as the interaction between the environment and health, are inherently complicated. They require both scientific quality and rigour, as well as an effective collaboration of diverse expertise. This thesis was inspired by the interest of understanding the essentials for an interdisciplinary and IKT research to achieve knowledge creation and translation in the context of environmental health. Learning from the DoMiNO project, I conducted an empiric study that identified the collaborative nature of IKT as being a complex process involving eight dynamic and significant components that are all interconnected. Together, the components shaped the DoMiNO project's IKT process and contributed to the growth and progress of the team and the achievement of the project's goals and outcomes.

7.1 THE PATH UNDERTAKEN TO UNDERSTAND THE IKT PROCESS IN THE CONTEXT OF ENVIRONMENTAL HEALTH RESEARCH

Learning about the IKT process in the environmental health research context started with getting familiar with the topic by learning from relevant scientific literature and specialized graduate courses, alongside the real-life experience of the IKT approach applied by the DoMiNO project. These encounters highlighted the complexity of research in the field of environmental health and the implications for KT. When considering the unique context of environmental health

research, the assumption was that this context requires a collaborative framework that will address the nuances of the research, which relate to the research process, uncertainties, sensitive outcomes, interdisciplinary practice, the inclusion of stakeholders, and commitment to KT (as described in **Chapters 2** and **4**).

Preliminary literature searches did not identify the use of any type of IKT approach in environmental and human health research, and literature from other contexts did not provide sufficient information about the practices required to support the unique characteristics of IKT in this context. Therefore, I decided to explore the extent and nature of the academic literature in environmental health that pertains to human health for any experiences or approaches of collaborative research processes that had similar characteristics to IKT principles. The results of this exploration were described in a scoping review (**Chapter 2**) (Wine et al., 2017), which was recently included in a systematic review of reviews on research partnerships (Hoekstra et al., 2020). The scoping review served as a foundation for a broad understanding of the processes of research collaborations in environmental health research by identifying facilitators and barriers by themes. These findings also provided *sensitizing concepts* for the analysis process of the case study. Through this scan of the literature, I realized that significant collaborative elements and recommendations for best practices were often described abstractly, without elaborating their meanings and domains, and were often not based on empirical data. For example, many papers mentioned the significance of 'trust'. However, empiric descriptions on how they identified trust as a significant element, what trust means, or how it can be achieved, were rare.

Moreover, the scoping review helped identify research gaps. These referred to the need for empiric explorations from real-life experiences to understand the collaborative research and the KT development processes. This was consistent with a growing interest in learning more about the

collaborative research processes in research teams identified by others in different contexts, specifically indicating a lack of empirical research to understand team dynamics and strategies to improve the performance of research teams (Bozeman & Youtie, 2017; Cooke et al., 2015; Gagliardi et al., 2016; Graham et al., 2018; Hall et al., 2018).

My research study responds to this identified gap. In pursuit of understanding the collaborative process of IKT, I chose to conduct a case study. The DoMiNO project was an invaluable opportunity for studying collaborations both as an *instrumental case*, that could represent other similar collaborative teams, and as an *intrinsic case* that has its unique aspects. The DoMiNO project, and its collaborative process along with preliminary insights, were described and published as a case report (**Chapter 4)** (Wine et al., 2019).

My approach to this study was of a relativist ontology, which considers multiple realities, and a constructivist epistemology. Knowledge was constructed by different subjective perspectives, which were required to understand the collaborative research process phenomena. Thus, I learned from the team members' perspectives about the essential components for the collaboration. I developed the research to respond to my question of interest and allow an inductive process with a rigorous approach exploring the case. The case study methodology enabled me to follow the project and its progression and focus on the processes involved, while giving voice to participants' perspectives on the essentials for collaborative work. I conducted a thorough exploration by applying different research methods, prolonged engagement with the case, and an iterative process of data generation and analysis process. I had a unique researcher position of being an insider. I was involved in the research project as a coordinator, which ideally positioned me in the heart of the project and enabled access to participants, and familiarity with activities, and the progression of the project. This role was not without challenges or limitations, as further discussed below.

In order to guide the discussion, I collated the various parts of the thesis together and expanded the conceptual framework presented in Chapter 6 (**Figure 6.1**) to include the following aspects: 1) the research context; 2) the initiation phase; 3) the essential components; 4) the tangible and intangible outcomes; 5) the connections between the components; and 6) visualization of the IKT collaborative process as a process over time, represented by the growth of a tree, as a metaphor **(Figure 7.1)**.

This framework considers the context, which creates the setting and the specific characteristics of the research field that may impact the research project. For the DoMiNO case, the setting was interdisciplinary exploratory research in environmental health. The starting point of the project is illustrated as a seed. It embodies several assets that serve as a base from which the project can grow. They include previous individual and professional relationships, the team members' competencies, expertise, experiences, expectations, attitudes, interest, readiness, curiosity, and will to take part in the project. The seed also includes the research questions, goals, the predesigned research framework, the IKT collaborative approach that were ratified to guide the research process, and the resources (*e.g.,* funding, support personnel) available for the project. These are the initial ingredients for successful partnership outcomes; however, more needs to occur to keep the project growing.

The analysis identified eight components that, through their interactive evolution, were fundamental to establishing performance and production of new knowledge and the development and application of the KT plan. The maintenance of these components and their evolution help sustain the motivation required for the tree - the project - and team to grow and achieve the research goals, tangible, and intangible outcomes. The tree's growth metaphor is used to illustrate the collaborative process of IKT as a dynamic evolving process (**Figure 7.1)**.

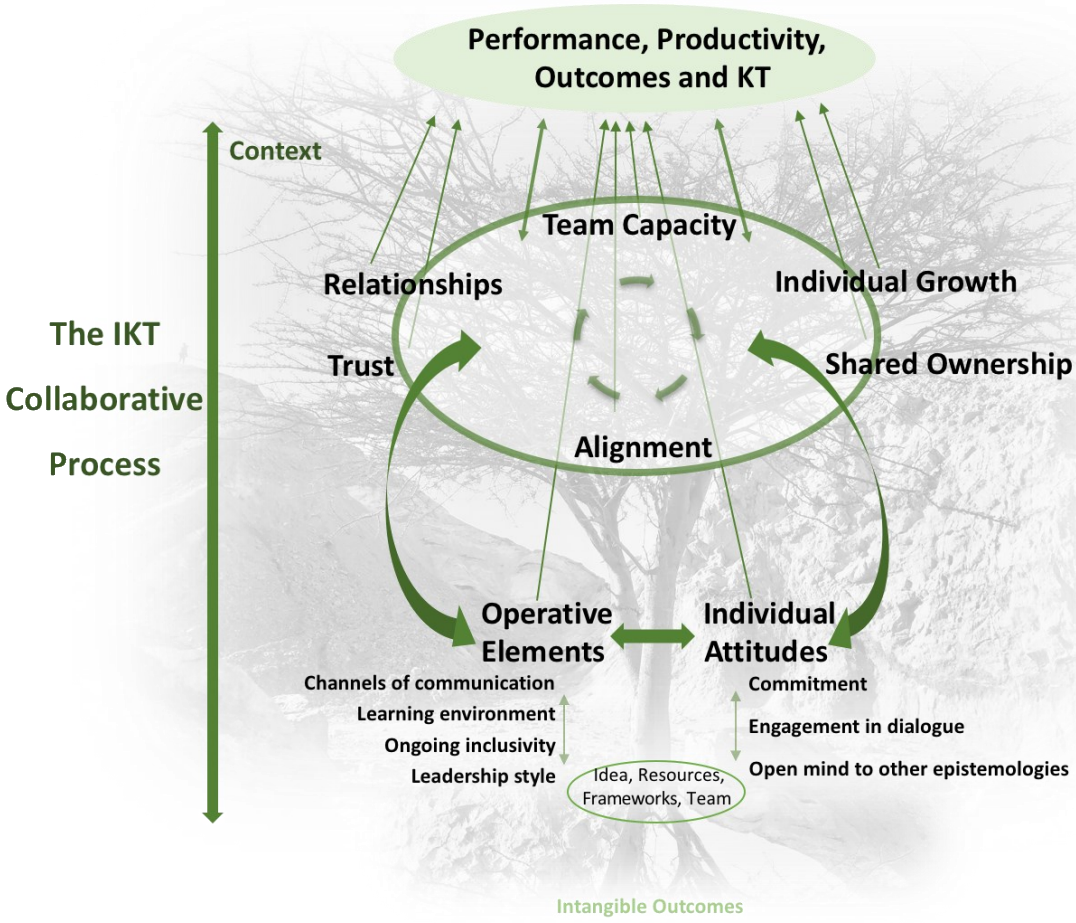

Figure 7.1: The metaphor of a tree to represent the growth of the team in a unique context. It starts with a seed, and through different processes and conditions the collaborative project evolves. The tree's maturity (treetop and roots) represents the 'products' of the collaboration: performance, productivity, tangible and intangible outcomes, and KT.

In the following sections, I discuss the different elements included in this conceptual framework: the components alone and combined, the context, outcomes, and KT. I describe how my research situates in the relevant scientific literature that pertains to environmental health, but

also draw on literature on IKT, transdisciplinary research, and team science. I indicate similarities to existing literature and specify new insights that this work is contributing to the science of research collaborations.

7.2 THE ESSENTIAL COMPONENTS OF COLLABORATIVE RESEARCH

My research has empirically identified eight essential components of IKT collaborative process. I provided descriptions of the domains and meanings and created a comprehensive map of their joint and dynamic participation in the collaborative process. A vital building block for collaborative practice identified in my analysis was *building friendly and collegial relationships* among team members. This was also a common theme in the literature. Many studies in the environmental health research context, as evidenced by the scoping review (**Chapter 2**), indicated the need to build strong relationships among team members as a significant factor for building the team's capacity and establishing trust. Relationships were identified to be especially vital for long term research (Meadow et al., 2015). Several authors practicing Community Based Participatory Research (CBPR) described the importance of establishing and maintaining good relationships between researchers and the communities as a pre-requisite for collaboration and in order to build future trust in each other (Collman, 2014; Ravenscroft et al., 2015; Sibbald, Tetroe, & Graham, 2014). Many of the CBPR papers, included in the scoping review discussed the need for trust, respect, and reciprocity as part of effective relationships mostly as non-empiric lessons learned. My research further articulated the nature of relationships. Through analysis of the data I identified relationships needed to be built at the collegial and individual levels, creating an enjoyable social atmosphere, and developing professional loyalty among members to enable the joint performance

and productivity of the research team. It was also evident in this case that relationships within the team took time to build and evolve, and that they needed to be maintained throughout the research project. As reported by other CBPR research projects, building strong relationships could also be a significant challenge of building true partnerships based on equal participation between communities and other partners (*e.g.,* for-profit organizations, academic researchers). They also noted that building good relationships and addressing and mitigating power issues between research partners require significant time investments (*e.g.,* developing partnership agreements) (Johnson et al., 2014; Metzler & Higgins, 2003).

This vital role of good relationships also aligned with other types of research partnerships such as IKT, transdisciplinary, and knowledge exchange projects (Bennett & Gadlin, 2012; Reed et al., 2014; Sibbald et al., 2014; Stokols et al., 2008). Many research partnerships are often based on previous relationships between team members (Gagliardi et al., 2016; Zych, Berta, & Gagliardi, 2019). Already established relationships can lead to 'quicker wins and greater appreciation of each other' (Rycroft-malone et al., 2016). Moreover, having a good social climate was found to enhance the cognitive abilities of team members. An enjoyable social climate was a strong motivator for taking part in and staying in collaborations (Robson, 2019). Many members of the DoMiNO project described their appreciation of the social environment developed in the research project and identified this as the strength of the project, keeping them engaged and committed.

The building of relationships was important for team members to establish joint capacity and to enable them to develop *trust* in each other, which was identified in the analysis as a pivotal component for the research partnership. I refer to trust as the confidence in each other, reliability in one's actions, procedures, and products. As noted by others, confidence in others is key for the success of research teams (Reed et al., 2014). In contrast, lack of trust is a major constraint on

performance, in which team dynamics may be prone to deterioration over time (Bozeman & Youtie, 2017). Previous relationships enhance trust, but if the prior experience was negative, this will result in a lack of trust and impact scientific outcomes (Stokols et al., 2008). Some studies suggested that trust was stronger in teams that exchanged messages, initiated communication and clear conversations on expectations and roles, had a transparent decision-making process, provided timely feedback, and had an honest conflict resolution process (Bennett & Gadlin, 2012; Stokols et al., 2008). The team's emotional intelligence was suggested to be the base for promoting trust, fostering a collaborative culture, and contributing to creativity in teams (Barczak, Lassk, & Mulki, 2010). My study found that trust was especially important because of the diversity of disciplines involved and the exploratory nature of the project. In DoMiNO, comprehensive communication, deliberations, and feedback, among other processes, enabled the establishment of trust and helped overcome instances in which trust was more difficult to achieve.

Bennet and Galdin (2012) describe three types of trust relevant to research teams. The first is 'identity-based trust', which refers to understanding and appreciating each other's goals and values and reaching mutual understanding. The second is 'calculus-based trust', built by delivering promises, meeting deadlines, and fulfilling expectations with clear deliverables. The third type of trust is 'competence-based trust', which implies confidence in others' capability and competency (Bennett & Gadlin, 2012). This classification of trust correlates with the dimensions of trust described in my findings. My study provides further articulation of those classifications by illustrating in detail what trust meant, how it was achieved, and how it manifested in real-life. Trust was established over time by developing a comfortable feeling with each other, through a lengthy process of alignment of knowledge (identity-based trust). Established trust between members of the team was attained for some members by deliverables (calculus-based trust) and was reflected

by members having confidence in others' abilities and assigning tasks on individuals (competence-based trust). Moreover, my study extends the conceptualization of trust to also include the process of establishing confidence in the project's results by all team members. This was an integral but complex part of the interdisciplinary nature of the project.

Another element that was identified as a key factor by the analysis was the component named *alignment*. I described alignment as the process of forming and maintaining collective and individual orientation and being, more or less, on the same page regarding to the project progress, the project-specific derived knowledge, and the different individual expectations. Similar to the component of alignment, many papers identified the need to find common ground. In interdisciplinary research, common ground implies the need to develop shared bases between conflicting disciplines or theories, and is a necessary process for the integration of competing concepts, assumptions, or theories to provide a better understanding of the research problem (Repko & Szostak, 2017). Often, common ground was discussed in the literature regarding terminologies used (Bracken & Oughton, 2006) and the need to recognize differences in order to integrate different perspectives (Hovelynck et al., 2010). Others discussed the need to align goals (Sibbald et al., 2014) and develop shared understanding and transparency of methods goals and roles, but also acknowledged that obtaining alignment in teams may create challenges to the team progression and performance (Burger et al., 2007; Cooke et al., 2015). As this case described, there were instances in which alignment was more difficult to achieve, and that progression was delayed.

This case study identified another level of alignment, which refers to the project's *progress* and milestones achieved. This was necessary for an interdisciplinary project, such as the one I studied. Like in many other large teams, there was a core of doers, and the team was geographically dispersed. This required common alignment of the progress made, and the different milestones

achieved, as part of creating common ground. Moreover, the progression of the project required an understanding of the background and principles of the different disciplines and the methods used. I named this process the *alignment of knowledge*. It was important to maintain a certain level of alignment between members to foster discussion and support decision-making, integration, and progression. According to the literature, the achievement of what I call *alignment of knowledge* is reliant on several factors; specifically, it requires a comprehensive process of *social learning* to support decision-making processes (Gagliardi et al., 2014; Reed et al., 2010). The need for learning in interdisciplinary teams was described as a necessity and strong motivator for taking part in collaborations and as a significant factor for supporting and training students as part of the research projects' agenda (Lotrecchiano et al., 2016). In IKT, learning was recognized as a significant process in which knowledge users and researchers needed to learn from each other (Sibbald et al., 2014). In my case study, learning had a role in many of the different components identified besides alignment. For example, learning was necessary for building team capacity, individual growth, and a principle fulfilled by DoMiNO's operative elements, like the creation of a supportive learning environment.

The case study presented a need for more in-depth learning of non-commonly used methodologies (*e.g.,* data mining, GIS); therefore, the concept of learning, as part of *individual growth*, had additional significance. *Individual growth* refers to the development of individuals' capacity, intellectual growth, competency, and knowledge. Similar to the, *individual growth* component identified in my study, Cooke et al. (2015) identified 'professional development' as one of the three pillars supporting team effectiveness. They describe this as training and education, or professional development strategies, for all team members, as measures that help address different challenges that team science introduces. They describe training as the intervention to improve team

performance for three categories of outcomes: team knowledge (*e.g.,* task understanding), team skills (*e.g.,* communication), and team attitudes (*i.e.,* orientation, trust, and cohesion) (Cooke et al., 2015). Some individual knowledge-building activities have been shown to enhance collaborative problem solving and decision-making and contributed to team performance (Rentsch, Delise, Mello, & Staniewicz, 2014). My case study further described how the equivalent of a team's knowledge, skills, and attitudes participated in DoMiNO's learning and individual growth.

Further comparisons can be made with IKT settings, in which learning about the research and context, exposure to new ways of thinking and development of relationships, were identified by both researchers and knowledge users as benefits for individual team members (Bowen, Botting, Graham, & Huebner, 2016; Sibbald et al., 2014). In this case study, the interdisciplinary setting fostering a joint process of thinking and doing, created different individual growth trajectories for team members. The setting contributed to intellectual growth, acquaintance with new ideas and perspectives, learning new skills, developing competencies, and professional and personal development *e.g.,* creating new networks and relationships.

These gained individual capacities were part of a transformative process that contributed to the team's collective capacities, which I referred to as the building of *team capacity.* In this case, it was referred to as the team's joint ability to perform together (*e.g.,* co-creation and knowledge translation) and achieve their common goals. As described in the scoping review (**Chapter 2**), interdisciplinary practice and intersectoral research partnerships were instrumental in constructing new knowledge. These partnerships were built on different expertise and experiences and through team development and formed team capacity (Angelstam et al., 2013; Conrad et al., 2013). The essence of team capacity can be indicated by the tangible outcomes of a project, which rely on an integration process as an interdisciplinary research output. Repko and Szostak (2017) define

integration as "*the cognitive process of critically evaluating disciplinary insights and creating common ground among them to construct a more comprehensive understanding within a team*" (p. 21). Integration was a part of team capacity in the case study, and many of the outcomes were the result of the integration of knowledge, ideas, and perspectives between members. Integration could also occur within a single mind (Wagner et al., 2011), which implies the significance of individual growth and capacity building as part of the interdisciplinary collaborative process. Integration contributes to a comprehensive product of an interdisciplinary practice; however, some discuss how this phase of integration may be challenging for teams (Hovelynck et al., 2010; Lillehagen, 2017; Mengis et al., 2018). This phase could include conflicts, opposition, and power inherent to knowledge co-production required for innovation (Klenk & Meehan, 2015). My findings shed light on this process and articulate the development of team capacity over time. At some points in time, it may not have been evident for the team members that it was a joint effort. However, as members reflected on the process, it became apparent that the team's performance and productivity were reliant on the team's capacity. This process was a smooth ride in some instances and also needed to jump over hurdles on other occasions. The built team's capacity enabled the team to overcome challenges and produce satisfying results.

Reflecting on the integration process of insights to create new knowledge, an interesting question arises about value rationalities – whose values should be considered in the integration process? Furthermore, how should this be determined? (Polk & Knutsson, 2008). Additionally, following the principles of equality in an IKT approach in which all voices matter, how should one address hidden hierarchies? For example, in the scoping review, some CBPR papers raised the issue of power among researchers and community members (Downs et al., 2009; Metzler & Higgins, 2003). Hierarchies could also be present among disciplines and this case further

exemplifies this complexity. As described in this case, as part of the integration process, members from different disciplines were sometimes pulling in different directions. The more traditional research methods had a stronger hold. In response to these potential issues, Polk and Knutsson (2008) emphasize the value of participation in a joint co-production, mutual learning, and exchange of knowledge based on reciprocity and reflexivity, as the foundations for increasing the team competence to produce accountable knowledge. In retrospect, in this case, lack of time-restricted deliberations on these specific issues, and joint reflection could have helped to further understand hidden hierarchies and their impact on the integration of knowledge.

Another vital component, identified in the case study, was *shared ownership,* which refers to fulfilling a role or task, conducting individual responsibilities, or taking part in the collective work and ongoing activities, and making contributions over time to the joint effort. Shared ownership also refers to developing a sense of partnership, belonging, and responsibility of the collective work. In this case, the evolution of *shared ownership* had significantly contributed to co-creation, and in particular, to KT development, promotion, and utilization. The general concept of ownership was discussed in the literature under different contexts, emphasizing the purpose of ownership in CBPR for the empowerment of those who may be underprivileged or marginalized or in perceived different power hierarchy (*e.g.,* community and researchers). Others described the concept of ownership as taking an active part in the project, allowing the recognition that the data and research belonged to the community (Burger et al., 2007; Johnson et al., 2014; Schell & and Denham, 2007; Wilson, Wilson, Heaney, & Cooper, 2007). In those cases, stakeholders had ownership over the data and its management, took an active part of the research process, and were owners of the outcomes (Burger et al., 2007; Johnson et al., 2014; Schell & and Denham, 2007; Wilson et al., 2007). Others described that the factors contributing to the sense of ownership in

research partnerships were transparency related to intended outcomes and the activities to get those, inclusion, knowledge sharing, and collaboration throughout the knowledge production (Reed et al., 2014). These concepts could be compared to those applicable in the business sector. Sharing knowledge was described as the means of developing a sense of ownership, which in turn impacted employees' commitment to their workplace (Jian, 2015). Transdisciplinary research literature described that the development of ownership promoted mutual responsibility, joint inquiry, and shared purpose, which enabled and motivated practitioners and stakeholders to contribute to the research and its implementation actively. In addition, it was noted that a lack of balance of ownership within the team could hinder the participatory process (Lang et al., 2012; Polk, 2014).

The findings from my analysis extend the dimensions of the definition and understanding of shared ownership in the IKT process. It articulated how shared ownership developed over time and increased the team members' willingness to participate and take responsibility and encouraged members to be actively engaged in the various knowledge production stages. Moreover, the findings emphasize the significance of shared ownership to KT. Team members felt that the project belonged to all members, which drove many of the KT activities. During, and at the end of the project, members of the team, as groups or individuals, initiated KT activities to present and share knowledge outcomes of the research project and supported knowledge exchange with a variety of knowledge users and settings.

To support research collaborations, existing empirical and non-empirical research identifies the need to promote opportunities to facilitate physical, social, and intellectual connectivity. They emphasize that communication and socialization increase trust levels, facilitate social norms, and establish group identity (Burger et al., 2007; Kothari, McPherson, Cohen, Marjorie, & Sibbald,

2015; Rycroft-malone et al., 2016; Stokols et al., 2008). Additionally, the need to dedicate considerable continuous investment of time and money for meetings and effective communication strategies to help maintain relationships was recognized (Matso et al., 2008; Ramirez-Andreotta et al., 2014; Stokols et al., 2008). My findings are in line with those described in the literature. My study acknowledged the significance of several enabling conditions, which referred to the structural elements available to support a collaborative climate, named *operative elements*. Those were the actions required to support, implement, and sustain the IKT approach. In DoMiNO, members of the team indicated face-to-face meetings (and other communication channels) were instrumental for the teams' growth, and that the time and resources invested in those were worthwhile. Additionally, my analysis identified other operative elements, such as supporting a learning environment and sustaining an inclusive setting to support engagement, inclusion, learning, and reflection **(Figure 5.2)**. **Chapter 4** described in detail the different activities **(Figure 4.2)**, which helped shape and facilitate the IKT approach.

Another interesting aspect of the *operative elements,* identified by the analysis, was the significance of *embracing an attentive leadership style*, which was necessary for setting the tone for collaboration and impacting how the partnership evolved. There is an overarching agreement in the scientific literature about the significance of leadership to the effectiveness of teams (Gagliardi et al., 2014; Nancarrow et al., 2013; Stokols et al., 2008). Existing empiric and non-empiric evidence imply that leadership could influence different team processes, such as team mental models, team climate, physiological safety, team cohesion, team efficacy, and team conflicts (Cooke et al., 2015). Others also describe leadership as a dynamic process that is transformational and adaptive to the team's needs, fosters positive interpersonal processes, promotes participation, inclusion, and empowerment of the team, providing encouragement and

generous feedback, and helping others to succeed. These features of leadership enable leaders to build trust and cohesiveness among team members and facilitate high performance (Robson, 2019; Salazar, Lant, Fiore, & Salas, 2012; Stokols et al., 2008). These descriptions correlate with the findings of this case study. The analysis provides additional empirical evidence identifying that leadership had a key role in the project's success by creating a collaborative climate, encouraging individual participation, keeping the momentum, and promoting the development of the sense of true partnership. The analysis also articulated the attributes that make a valuable leadership style, such as, respect, patience, commitment to inclusion, generosity, sincerity, inspirational as role models, providing feedback, and responsive to input from the team; all of which contributed to setting the stage for collaboration and success.

The scientific literature often targets best practices for the project's management, placing the responsibility for the collaborative aspects on the leadership. Considering the important role of leadership in the collaborative process, this is expected. However, contemplating the concept of two-way communication in a collaborative project, as an individual's responsibility is an important aspect. This aspect of collaborative research is described in less detail in the literature. It was referred to as 'self-awareness'; how one operates within the team, individual characteristics, or intrapersonal elements that include different individual motivators and traits (Bennett & Gadlin, 2012; Lotrecchiano et al., 2016; Nancarrow et al., 2013). In this study, I identified *individual attitudes* as a vital component for building a collaborative climate. This component helps emphasize and articulate the meaning of the two-way approach, as a recommended practice for collaborations and partnerships. As described above (**Chapter 5**), participants acknowledged that there was an individual component that was essential for two-way communication to create a collaborative climate. It included individuals' commitment of time, attention, and active

engagement to provide feedback and input, participate in deliberations, take part in a reflective process, and have a mindset of being open-minded to different perspectives. Together, they define what it means to be a team member.

The eight components identified in this study support the advancement of the research project and contribute to the research team's performance and productivity. These findings suggest that the lack of these components, or difficulty in achieving them, can hinder and delay progression. The components described in my study have similarities with empirical findings and non-empirical conceptions existing in the broader literature, which confirm the validity of the findings. My research contribution expands current understanding and clarity of the IKT collaborative process by describing additional nuances and articulating some of the concepts and their meanings, significance, and implication for research collaboration, research outcomes, and KT, based on empiric evidence from a real-life example. Moreover, similarities to other contexts suggest that the IKT collaborative components identified in this case study may be of value, beyond the specific case, to other research partnerships in different contexts.

Another contribution of my study is providing one comprehensive list of the essential components for collaborative research. Although there were similar elements described in the literature, they appeared in a fragmented manner. I did not find all components identified in my study as part of any paper, empiric or not, regardless of context or research approach. Therefore, introducing these components together, as those essential for inter- and intra-team processes, suggests a new angle for understanding the collaborative research process.

7.3 PUTTING THE PIECES TOGETHER – MAPPING THE COLLABORATIVE PROCESS AS A JOINT EVOLUTION OF SEVERAL COMPONENTS

My case study's findings identified and articulated, the components that constructed the IKT process and what they meant in-depth in one actual case situation (*i.e.,* DoMiNO) (**Chapter 5**). One may ask, is there one component among those identified that would be the most significant for an effective collaborative process?

The scoping review (**Chapter 2**), showed no indication of prioritizing a specific aspect of the collaborative process as more significant than others. Instead the review identified that the collaborative process is composed of several factors acting in combination. Similarly, in this case study, the described independent components overlapped and had interdependent connections among them reflecting a dynamic and complex framework. The framework identified in this study provides a comprehensive map that conceptualizes the team's processes required to build, shape, maintain, and implement interdisciplinary IKT collaboration and promote team performance, productivity, outcomes, and KT.

I present several examples of empiric and non-empiric studies that portray a map of the different elements that shape the collaborative process, presented as frameworks, models, principles, and typologies. For example, Reed *et al*. (2014) developed five practical principles of knowledge creation and translation for research collaborations of researchers and stakeholders in environmental management. Based on their empiric findings, the first principle considers knowledge exchange as part of the project design from the outset throughout the research project. Other principles refer to representing a diversity of perspectives, engaging in creating a collaborative culture, generating impact, and reflecting and sustaining the collaboration through

evaluations and learning. They indicate the rationale behind those principles to enable the development of long-term relationships, trust, and shared ownership to support the KT process (Reed et al., 2014).

The transdisciplinary research literature provides more insights into collaborative frameworks. One example is the 'TD-co Production Framework'. This framework was developed by an organization committed to sustainable urban development, which included researchers and various stakeholders in the research and translation processes (Polk, 2014). Their framework's objective was to create mutual responsibility, joint inquiry, and shared purpose that will help capture and integrate different views to develop valuable knowledge for societal change. That framework was operationalized by focusing on five focal areas: inclusion, collaboration, integration, usability, and reflexivity. The author included five case studies from their organization and described the methods, activities, and strategies used in the project in separate phases. The focal areas of this framework align with the components of my proposed model such as the principles that inspired the operative elements and encouraged responsibility (ownership) and commitment, as identified in my study. The author described different activities to support co-production, such as communication, reflection, and learning opportunities. The strategies address the need to find ways to embrace all perspectives, bring everyone to the same line of knowledge to foster co-production (maintain alignment and build team capacity), and find ways to integrate knowledge and identify useful (translatable) knowledge. Although my research is based on one case study, existing similarities confirm the validity of my findings. In some aspects, my study adds a more in-depth understanding of some of the processes described. I suggest that my study can complement Polk's framework by illustrating the common concepts as an evolution of processes, describing and articulating the process of learning, and the significance of individual

growth, the building of good relationships, and the establishment of trust to the collaborative process.

An example from the CBPR literature is the 'Conceptual Logic Model of CBPR Process to Outcomes' (Belone et al., 2016). The authors suggest this model as a self-reflective tool for collaborating teams. In this model, the context (socio-economic status, policy trends, institutions' role, previous collaborations, the partners' capacity, and health issues) constitutes a significant role in the collaborative process. The other constructs of the conceptual model that contribute to outcomes were group dynamics (*i.e.,* structural, individual, and relational dynamics), and intervention and research. The authors emphasize the significance of trust development, capacity building, mutual learning, reflection, and power sharing. My project findings confirm the essence of these points and contribute additional understanding and articulation of the different dimensions of individual and combined evolutionary processes that are essential for collaboration such as trust in the outcomes, or alignment of progress, knowledge, and expectations.

Other instances of collaborative research originate from 'team science' literature. For example, Bozeman *et al*. (2016) developed a model to illustrate the factors, which lead to the effectiveness of research collaborations based on interviews with academic researchers. This model includes external factors, internal factors (*i.e.,* team and individual characteristics), and team management factors, (Bozeman, Gaughan, Youtie, Slade, & Rimes, 2016). My project findings extend this model by adding another level of processes required for the team to build cohesion, such as alignment and ownership while acknowledging individuals in the partnership (*e.g.,* the contribution of individual development to the team's growth). Salazar *et al.* (2012) developed another interesting model based on several conceptual works published by others. They argue that social integration evolves alongside knowledge integration through the development of emergent

states, such as trust and team identity. They suggest that integrative capacity built on cognitive processes, psychological states, and social processes enables science teams to overcome team processes and contextual barriers, to generate innovative scientific insights and products (Salazar et al., 2012). My project supports this model. As seen in the case studied it was the team joint capacity that helped overcome challenges. Furthermore, my study offers empirical evidence that illuminates the processes required for building this joint capacity for integration and innovation.

Stokolos *et al*. (2008) created a typology of contextual elements that influence transdisciplinary collaborations to describe the ecology of team science. Based on their review of empiric and non-empiric literature, they classified the contextual factors, which may hinder or enhance the effectiveness of transdisciplinary teams. This classification included inter-personal factors (*i.e.,* between team members), intra-personal factors (individual attributes), the physical environment, organizational (institution supports), technologic (infrastructure), and societal and political environment contexts. They provided a comprehensive list to describe each of these contextual elements (Stokols et al., 2008). Of relevance was their description of the social cohesiveness, diversity of perspectives, ability to adapt, communication for developing common grounds about goals, and a hospitable environment. The authors discuss 'shared responsibility' as a concept, but not its evolution or the significance for KT. They identify in their typology elements like relationships, trust, alignment, individual attitudes, leadership style, and communication channels as significant to the collaborative process. They suggest that since each project is unique, research teams should adapt them according to their specific project relevance.

There are similarities that pertain to interpersonal and intrapersonal concepts discussed in this typology and my findings. My findings add detailed descriptions for some of the concepts, such as trust and ownership. My study also extends the notion of alignment, introduces the issue of

advancing individual and collective knowledge, and the concept of ownership to enable processes to evolve and operationalize KT. It also adds an understanding of the challenges identified by this case, which could relate to an individual, team, or contextual conflicts. Furthermore, my study emphasizes the efforts and time required for IKT partnerships to develop and grow as well as the evolution of the KT planning and its application, which develop as the research progresses, from start to finish (**Figure 7.2)**.

Research projects start with an 'initiation phase' (Zych et al., 2019). In this case, this phase included putting together a partnership, applying for funding and then shaping the frameworks for the research project, establishing initial relationships, identifying tasks and roles, and discussing the development of KT. Team members in the DoMiNO project were engaged in formal and informal deliberations to articulate KT plans to exchange knowledge during, and at the end of the project. The exploratory nature of the research implied that only part of the KT planning could be predefined, and articulation of the end-of-project KT had to mature over the project progression. KT plans to design the goals, messages, audiences, and strategies were articulated once the research matured; thus, the development of KT plans and outputs was an evolving process alongside the evolution of the team and project. Different components contributed directly and indirectly to the development, initiation, planning, dissemination, and application of KT initiatives. For example, establishing alignment of the project's expectations, goals, and outcomes were necessary processes to foster the discussion and guide the design of KT activities for articulating the audiences and messages (*i.e.,* what is feasible and appropriate to share). Additionally, developing individual and team capacity, establishing trust in the outcomes, and developing a sense of shared ownership were major processes that contributed directly to the initiation and application of KT activities.

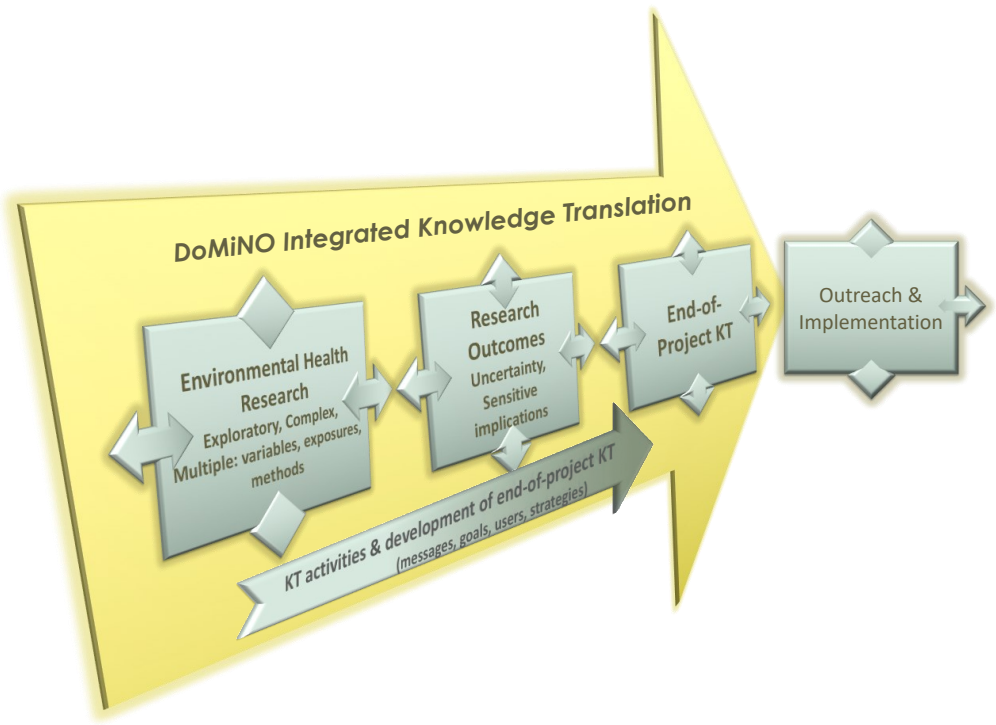

Figure 7.2: KT is a dynamic process that evolves alongside the research project. The specific characteristics of the project impact it. The KT activities occurred during and at the end of the research project. The end-of-project KT planning evolved alongside the research project. Although there were predesigned plans when the project started, considering the exploratory nature of the DoMiNO project, articulation of the end KT plan (messages, audiences, goals, and strategies) transpired once the research progressed and matured.

As part of my journey to learn about the IKT process in the context of environmental health, I also drew from other collaborative approaches (*e.g.,* transdisciplinary research, participatory research). In the DoMiNO case, I had much to learn from the sensitivity of CBPR about research partnerships. For example, CBPR literature extensively discussed the significance of relationships, trust, learning from each other, and the concept of inclusion, which contributed to understanding

intra-personal aspects of collaborations. Transdisciplinary literature provided insights into the complex process of integrating different perspectives that contributed to the understanding of intra-team processes essential for knowledge creation. Despite similarities to other collaborative approaches, the uniqueness of IKT is the explicit inclusion of knowledge translation use and impact as part of the research process (Nguyen et al., 2020). In other research approaches, these are described in broader strokes. Based on these observations, I argue that cross-fertilization by different collaborative research approaches can enrich the practice and science of IKT.

This thesis provides a holistic map of components that, otherwise, appeared in a sporadic, fragmented manner in the literature. The findings extend the current literature on IKT collaborative processes by providing in-depth empiric evidence to understand the nuances and dimensions of different concepts from a real-life experience. The theory and model developed based on the findings from this case can complement the typologies and models described above by enriching the understanding of what these processes could encompass and the interdisciplinary collaboration as an evolving process. It emphasizes that the collaborative process is based on the joint evolution of components and provides a comprehensive framework that includes the process outcomes and KT (**Figure 7.1**). Moreover, based on my findings and similarities to other approaches in the broad literature, I suggest that the findings from this case may be of value to IKT initiatives or other collaborative research approaches. Additionally, the lessons learned may be transferable to research teams in other contexts (beyond environmental health research) to optimize interdisciplinary and collaborative knowledge creation and translation.

7.4 THE SIGNIFICANCE OF CONTEXT TO THE IKT PROCESS

As shown, the context is one of the variables in the framework presented in **Figure 7.1**. In light of the potential transferability of my findings, one may ask: what is the significance of the context to the IKT process?

Context adheres to external elements, such as political, social, and institutional factors that impact the research collaboration, as identified in the scoping review (**Chapter 2**) and demonstrated by others. The context also refers to the topic or field of research and its unique characteristics. In this thesis, I focused on the latter and identified the impact of the research field context and its accompanying features (*i.e.,* interdisciplinary practice, discovery research) on the IKT process.

As I described in the previous chapters (**4, 5, and 6**), the context of research in the field of environmental health had an impact on the research partnership progression and performance (*i.e.,* co-creation and KT), and how the essential components of the collaborative processes manifested in this case. In addition, the context had implications on the outcomes and KT.

The topic of the research directed the team composition (*i.e.,* expertise and roles) and was a significant motivator that encouraged team members to participate; for some, it was addressing the hope to conduct research that could benefit society. The research context also had a role in shaping how the different components identified in this study play out. Some components may be more relevant and necessary for this context than in other research contexts. For example, in this case study, individuals needed to learn about different disciplines (*i.e.,* individual growth), which required a steep learning curve for some team members. These learnings fostered discussion and progression (alignment of knowledge) and were instrumental in building the team's capacity. Another consideration of the components is the need identified by knowledge users to approach KT development with caution to avoid the creation of health alarms. This meant the need to ensure

alignment of the team members' expectations of what the project outcomes impact could be, and what was feasible. These components may have a lesser or different role or expression in other contexts.

There are also difficulties introduced to the research process by the context. The context of research is complex because of the research question; *i.e.,* an evaluation of the impact of chemical mixtures, and the research outcomes that may include some level of uncertainty and may not have the same scientific confidence level achieved by case-control studies. These characteristics of the research context create a complex decision-making process, because of the difficulty of agreement or validation of research outcomes. This challenge of reaching agreement can occur in interdisciplinary projects, as demonstrated in several other cases (Mengis et al., 2018; Podestá et al., 2013). Similar challenges were also apparent in the DoMiNO project; finalizing the kind of findings resulting from the research was decided according to how outside knowledge users will perceive the findings and not the original objectives of the project. Some researchers perceived that the results might not be acceptable to other users. In order to overcome these hurdles, a flexible co-creation process was required at the finalization stages to accommodate all perspectives. Descriptions of these challenges further illustrate the need for interdisciplinarity alignment on many spheres, including expectations on what the project can and cannot achieve. The need for team capacity for the integration of knowledge is also necessary.

These observations of challenges experienced by research collaborations may be of special relevance in a sensitive context, such as air pollution. Collaborations of researchers with policy-makers may be helpful to advance policies, and such interaction was described in a case study on promoting policies in air pollution (Garnett et al., 2019). Their collaboration included a complex process that implied many compromises from researchers on the significant topics for future

policies. Additionally, at times, structured collaborations with stakeholders for co-production and translational efforts, do not ensure change and results are not easily integrated into policy contexts (Polk, 2014). An example representing the complexity of research impacting policies is the process of evaluating the causes of cancer in humans by the International Agency for Research on Cancer (IARC) (IARC, 2020). Although IARC is considered the highest authority of classification in the topic, it does not recommend regulations, legislation, or public health interventions, but acknowledges that these steps are the responsibility of governments and international organizations. Thus, the social, economic, and political environment has a substantial role in determining policy changes.

The complexity of formalizing the KT (*e.g.,* goals and messages) in this context also relates to the expectations of the funding agencies and the research team, that research would have an impact facilitated by KT activities. It was indicated that dealing with preliminary results was a challenging issue to negotiate with knowledge users (Reed et al., 2014). Some argue that the sense of accomplishment achieved by translating knowledge to practice requires that all expectations are met for all those involved in the project (funders, researchers, and users) (Roux et al., 2010). However, is that feasible? IKT may create an illusion, and maybe build expectations of visible and fast impact on policy, practice, or research. Nonetheless, results from exploratory research like the DoMiNO project can hardly make enough of a difference to achieve changes in practices or policy (*e.g.,* air quality standards). Rather, they are a preliminary, yet an important phase in the accumulating scientific evidence on air pollution and health. On the continuum of knowledge translation possibilities, a project like this could apply dissemination strategies, which refer to tailored communication but not the application of knowledge for impact (CIHR, 2016a).

It is also important to mention the influence of the context on knowledge users' role. The DoMiNO project *integrated knowledge users* were representatives from government, health agencies, and an NGO. The other atypical integrated knowledge users were data providers. As this case shows, knowledge users felt unclear about what would be expected from them and what their role would encompass at the outset of the research project. Much of this unclarity was related to the exploratory nature of the project. Over time, the knowledge users' role evolved and materialized, as they became vital contributors to the progression of different spheres of the research project. They contributed to steering the project and were involved in KT activities in their organizations. This evolution required the development of individual growth and other processes, such as relationships, trust, alignment, and the development of shared ownership, which inspired knowledge users to stay interested and engaged despite preliminary uncertainties. In the DoMiNO project, there was also an evolution of a dual role of interdisciplinary team members/researchers as knowledge users. As the project progressed, researchers from different disciplines and practitioners initiated and applied KT activities in their faculty and with their discipline colleagues. This observation suggests an extension of the usual classification of integrated knowledge users, especially in highly diversified teams, which invites creativity into who knowledge users can be. This is also a suggestion to consider team members as knowledge users at the outset of the project to foster the discussion on KT throughout the research progress.

The complex research context also implies that the end-of-project KT may be impacted by the time available for the finalization of KT. Although there are the official start and end time for research projects (*i.e.,* as defined by funding agencies), the actual time required for a complex research project from conception to end is frequently much longer. Projects start before funding is allocated and continue after their official end, especially the KT efforts. It often happens that there

is a lag between the official end of the project, the finalization of research outcomes, and the KT (Reed et al., 2014), and those translational efforts are limited by the project time frame (Polk, 2014). In many cases, certain parts of the KT plan can only occur long after the project has officially ended, because finalizing some parts of the project and validation in terms of published outcomes of the research, may occur at the end or outside of the funded research project timeframe. This means that after the official end of the project, a lack of resources (personnel, funding, and the team's active engagement in planning) may limit KT and subsequent completion of the end-of-project KT. Some projects seek additional funding, or as demonstrated in this case, team members' commitment beyond the project's timeframe enabled KT activities to occur.

This presents a challenging issue: how can researchers, knowledge users, and funding agencies accommodate and address the lag between finalizing the research outcomes (*e.g.,* publication) and the KT for these outcomes once the project officially ends? Moreover, how would one best apply end-of-project KT beyond the boundaries of the research project? Perhaps, research projects (and funding agencies) should plan for a separate time block and resources dedicated to KT for those outcomes achieved later. Moreover, IKT and KT may require additional or different measures to evaluate success (Dixon & Elliott, 2019). In this case, the measurement of success could be viewed as the tangible outcomes (contribution and outreach /KT of new knowledge), and intangible outcomes, such as long-term impact of the outcomes, team growth, and the formation of strong connections, capacity, collaborations, and individual learning on multiple domains.

As described above, the context is relevant to the IKT process. Therefore, IKT applied in other research contexts may look different in some aspects of co-creation and differ in the design, implementation, and impact of KT. Indeed, no one size could fit all, and context should be considered in the application of IKT. In the specific context of environment and health research,

considering the interest and need for safeguarding public health, and understanding the role of environmental variables, collaborations are required for co-production and translational objectives. Thus, as described in this case study thesis, a collaborative framework could be complementary and guide other research initiatives in environmental health research that usually do not consider the aspect of collaboration practice as part of the research process.

7.5 STRENGTHS AND LIMITATIONS

STRENGTHS

The thesis provided an in-depth understanding of complex team processes of an IKT approach. As with any research, limitations, and strengths shape the outcomes. The realm of methodological and contextual aspects applied contributed to the strengths of this study and helped to overcome some of the limitations, as discussed below. Through this work, I am contributing empiric evidence to the literature. At many times existing publications provide descriptions of the collaborative process that are based on opinions, commentaries, and conceptions. With this case study, I confirm previous observations and illuminate new understandings of the IKT process that may be valuable for other research teams.

Contextual strength

Environmental health literature and literature from other contexts described the components identified in this study in a fragmented manner (*i.e.,* none discuss all these components, regardless of context). This study adds empirical evidence to help narrow the gap of understanding collaborative conditions and practices for those involved in environmental health research by using a detailed qualitative methodological approach. Thus, the study sheds light on team processes and,

more specifically, on the application of IKT. These aspects, unlike in social sciences or KT science domains, are not usually considered in this field.

Moreover, this study followed, as a case, a research project that was unique in its context, but similar to other projects in regards to the processes and conditions required to enable a collaborative climate. Thus, this study results may provide learnings applicable for other contexts and enable readers to draw implications for their research collaborations.

Methodological strength

Through a prolonged engagement with the case, I provide a comprehensive description of components of individual and team processes that are essential for research collaborations, as perceived by the team members. In that sense, a methodological strength was the case study research design that included prolonged engagement with the case from start to finish. The research design also included various methods to collect and generate data in all phases of the case, including in retrospect, to support the crystallization of my findings. Bringing together multiple methods and sources enabled a comprehensive view of the collaborative process. I employed a rigorous analysis process, which enabled overcoming some of the limitations this research introduced (see below). Furthermore, my position as an 'insider' (as the coordinator) enabled access to the project happenings, documents, events, and detailed information on the project progress. Moreover, it facilitated the team cooperation to fulfill the case study requirements (*e.g.,* participation in focus groups). I will further discuss the pros and cons of my position as an insider researcher in the next section. All these measures enabled me to provide a robust description of experiential learning and multiple realities and reliable empirical evidence that 'particulate' the collaborative process, which is the aim of case studies (Stake, 1995).

LIMITATIONS

It is important to recognize some of the limitations related to the project's scope and methodological aspects and how I addressed those when possible.

Methodological aspects

Limitations of this study relate to the research design and methods applied. This thesis focused on a single case study approach, which implies no comparison with other cases as part of the research design. Some may consider applying a single case study approach to hinder generalizations, limit the implications from the case, and thus, question the contribution of such research. However, according to Flyvbjerg (2006), the force of examples from a single case study as a source of scientific development is underestimated. A singular case study enables an in-depth and at length exploration. It can capture the complexities of the case and articulate the details of the case and its interaction with its context. Generalizability of results cannot be assumed from a single case; however, a case study invites 'natural generalizations' (Stake, 2005), which mean that the readers recognize the case to be relevant to their own cases and find commonalities of processes and situations, which can then enable transferability of the findings (Denzin & Lincoln, 2005). In this dissertation, I provided ample angles and detailed descriptions of the case to enable understanding of the case, its context, and the themes that compose the IKT collaborative process, to enable the readers' 'natural generalizations'.

Exploration of a singular case also implies that the research cannot be reproducible. Reproducibility usually relates to a positivist paradigm, in which a hypothesis is investigated, and the results can be reproduced wholly or partially by conducting another study using the same

material as in the original investigation. However, from a constructivist perspective, it would be impossible to recreate the particular conditions that construct the research, nor is it the intention of this study; rather, the aim is to tell the story of this case. I acknowledge that the story was told in the way that I have seen it and that others may see some aspects, differently. Hence, by providing a 'thick description' of the case I offer the readers enough material to make their own 'natural generalizations' and understanding of the case, research procedures, and findings. The DoMiNO case had a unique context and characteristics. Thus, this case cannot be reproduced; however, many aspects identified in this case may be similar in other research projects. Therefore, this case study serves as an instrumental case, which could provide learnings for others in the context of environmental health or other contexts.

Another limitation relates to potential bias introduced by my dual role as a team member and as a researcher. It is important to note that bias may be integral to qualitative research (Morse, 2003), but I followed some strategies to minimize the bias and its impact. Moreover, in qualitative research, the researcher is considered the instrument in the research (Brodsky, 2012). This means that the researcher's generation of data and interpretations of those data are the result of the researcher's experience, knowledge, and position. Nonetheless, a possible limitation to this research could be conscious and unconscious bias and their impact on the assumptions made and interpretation of results. I addressed the potential bias by applying an iterative data collection and rigorous analysis procedures to test if the bias led the analysis and findings. I benefited from prolonged engagement with the case and a rich dataset that enabled testing, comparisons, and views from different angles. Regular analytic discussions with supervisor and committee member, including one not involved in the IKT world, provided the opportunity to be challenged in my

interpretations and assumptions and to consider alternative explanations. This assisted in helping prevent imposition of my preferred ideas on the data.

The project's scope

The case study is a 'bounded system' with defined borders of exploration *i.e.,* the time period of the case and accompanying activities, and the included or excluded participants. While these enable a rich and in-depth perspective of the case it excludes other issues that are beyond the scope of the case. For example, although the case was spread over five years, I was unable to capture all outcomes of the DoMiNO project and the activities that led to those. Some of the research project outcomes were not fully-fledged at the official end of the project (which often occurs in such complex research projects). Therefore, I was unable to follow all the processes that led to the KT activities that ensued after the project ended. However, my study was able to identify and articulate the processes leading to KT activities within the IKT framework that occurred during the period of the case study.

Another bounding factor relates to the participants included in the study, which were all members of the team who took part in all or most of the research project. My choice was to learn about the ongoing processes, and they were the ones who could provide rich data that refers to processes that occurred over time. Therefore, the rationale was that those who were not part of the entire project (joined for a meeting or two as guests or members who left) could not provide input about the ongoing progression of the collaborative process. However, I acknowledge that those individuals' perspectives may have offered additional views on the concepts described (*e.g.,* if the components identified were connected to the reasons for not staying involved).

Another limitation that refers to the project scope is that the case study was constructed and based on the team members' perspectives. I aimed to capture all perspectives by using various methods and measures to attain rigour of the analysis procedures and findings. However, it is possible that I was unable to capture some members' perspectives. To address and minimize this limitation, I benefited from being situated in an insider position, which enabled me to capture the activities in DoMiNO for the whole duration of the process (from inception to completion). I have also applied multiple data collection methods to optimize the data available, reach saturation, and establish the findings.

7.6 THE PROS AND CONS OF CONDUCTING RESEARCH AS AN INSIDER

In my study, I had a unique position as a *complete member researcher* (*e.g.,* a researcher who is fully affiliated with the case setting, an *insider*). My research study was part of the DoMiNO project, where I had a dual role in an overlapping period. I was DoMiNO's research coordinator (2013-2017) and a Ph.D. student (2014-2020), conducting my research on the collaborative process, the subject of this thesis. A researcher position could have implications on the research. In this section, I articulate this role's benefits and challenges and how they were addressed and discuss the advantages of such position for future studies on the IKT process.

This insider position has been contested in the literature. Stake recommends that researchers in case studies should try to minimize involvement in the case (Stake, 1995). Concerns were also raised that researchers involved in the actual research will be placed in an untenable position (Johnson-Bailey & Ray, 2012). Others claim that this type of research could lack an appropriate

standard of intellectual rigour because of personal involvement and emotional investments in the setting. They argue that being too close to the project prohibits the distance required in order to attain neutrality, which, for some, is a necessity for valid research. These claims mainly originate from a positivist paradigm, which supports objective inquiry, thus, placing the researcher 'outside'-detached and neutral from the research topic (Brannick & Coghlan, 2007).

In contrast, counterarguments, addressing these concerns about complete member research, highlight the benefits and advantages of insider research as a valid research approach. Inquiry from the 'inside' involves researchers as actors immersed in the setting, who can generate contextually embedded knowledge. Brannick and Coghlan (2007) describe insider researchers' positions in organizations as being native to the setting, enabling insights from the lived experience, pre-understanding, and built-up knowledge of an organization. Furthermore, complete member researchers have access to the issue in question and secondary access to documents, people, and meetings. Garrent *et al*. (2019) described their experience in an ethnographic research of a project that brought together scientists and policymakers to prioritize actions to address air pollution and health. They indicated their partial access to different aspects of the research and researchers' work as a limitation to their study. Accessibility and familiarity with the research team also suggest rapid acceptance by participants. Participants may be more open and willing to share their experiences and perspectives with the researcher (Garnett et al., 2019). Dwyer and Buckle (2009) argue that being a team member automatically provides a level of trust and openness and that this position provides a good starting point for research. It helps build common ground and develop intimacy and knowledge available only to insiders.

My experience demonstrates that my dual role enabled access to both participants and context-specific knowledge. Moreover, I have also noticed the DoMiNO members' willingness to

participate in the different activities my research required and share their perspectives throughout the research (*e.g.,* interviews, focus groups, and reflective activities). A good example is the invitation to participate in the final focus group. All invited participants responded to the request and generously volunteered their time, perspectives, and thoughts (except for those who left the group or were not available at suggested times). I assume this was partially a result of the relationships and trust built between the team and myself.

Corbin Dwyer & Buckle (2018) also discuss possible challenges and drawbacks to a researcher having complete membership in the setting studied. It is possible that because of this acquaintance, participants will fail to explain themselves fully and that the researcher may be led by their own assumptions and personal experience as a member of the group. As a result, they may find it difficult to separate their perspective from those of the participants. When the researcher is familiar with the setting and participants and has an additional role, this might create confusion in distinguishing whose perspective is presented, which may impact data analysis. However, it is important to note that there is no immunity to this confusing issue and risk in any research. Throughout my research, I have noticed this challenge, especially while analyzing the data. Through a reflexive process, I had to continually question what the participants' perspectives were, and what were my own. At times, they mingled.

To address this difficulty, I developed the sensitivity to identifying when my perspective as a member came to play, or when my interpretations were based on intuition and my own knowledge or assumptions, instead of the participants' views. I clearly documented these instances in any of my written data resources. For example, concepts that were not as explicit as others, such as trust or ownership, could have been intuitive. This required an iteration of analysis to conceptualize latent meanings and additional verification with participants (*i.e.,* in the final focus groups). Since

I was well aware of this possible bias, I was able to minimize it. When we are not aware of biases is the time that they will more likely have an impact on our work. I repeatedly 'dug' into the data, to explain, compare, and crystalize in order to minimize misperceptions, verify, and increase the validity of my findings. I benefited from prolonged engagement with the case and multiple data sources, which enabled me to conduct those explorations in various data sources from different time points.

Other descriptions of challenges in the literature refer to the burden of a dual role on the researcher, who needs to fulfill the demands of both roles (Brannick & Coghlan, 2007; Corbin Dwyer & Buckle, 2009). These roles require the researcher to juggle between the two to provide enough attention, time, and focus on one of the two. This was indeed challenging at times; I was involved in coordinating different parts of the project for most of the DoMiNO project 'life'. At the same time, I was collecting and generating data for my qualitative project and engaging in analysis. However, both of those role experiences contributed to my research. Researchers in qualitative studies are considered a tool or instrument in the research (Brodsky, 2012); *i.e.,* the interpretations made by the researcher are the result of the researcher's experience, knowledge, and position. By taking part in these two roles, I was engaged in a journey from inside to outside and back, and from near to distant and back, in a newly defined space. In the fourth year of the project, my role as coordinator ended, and my time was entirely dedicated to my research. Creating some distance from the DoMiNO project helped me progress my Ph.D. project, especially in the later stages of my thesis. This distancing provided me with uninterrupted time to give full attention to the research and analysis. It enabled me to look at the DoMiNO project with more neutrality of the whole collaborative process.

Adler & Adler (1987) state that the distinction between an insider and outsider exists more in theory than in practice. In fact, this binary dichotomy between insider and outsider does not reflect the 'space in between' (Corbin Dwyer & Buckle, 2009), which many researchers occupy. This space enables a more in-depth knowledge of the experience studied. The 'space in between' implies that the researcher is similar and un-similar to the participants and that in order to understand yourself, you need to understand the others. Dwyer & Buckle suggest that qualitative researchers are more connected to their research participants (compared to quantitative researchers) since they live the stories and voices of their participants. Qualitative researchers cannot retreat to a 'researcher only' space or role. Thus, this 'space in between' represents the intimacy of qualitative researchers, which does not allow them to be true outsiders. On the other hand, because of their researchers' role they are not complete insiders and so occupy the 'space in between' with its benefits and costs (Corbin Dwyer & Buckle, 2009).

In summary, my dual role in the case had both benefits and challenges. However, it is my opinion that this dual role as a researcher and coordinator ended up nurturing both roles, despite the limitations. The coordinator role enabled access to data, promoted cooperation of participants, and provided a comprehensive understanding of the case, the context, and the different stages and situations team members were involved in during the project operation. In that sense, I cannot think of any other person, or role, that could have had access and knowledge of the project to enable the attainment of this case study. Although this dual role may have introduced challenges and limitations to my research, a thorough and robust design of data generation, analysis and reflection helped to mitigate these limitations. On the other hand, the knowledge acquired during my research process benefited the project. I was able to identify and inform the operation of the

project about different requirements and apply adjustments for the collaborative process. Moreover, I believe, I improved my performance as a coordinator.

The IKT approach promotes the evaluation of the collaborative aspects to optimize the project's operation. The idea of having an individual whose role is learning from the team, as part of a collaborative research project exists in the literature under different contexts for example, as the role of an embedded researcher (Cheetham et al., 2018), or formative accompanying researcher in an interdisciplinary project (Freeth, 2019). Other authors recommended that interdisciplinary teams include an individual, or researcher, whose responsibility would be to manage the collaborative aspect of the research project (Meadow et al., 2015; Ramirez-Andreotta et al., 2014). This insider researcher position experience illustrates a real-life example of this role complexities; the benefits, challenges, and how those were addressed. This description may be relevant for researchers and research teams who wish to engage in reflective and formative evaluation of the collaborative practice or IKT research.

7.7 Reflection: My research journey

In qualitative research, the researcher is considered a tool in the research process, as the researcher brings their position, assumptions, values, and experience into the research process. At the same time, the researcher aims to be as neutral as they can when they approach the research and engage in analysis and interpretations. I have written this reflection to further articulate my personal experience in this research journey.

I have always been interested in understanding why despite all the abundance of research done and knowledge accumulated there seems to be little impact on policies, specifically regarding environmental health issues. I became familiar with the complexities involved in such research, its communication, application, and impact. I realized that in order to promote knowledge use there is a need for more than communication strategies and exploring the contribution of collaborative research to both the research and KT was an exciting avenue.

An invaluable opportunity came to be with the DoMiNO project. I was involved in the inception of the project, and the different phases it went through before it received funding and came to life. As the research coordinator at the time, I was responsible for conducting the baseline interviews with the DoMiNO team members. This was an exciting exposure to a new way, for me, to approach research. I enjoyed the discussion, interaction, and learning that were possible through this method. I was hooked. Soon enough, I found myself registered as a Ph.D. student. This was a perfect fit. Researching the complex phenomena of the IKT process introduced an opportunity to learn about the contribution of collaborative research to co-production, KT, and the processes involved. It was also a neutral development of my role as a coordinator. The research would help me achieve a deeper understanding of team processes; what was important for team building, and why.

Having mostly a quantitative background, I came into the research as a novice qualitative researcher. I needed to acquire new research skills, but moreover, adapt to a new way of thinking and doing research. I needed to acknowledge that my approach to research and accompanying assumptions were guiding the research process. It was challenging and required transformation and reflection to genuinely appreciate and represent the different voices of team members without imposing my assumptions and thoughts. It has not been a simple route. As I discussed in the thesis,

being an insider in the case I was researching introduced some challenges. I applied several approaches to ensure I am not letting my assumptions take over the analysis and that I was staying as neutral as I can throughout the data collection and analysis, while recognizing myself as a tool in the research. It was a route of constant learning and revelations. I was moving from descriptive analysis into deeper explicit and implicit meanings of my findings. I went through numerous iterations that at times seemed to have no end. Once the findings became clear and comprehensive it was an eye-opener of what can be achieved and was extremely satisfying.

7.8 CONCLUDING REMARKS, IMPLICATIONS, AND FUTURE DIRECTIONS

This thesis illustrated the DoMiNO project's journey and identified what it takes to shape and implement IKT in an interdisciplinary project engrained in the context of environmental health bringing attention to the collaborative aspects of this field of research. It is the first study to explore IKT in an environmental health context, to the best of my knowledge. My work offers a comprehensive example of the team processes in which interdisciplinarity and IKT need to be managed for the co-production of knowledge and KT. The study articulates eight essential components for the collaborative research processes as intertwined processes and describes practices that support it. Together, the components build the collaborative process and support team growth and capacity, which led to performance, productivity, and ultimately to tangible and intangible outcomes.

The work included in this thesis study further evidenced the complexity of collaborations by describing the collaborative process, as a holistic process that encompasses the interaction of

several aspects whereas investing in just one may not be enough. The study introduced original empirical evidence and illustrated IKT as an evolutionary process, which requires long-time commitment and flexibility to build, sustain, maintain, and enable the development of different individual and team processes. In this case, I followed the development of KT planning over time as an integrative part of the project and observed how it had evolved alongside the research progress. These findings re-enforce the beneficial effects of IKT to optimizing KT efforts and offer lessons and possible propositions to those involved in collaborative research in environmental health and other fields.

The significance of this study and its findings is its contribution to the practices and scientific literature in several fields, but particularly IKT and transdisciplinary research. The study provides empirical evidence for a new and more comprehensive understanding of research teams' collaborative process, a research gap to date (Bozeman and Youtie 2017, Graham 2018). The study unpacks the collaborative process, identifying and articulating eight essential components of individual and team processes. Together, they are essential for the IKT collaborative process and the team's optimized operation. Similar concepts have been previously discussed in the literature, but this is the first time they have been pulled together and described into a single framework. The essential components' conceptual framework is suggested as a future focal guide for the collaborative research team's planning and operation. This work extends the understanding of the challenges and future opportunities for science to support research collaborations.

Different implications and recommendations can be drawn from this study **(Table 7.1)**. They are of relevance for researchers, academic institutions, and funding agencies' policies towards the promotion and application of collaborative projects. The first significant implication is the acknowledgment of the collaborative team processes occurring alongside the research

process and their significance to IKT or any other collaborative research approach, as described in this dissertation. In order to enable the collaborative processes to occur, researchers are encouraged to include in their research proposals plans to support and maintain the collaboration, *i.e.,* identifying and agreeing on collaborative principles and values (*e.g.,* equity, inclusion, learning), allocating the resources required, putting the mechanisms in place to promote collaborative process, and securing sufficient time for processes to evolve. To operationalize collaborative practice, support of the collaborative efforts is also required from academic institutions on various levels. This includes the allocation of institutional support, reward systems to those engaged in collaboration, and educational platforms to prepare researchers and students so they can be readier to engage in collaborative, interdisciplinary, and IKT research. In addition, funding agencies need to recognize and support the collaborative aspects of research projects by acknowledging the time and resources required for collaboration and credit those engaged in collaborative research. These actions will provide support for team collaborative processes from a policy point of view.

A second set of implications drawn from this dissertation refers to the practice of collaborative research. Based on my findings, I suggest several practices for individuals who engage in collaborative research, either as leaders (*i.e.,* principal investigators), management (*e.g.,* coordinators), or team members. I encourage them to be conscious of the collaborative process and apply the means and activities to support team processes according to their research project needs. These teams need to identify how to manage values that promote participation and commitment of different disciplines and partners in research and put in place the mechanisms to support it, such as different opportunities for keeping rapport, engagement, inclusion, and learning, and continuous discussion on roles, expectations, and objectives. At the same time, it is

fundamental to apply practices and activities that will build and sustain the team's growth and the development of relationships, trust, alignment, joined ownership, and the team's growth, while enabling individuals' growth. Additional mechanisms to support these processes are evaluation and reflection; these require attentive management that responds and is flexible to the project and team needs. In that sense, the principal investigators are key to building a collaborative atmosphere in which attention is dedicated to collaborative processes and their maintenance, as well as response to evaluation and feedback. Additionally, teams can consider including a role within the team that would be responsible for the maintenance of collaborative mechanisms, evaluation, and management of the team (*e.g.,* research coordinator, collaborative process fellow, or researcher).

The third point refers to those who engage in collaborative research (*e.g.,* principal investigators, researchers, knowledge users). While all platforms and mechanisms may be in place, there is a need for all team members to take an active part by participating in two-way and even multiple routes of interaction between the team members – communicating, learning, and practicing in reciprocity. This will enable the development of the collaborative team processes, which are fundamental to IKT and inter /transdisciplinary research to co-create innovative research. Team members will need to transform ways of thinking, in which established trust and alignment, for example, will help the acceptance of different ways of working, challenging norms, and the agreement on the outcomes of such efforts. The collaborative process requires all team members to be committed, open, flexible, and patient as these processes are complex and require a long time to evolve.

Lastly, I articulate suggestions for future research that would help further understanding and practice of collaborative research and explorations of the IKT approach. These include further verification of the model proposed for IKT collaborative processes, as described in this

dissertation. This can be done in several ways such as a Delphi process with experts and stakeholders, or the testing of the theory behind the model with other research contexts or teams. Future research could also include further identifying the best mechanisms to support the collaborative approach. These steps could help develop guidelines for researchers, principal investigators, and coordinators to support the building of accomplished research teams. Other areas for future exploration could focus on the context of environmental health research and exploring the IKT approach long-term outcomes and impact, while considering the evidence available alongside the uncertainty engrained in this context.

While writing these concluding remarks and finalizing this thesis a pandemic has overtaken the world and changed research work practices. I am unsure what implications these changes will bring, but I hope that we will continue and find ways to build strong collaborations despite the social distance forced by the current situation.

This research is one phase in the journey of seeking knowledge. While these words conclude this thesis, a door opens for additional quests for future research and fruitful collaborations.

Table 7.1: Implications of the case study for policy, practice, and future research

Significant implications		
Policy	Funding agencies	• Consider the time required to operationalize team processes and KT when allocating funds for research projects • Include funding for initiation phase, IKT, KT, and evaluation • Reward teams that invest in team processes in funding criteria
	Academic institutions	• Define reward systems for collaborators and collaborative efforts • Recognize interdisciplinary academic achievements • Extend training on collaboration, interdisciplinarity, and KT for students and researchers • Provide institutional support to collaborative efforts
Practice	Leaders, team members & coordinators	• Allocate time to build, sustain, and maintain different team processes • Include collaborative strategies at the planning phase • Follow participatory principles of inclusion and equity • Commit to be actively engaged • Keep momentum by rapport, learning, engagement, reflection • Ensure attentive leadership • Include a position to help sustain the collaboration and apply evaluations at different time points • Invest in learning and individual development • Aspire for building individual and team capacity, trust, relationships, ownership, and aim for alignment • Join with an open mind to other epistemologies and be ready to challenge norms • Have continuous discussion on roles, expectations, and objectives • Be flexible to address emerging needs- not everything can be anticipated • Secure 'lots' of patience
Future Research	Supporting the process	• Evaluate long-term research KT requirements • Articulate tools and mechanisms to ensure components are built and maintained (*including circumstances like self-isolation or physical distancing))
	IKT Science	• Develop practical guidelines for researchers • Focus on long-term evaluation of outcomes, KT, and impact • Explore the role of a researcher to support, inform and learn from the IKT collaborative process
	Environmental health	• Articulate the end-of-project KT planning process in an uncertainty research reality • Focus on the contribution of different members to end-of-project KT and impact
	Research collaborations	• Test the conceptual framework with different teams and contexts

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APPENDICES

Appendix 1.1: Terms and definitions

Terms and Definitions Used in the Scoping Review (Wine et al., 2017)

Term	Definition
Co-production / Co-creation	Implies a process where new knowledge is or can be produced through interaction and collaboration between scientists and knowledge users possibly with people with different perspectives and backgrounds, through cooperative endeavors and mutual learning (Fazey & Evely, 2013; Meadow et al., 2015).
Collaborative research	An umbrella term for methodologies that actively engage researchers, communities and policy makers in the research process from start to finish (Centre for Collaborative Research for an Equitable California, 2010).
Community-based participatory research (CBPR)	CBPR is currently one of the more widely recognized participatory research approaches, with a growing number of applications, particularly in geographic and racial/ethnic communities. The emphasis is on the participation and influence of non-academic researchers in the process of creating knowledge and specific community's needs with the aim to empower the community and support action for the community. The collaborative approach to research equitably involves community members, organizational representatives, and researchers in all aspects of the research process. The partners contribute "unique strengths and shared responsibilities" to enhance understanding of a given phenomenon and the social and cultural dynamics of the community, and integrate the knowledge gained with action to improve the health and well-being of community members (Cargo & Mercer, 2008; Israel et al., 1998).
Environmental health	Environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviors. It encompasses the assessment and control of those environmental factors that can potentially affect health. Such

	effort is targeted towards preventing disease and creating health-supportive environments (Prüss-Ustün et al., 2016).
Integrated knowledge translation	Potential research knowledge users are engaged in the entire research process by collaborating to determine the research questions, and methodology, being involved in data collection and tools development, interpreting the findings, and helping disseminate the research results. This approach should produce research findings that are more likely to be relevant to and used by the end users (Canadian Institutes of Health Research, 2016).
Interdisciplinary	Refers to a process of addressing a complex topic, which draws on several disciplinary perspectives and integrates their insights to produce a more comprehensive understanding (Repko, 2008).
Knowledge brokers	In public health knowledge brokers are intermediaries between researchers and intended users / knowledge users (Dagenias et al., 2015). Knowledge brokers can facilitate translation of scientific expertise to influence regulatory processes by connecting academic researchers with decision makers to facilitate the translation of research findings into policies and programs (Pennel et al., 2013), or act as cultural brokers with communities (Jack et al., 2010).
Knowledge exchange	Refers to the interaction between the knowledge user and the researcher resulting in mutual learning. It encompasses the concept of collaborative or participatory, action-oriented research whereas researchers and knowledge users work together as partners to conduct research to sole knowledge users' problems. It Implies a two- or multiple-path process with reciprocity and mutual benefits, with multiple learning, but not necessarily recognition of the equitable value of the different forms of knowledge being exchanged (Fazey & Evely, 2013).
Knowledge mobilization	Implies eliciting or spreading knowledge to a wider range of recipients, possibly with the intent of increased application of knowledge (Fazey & Evely, 2013).
Knowledge translation	A dynamic and iterative process that includes synthesis, dissemination, exchange and ethically-sound application of knowledge which takes place within a complex system of interactions between researchers and knowledge users (an individual who is likely able to use the knowledge generated through research to make informed decisions about health policies or practice to improve the health of Canadians) (Canadian Institutes

	of Health Research, 2016). Also, could imply communication using a mediated language modified for recipients (Fazey & Evely, 2013).
Participatory research	An umbrella term for a school of approaches that share a core philosophy of inclusivity and of recognizing the value of engaging in the research process (rather than including only as subjects of the research) with those who are intended to be the beneficiaries, users, and stakeholders of the research systematic inquiry, and with the collaboration of those affected by the issue being studied, for purposes of education and taking action or effecting change (Cargo & Mercer, 2008).
Scoping reviews	A form of knowledge synthesis that addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting and synthesizing existing knowledge (Colqhoun et al., 2014).
Transdisciplinary	Similar to interdisciplinary, transdisciplinarity is descriptive of collaborative research and problem solving that, unlike interdisciplinary, it crosses both disciplinary boundaries and sectors of society by including stakeholders in the public and private domains. Transdisciplinary research generally focuses on a larger scale questions (*e.g.,* climate change adaptability, eco system health) and its leading principle is interdisciplinary approach to the research question that aims for innovation and creative solutions (Hadorn et al., 2008; Repko, 2008).

Appendix 2.2: Excluded publications, Scoping Review

Excluded Publications (n = 57), Phase 2 of Screening Process (Not included in the Scoping Review) (Wine et al., 2017)

Author(s)	Year	Title	Source
Anex & Focht	2002	Public participation in life cycle assessment and risk assessment: A shared need	*Risk Analysis*, *22*(5), 861-877
Anwar	2005	Possibilities and pitfalls for modern biotechnology in the development of African genetic toxicology	*Toxicology and applied pharmacology*, *207*(2), 706-711
Baker	2001	Community Based Research of Autoimmune Disease & Asthma	University of Buffalo
Beyer	2009	Exploratory spatial data analysis in community context: Integrating geographic information science and community engagement for colorectal cancer prevention and control	The University of Iowa
Christopher et al.	2008	Building and maintaining trust in a community-based participatory research partnership	*American Journal of Public Health*, *98*(8), 1398-1406
Cochran et al.	2008	Indigenous ways of knowing: Implications for participatory research and community	*American Journal of Public Health*, *98*(1), 22-27
Cole et al.	2011	An agriculture and health inter-sectoral research process to reduce hazardous pesticide health impacts among smallholder farmers in the Andes	*BMC International Health and Human Rights*, *11*(Suppl. 2), S6
Cook	2008	Integrating research and action: A systematic review of community-based participatory research to address health disparities in environmental and occupational health in the USA	*Journal of Epidemiology and Community Health*, *62*(8), 668-676
Corburn	2002	Street science: The fusing of local and professional knowledge in environmental policy	Massachusetts Institute of Technology
Crowe et al.	2008	Striving to provide opportunities for farm worker community participation in research	*Journal of Agricultural Safety and Health*, *14*(2), 205-219
Di Chiro	1995	Local actions, global visions: Women transforming science, environment, and health in the united states and India	University of California, Santa Cruz
Drechsel et al.	2008	Linking research, capacity building, and policy dialogue in support of informal irrigation in urban west Africa	*Irrigation and Drainage*, *57*(3), 268-278
Easley	2002	Community empowerment through participatory research: Environmental enhancement on the west side of Chicago	Northern Illinois University
Eggers	2014	Community based risk assessment of exposure to waterborne contaminants on the crow reservation, Montana	Montana State University

Finn & Thompson	2012	Community-based participatory research through the lens of environmental health: More than a catchy sounding name	*Epidemiology*, 23(5, Suppl. 1), S256
Guttmacher	2013	The future of scientific research	*Hematology Reports*, *5*(Suppl. 1)
Heaney et al.	2007	The west end revitalization association's community-owned and -managed research model: Development, implementation, and action	*Progress in Community Health Partnerships*, *1*(4), 339-349
Israel et al.	2001	The Detroit community-academic urban research center: Development, implementation, and evaluation	*Journal of Public Health Management & Practice*, *7*(5), 1-19
Israel et al.	2010	Community-based participatory research: A capacity-building approach for policy advocacy aimed at eliminating health disparities.	*American Journal of Public Health*, *100*(11), 2094-2102
Keeler et al.	2002	Assessment of personal and community-level exposures to particulate matter among children with asthma in Detroit, Michigan, as part of community action against asthma (CAAA)	*Environmental Health Perspectives*, *110* (Suppl. 2), 173-181
King	2012	Collaboration program effectiveness: Comparing two community partnership programs.	George Mason University
Korfmacher et al.	2014	Unconventional natural gas development and public health: Toward a community-informed research agenda	*Reviews on Environmental Health*, *29*(4), 293-306
Kyle et al.	2006	Integrating research, surveillance, and practice in environmental public health tracking	*Environmental Health Perspectives*, *114*(7), 980-984
Linkov et al.	2011	A decision-directed approach for prioritizing research into the impact of nanomaterials on the environment and human health	*Nature Nanotechnology*, *6*(12), 784-787
Loh et al.	2002	From asthma to AirBeat: Community-driven monitoring of fine particles and black carbon in Roxbury, Massachusetts	*Environmental Health Perspectives*, *110*(Suppl. 2), 297-301
MacDonell et al.	2002	Integrating information for better environmental decisions	*Environmental Science & Pollution Research*, *9*(6), 359-368
Mathe	2014	Integrating participatory approaches into social life cycle assessment: The SLCA participatory approach	*International Journal of Life Cycle Assessment*, *19*(8), 1506-1514
McGrath et al.	2009	The limits of collaboration: A qualitative study of community ethical review of environmental health research	*American Journal of Public Health*, *99*(8), 1510-1514
McPartland et al.	2015	Building a robust 21st century chemical testing program at the U.S. environmental protection agency: Recommendations for strengthening scientific engagement	*Environmental Health Perspectives*, *123*(1), 1-5
Miller et al.	2013	Community-based participatory research projects and policy engagement to protect environmental health on St Lawrence island, Alaska	*International Journal of Circumpolar Health*, *72*(1), 21656
Minkler et al.	2010	Using participatory research to promote environmental justice in a Latino community in San Diego, California	*Journal of Urban Health*, *87*(5), 796-812

Molina & Molina	2004	Improving air quality in megacities: Mexico City case study	*Annals of the New York Academy of Sciences*, *1023*(1), 142-158
Nativi et al.	2014	The GEOSS solution for enabling data interoperability and integrative research	*Environmental Science & Pollution Research*, *21*(6), 4177-4192
Neri et al.	2015	Common pathways toward informing policy and environmental strategies to promote health: A study of CDC's prevention research centers	*Health Promotion Practice*, *16*(2), 218-226
O'Mullane	2009	An investigation of the utilization of health impact assessments (HIAs) in Irish public policy making	University College Cork (Ireland)
O'Fallon et al.	2000	Improving public health through community-based participatory research and outreach	*Environmental Epidemiology and Toxicology*, *2*(2-3), 201-209
Orozco and Cole	2012	Tackling challenges to farmers' health and agro-ecosystem sustainability in highland Ecuador	In *Ecohealth Research in Practice* (pp. 47-58). Springer New York
Osuch et al.	2012	A historical perspective on breast cancer activism in the united states: From education and support to partnership in scientific research	*Journal of Women's Health*, *21*(3), 355-362
Parkes et al.	2003	Converging paradigms for environmental health theory and practice	*Environmental Health Perspectives*, *111*(5), 669-675
Parkinson	2013	The arctic human health initiative: A legacy of the international polar year 2007-2009	*International Journal of Circumpolar Health*, *72*(1), 21655
Passerini & Wu	2008	The new dimensions of collaboration: Mega and intelligent communities, ICT and wellbeing	*Journal of Knowledge Management*, *12*(5), 79-90
Pennell et al.	2013	Bridging research and environmental regulatory processes: The role of knowledge brokers	*Environmental Science & Technology*, *47*(21), 11985-11992
Phillipson et al.	2012	Stakeholder engagement and knowledge exchange in environmental research	*Journal of Environmental Management*, *95*(1), 56-65
Plagerson & Mathee	2012	Changing an urban community through health research: A South African case study	*Health Promotion Practice*, *13*(3), 339-343
Postma	2008	Elucidating empowerment in El Proyecto Bienestar (the well-being project)	*Journal of Advanced Nursing*, *62*(4), 441-450
Powers et al.	2014	Sparking connections: Toward better linkages between research and human health policy-an example with multiwalled carbon nanotubes	*Toxicological Sciences*, *141*(1), 6-17
Quigley et al.	2000	Participatory research strategies in nuclear risk management for native communities	*Journal of Health Communication*, *5*(4), 305-331
Quigley	2009	Promoting research ethics training: Understandings of community, partnership, virtue and diversity	Syracuse University
Schug et al.	2013	ONE nano: National Institute of Environmental Health Sciences's strategic initiative on the health and safety effects of engineered nanomaterials	*Environmental Health Perspectives*, *121*(4), 410-414

Senier et al.	2008	Brown superfund basic research program: A multistakeholder partnership addresses real-world problems in contaminated communities	*Environmental Science & Technology*, *42*(13), 4655-4662
Spiegel et al.	2011	Establishing a community of practice of researchers, practitioners, policy-makers and communities to sustainably manage environmental health risks in Ecuador	*BMC International Health & Human Rights*, *11*(2), S5
Wallerstein et al.	2011	Integration of social epidemiology and community-engaged interventions to improve health equity	*American Journal of Public Health*, *101*(5), 822-83
Wallington et al.	2013	The co-location of academia with the community in addressing cancer health disparities: A new model of partnerships for environmental public health	*Cancer Prevention Research*, 2013, 6 (11, Suppl. 1)
Wesche et al.	2011	Community-based health research led by the Vuntut Gwitchin first nation	*International Journal of Circumpolar Health*, *70*(4), 396-406
White-Newsome et al.	2009	Climate change, heat waves, and environmental justice: Advancing knowledge and action.	*Environmental Justice*, *2*(4), 197-205
Wilson et al.	2007	Use of EPA collaborative problem-solving model to obtain environmental justice in North Carolina	*Progress in Community Health Partnerships*, *1*(4), 327-337
Wilson et al.	2012	The science of community engagement: Lessons from the field of environmental health	*Epidemiology*, 23(5, Suppl. 1), S267

Appendix 2.3: Facilitators and challenges, Scoping Review

Papers describing themes as facilitators and challenges (Scoping review)

*Table was not originally part of the published manuscript

Theme	Facilitators/ best practices	Challenges
Time and resources	**N=11** Angelstam et al. 2013; Austin, 2010; Brown et al. 2012; Burger et al., 2009; Israel et al. 2001; Matso et al. 2008; Parker et al. 2003; Pereira et al. 2009; Ramirez-Andreotta et al. 2004; Ravenscroft et al. 2015; Schell et al. 1998;	**N=25** Arcury et al. 2001; Austin, 2010, Bharadwaj, 2014; Burger et al. 2007; Garcia et al. 2013; Israel et al. 1998; Israel et al. 2001; Israel et al. 2005; Jack, et al. 2010; Johnson et al. 2014; Matso et al. 2008; Meadow et al 2015; Metzler et al. 2003; Minkler et al. 2008; Minkler, 2010; Parker et al. 2003; Pereira et al. 2009; Ramirez-Andreotta et al. 2004; Reed et al. 2014; Romero-Lankao, et al. 2014; Rosenthal et al. 2007; Schell et al. 1998; Schell et al. 2007; Vasquez et al. 2006; Witten et al. 2000
Disciplines/sectorial issues	**N=18** Angelstam et al. 2013; Arcury et al. 2001; Brown et al. 2012; Burger et al., 2009; Conrad et al. 2013; Corburn, 2007; Cummins et al. 2010; Downs et al. 2009; Haynes et al. 2011; Israel et al. 1998; Israel et al. 2001; Matso et al. 2008; Meadow et al 2015; Nielsen, 2001; Ramirez-Andreotta et al. 2004; Rosenthal et al. 2007; Schell et al. 1998; Vasquez et al. 2006	**N=24** Angelstam et al. 2013; Arcury et al. 2001; Bharadwaj, 2014; Burger et al. 2007; Collman, 2014; Conrad et al. 2013; Downs et al. 2009; Gonzalez et al. 2011; Harding et al. 2011; Israel et al. 1998; Israel et al. 2001; Johnson et al. 2014; Matso et al. 2008; Meadow et al 2015; Minkler, 2010; Nielsen, 2001; Parker et al. 2003; Parkes, et al. 2004; Pereira et al. 2009; Ramirez-Andreotta et al. 2004; Romero-Lankao, et al. 2014; Rosenthal et al. 2007; Schell et al. 2007; Wing, 2002
Relationships	**N=16** Arcury et al. 2001; Austin, 2010; Brown et al. 2012; Burger et al., 2009; Collman, 2014; Cummins et al. 2010; Downs et al. 2009; Jack, et al. 2010; Johnson et al. 2014; Meadow et al 2015 Minkler, 2010; Parker et al. 2003; Pereira et al. 2009; Ravenscroft et al. 2015; Reed et al. 2014; Strosnider et al. 2013	**N=12** Downs et al. 2009; Harding et al. 2011; Israel et al. 1998; Israel et al. 2001; Israel et al. 2005; Matso et al. 2008; McCauley et al. 2001; Metzler et al. 2003; Nielsen, 2001; Parker et al. 2003; Ramirez-Andreotta et al. 2004; Witten et al. 2000

Representation		**N=11** Arcury et al. 2001; Collman, 2014; Conrad et al. 2013; Downs et al. 2009; Garcia et al. 2013; Harding et al. 2011; Israel et al. 1998; Metzler et al. 2003; Parker et al. 2003; Schell et al. 2007; Witten et al. 2000
Framing the research	**N=22** Angelstam et al. 2013; Arcury et al. 2001; Bharadwaj, 2014; Brown et al. 2012; Burger et al, 2009; Burger et al. 2007; Collman, 2014; Cummins et al. 2010; Downs et al. 2009; Harding et al. 2011; Israel et al. 1998; Jack, et al. 2010; Johnson et al. 2014; Matso et al. 2008; Minkler et al. 2008; Minkler, 2010; Parker et al. 2003; Pereira et al. 2009; Reed et al. 2014; Schell et al. 1998; Vasquez et al. 2006; Witten et al. 2000	
Ongoing collaboration	**N=20** Angelstam et al. 2013; Arcury et al. 2001; Austin, 2010; Brown et al. 2012; Burger et al., 2009; Burger et al. 2007; Downs et al. 2009; Harding et al. 2011; Israel et al. 1998; Johnson et al. 2014; Matso et al. 2008; Meadow et al 2015; Minkler et al. 2008; Minkler, 2010; Nielsen, 2001; Parker et al. 2003; Pereira et al. 2009; Ramirez-Andreotta et al. 2004; Reed et al. 2014; Strosnider et al. 2013	**N=11** Collman, 2014; Conrad et al. 2013; Israel et al. 2005; Johnson et al. 2014; Nielsen, 2001; Parker et al. 2003; Romero-Lankao, et al. 2014; Schell et al. 2007; Schell et al. 1998; Wing, 2002; Witten et al. 2000
Knowledge translation and exchange	**N=7** Haynes et al. 2011; Jack, et al. 2010; Nielsen, 2001; Pereira et al. 2009; Reed et al. 2014; Strosnider et al. 2013; Vasquez et al. 2006	**N=12** Collman, 2014; Conrad et al. 2013; Ferris & Sass-Kortsak 2011; Gonzalez et al. 2011; Israel et al. 1998; Israel et al. 2005; Minkler et al. 2008; Parkes, et al. 2004; Ramirez-Andreotta et al. 2004; Reed et al. 2014; Schell et al. 2005; Schell et al. 2007

Appendix 3.1: Meeting evaluation sample

An example of the Annual Meeting evaluation form. There were four annual meetings and each of the meeting forms was modified according to the current evaluation needs.

DoMiNO TEAM MEETING #4: March 20-21, 2017

EVALUATION FORM

How long have you been part of the DoMiNO Project team?

I am a guest (Not part of the DoMiNO Project)	Less than 6 months	More than 6 months, but not from the start	From the start (2013, first team meeting)

I attended the following sessions of the first team meeting:

	Attended in person	Attended via remote connection
Morning March 20th		
Afternoon March 20th		
Morning March 21th		
Afternoon March 21th		

Please select the response that best reflects your feelings about the following statements

	Strongly agree	Mostly agree	Mostly disagree	Strongly disagree	Not sure
The content of the meeting was appropriate					
We achieved the meeting objectives					
The meeting met my personal expectations for the event					
The meeting was effective in building relationships between team members					
I feel the meeting was inclusive of my perspectives					
I feel the meeting was inclusive of everyone's perspectives					

I feel I have a good sense of the current status of the project					
I feel we have a shared understanding of key concepts related to the research					
I feel clear about my contribution to this meeting					
I feel clear about the contribution of others to this meeting					
I feel we have consensus on key issues affecting the project					
I am confident in the plan we have developed for the next phase of the research (KT)					
The format of the meeting was conducive to learning and being meaningfully engaged					
The meeting was well organized overall					
I was satisfied with the meeting venue and food					
Overall, I was highly satisfied with the team meeting					

Comments:

1. **The aspects of the meeting I liked or found most useful were** …
2. **The aspects of the meeting I did not like or found least useful were** …
3. **I would have liked to spend more time on** …
4. **Aspects of the meeting which I found challenging ….**
    a. **As an individual were:**
    b. **As a part of a team were:**
5. **Reflecting on aspects of the meeting, which represented teamwork....**
    c. **What did you feel was most like teamwork?**
    d. **What could be improved on?**
6. **Did this meeting tie together the DoMiNO project?**
    a. **In what way?**
    b. **Are there still gaps? Please explain**
7. **Other comments or suggestions for the overall session and project:**

Appendix 3.2: Observers' guide

An observation guide provided to external observers of DoMiNO small group discussions in the second and third annual meetings.

Observers' Guidelines

DoMiNO Meeting 3, August 10-11, 2016

(Small group discussions)

DoMiNO team members will work in 3 groups of 4-5 participants. Each group will include participants from different disciplines, seniority, and guests. An observer will be appointed to each of the groups. The groups will be composed of different participants for each of the discussion topics.

Observers: Are appointed to observe and record the process of collaboratively working to identify patterns, visualizations, desired success, and methods to achieve those. Observers do not have to be silent observers and are allowed to participate in the groups but have first priority of recording observations. Observations can be recorded during and/or right after the group discussion.

Observers' guidelines: In these activities, observers are asked to collect and provide feedback "what worked" and "what could have been improved" in your workgroup. The observer would capture notes on work group interaction, process, ideas/outputs and any 'aha moments. A list of suggested guiding questions is included below, and observers are welcome to follow all, part, or none of the questions. The more details observers can provide the better!

- Was the group able to respond to the questions?
- Was this exercise done in a collaborative effort? (*e.g.,* did everyone participate, encouraged to share ideas, show respect to others, etc.)
- Were there any dominant views? Who are the leaders?
- Could you identify common goals in the discussion?
- What were the topics with general agreement or disagreements? Were participants willing to be flexible? Accept different ideas? Was there a process of reaching consensus? or does the dominant voice rule?
- Did the discussion results represent individual goals or team goals?
- Were there terms, concepts, or other issues that were not clear?
- Were the teams able to communicate with regards to specific discipline terminology?

Appendix 4.1: DoMiNO project outcomes

A description of the DoMiNO project outcomes and KT activities, based on the final report to CIHR (August 2018), and DoMiNO CV (January 2020).

*The table was not originally part of the published manuscript

DoMiNO outcomes and KT		
Outcomes	Research method	Developed data mining algorithms for geolocated data
	Theory	Generated hypothesis on chemical mixtures and adverse birth outcomes
	Replication	Reproduced associations previously identified
	Tools	Developed VizAR- a visualization tool to present rule associations/data mining results
	Software/ database	Spatial data mining algorithm and visualization tool
	Data findings published	Manuscripts: published (20), submitted (3)
		Conference peer reviewed publications (6)
		Published abstracts (11)
		Invited oral presentations: international (6), national (14)
		Oral presentations international (9) national (24)
		Abstract – poster presentations: International meetings (6), National meetings (49)
		Interviews in the media1(5)
	Research capacity and training	Senior researchers (15)
		Knowledge users (4)
		Post-doctorates (3)
		Graduate students MA (3), Ph.D. (6)
		Summer students (5), International fellows (9), Collaborating students (4)
Stakeholder involvement	Stakeholders were involved in different phases of research process	Development of the research idea /question
		Development of the protocol
		Data collection phase
		Project implementation

		Interpretation of results
		End-of-grant KT activities
Audiences (of KT)	Health system	Health care organizations, mangers practitioners
	Study stakeholders	Non-governmental organization, health agencies, governmental agencies
	Municipal organizations	Provincial agencies
	Government agencies	Health and environment
	Community	Non-governmental organizations
	Academics	Other researchers, different disciplines. Local, national, and international
Impact on stakeholders	Awareness	Combinations and potential impact on health
		Combinations and methodologies
	Dissemination and knowledge exchange	Hands-on workshops Presentations and webinars to different audiences. Traditional knowledge transfer publications and presentations
	Continuity	Continuous collaboration with team members, as well as collaboration with new collaborators to advance the topic with new research questions based on the findings