Understanding Collaboration in the Context of Loosely- and Tightly-Coupled Complex Adaptive Systems

A thesis submitted to the Telfer School of Management in conformity with the requirements for the degree of

Master of Science in Health Systems

by

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ABSTRACT

Many of the technological and social systems our society has come to depend on can be classified as complex adaptive systems (CAS). These systems are made of many individual parts that self-organize to respond and adapt to changing outside and inside influences affecting the system and its actors. These CAS can be placed on a spectrum ranging from loosely- to tightly-coupled, depending on the degree of interrelatedness and interdependence between system components. This research has explored how the process of collaboration occurs in both a loosely- and tightly-coupled setting using one exemplar of each system. The loosely-coupled exemplar related to disaster risk reduction in two Canadian communities while the tightly-coupled one involved the implementation of a surgical information management system in a Canadian hospital. A list of core elements of collaboration that should be considered essential to the success of all collaborative endeavours was developed as a result: *Engagement*, *Communication*, *Leadership*, *Role Clarity*, *Awareness*, *Time*, and *Technical Skills and Knowledge*. Based on observing how the core elements of collaboration interacted with one another within each of these example systems, two models were created to represent their relationships. A list of considerations that collaborative tool designers should consider was also developed and the implications of these considerations were discussed. As businesses and other organizations increasingly incorporate team-based work models, they will come to depend more heavily on technology-based solutions to support collaboration. By incorporating collaborative technologies that properly support the activity of these teams—based on the specific type of complex adaptive system in which their organization exists—organizations can avoid wasting time and resources developing tools that hinder collaboration.

ACKNOWLEDGEMENTS

I'd like to take the time to thank the funders and principal investigators of the two original projects in this thesis. *The EnRiCH Project*, led by Dr. Tracey O'Sullivan, was funded by Defence Research and Development Canada Centre for Security Science. The SIMs implementation study, led by Dr. Craig Kuziemsky, was funded by a Discovery Grant from the Natural Science and Engineering Council of Canada.

I'd also like to acknowledge the individuals who—directly or indirectly—made this thesis possible. My thesis supervisors Tracey and Craig, who received more than a few panicked emails from me over the last few years. Christina Pickering, a friend and confidante without whom this thesis would be incomplete—literally. Ahsan Hadi, who supported me during one of the more difficult stages of writing. Shannon Tracey and Emily Guy, who were my closest colleagues and biggest supporters while working for years in the EnRiCH lab. Annie Baylor, who made sure the graduate office didn't forget about me. Drs. Kim Corace and Gretchen Conrad, who made the decision to try out a Master's student intern for a few months during this time. Tyler Lombardo, who was there for the lows and the highs of this wonderful journey.

Of course, I'd also like to acknowledge my parents, Barbara and Yvon Leduc, who supported me during this challenging period of my life. And you, the reader, who took the time to read. *Every. Single. Word*. of this painstakingly written thesis.

CHAPTER 1: INTRODUCTION

1.1 – Background

Increasingly, the health community (including the public health and disaster management fields) has placed importance on interprofessional collaboration and what it means for practice in modern society (Bell, Michalec, & Arenson, 2014; Hughes & Fitzpatrick, 2010). Collaboration enhances the ability of team members to pool their collective knowledge, build on different ideas, resolve conflicts, work efficiently, and share responsibility and tasks (Di Prospero & Bhimji-Hewitt, 2011). The term *interprofessional collaboration* has been defined by Barr, Koppel, Reeves, Hammick, and Freeth (2008) and refined by Reeves (2009) as "an active and ongoing partnership, between 2 or more professions, who work together to solve problems or provide service" (p. 143). It occurs in most domains of practice ranging from emergency medicine (Peller, Schwartz, & Kitto, 2013), to community-based participatory research (Willison & Palos, 2010), to early childhood education and kindergarten care (Cameron, Tveit, Midtsundstad, Nilsen, & Jensen, 2014). Collaboration is most effective when members of different professions have learned about one another and the roles that each fulfils in the collaborative initiative (Willison & Palos, 2010). This awareness helps to define role boundaries, clarify role responsibilities, and allows professionals to understand the scope of practice for each profession.

However, collaboration is context-specific and requires differing amounts and types of information to be exchanged in order to be successful (Cramton, 2001). The kinds of settings that require collaboration are diverse, with professionals developing unique ways of solving problems by drawing upon their experiences within their domain of practice. The resulting unpredictable solutions create dynamic working environments for professionals who must adapt to accomplish their goals. These dynamic work environments can be described as *complex adaptive systems* (CAS). Tsasis, Evans, and Owen (2012) provide a description of such systems:

> *"Complex-adaptive systems (CAS) are open systems with fuzzy boundaries comprised of numerous, diverse and highly interactive agents. Their patterns of interaction and ongoing adaptations often contribute to novel and unpredictable behaviours and events; CAS are thus characterized as emergent and self-organizing" (p.2).*

Complex adaptive systems can be classified as loosely- or tightly-coupled. Decisions made in loosely-coupled systems directly interact with fewer parts of a system than in tightly-coupled systems, creating varying degrees of interaction between system components (Coiera, 2014). Systems that have tightly-coupled components have highly-interdependent parts—where changes to one of these parts cascade into different areas of the system and may have unintended, dramatic consequences. In contrast, changes made to a component of a loosely-coupled system are not as likely to have dramatic effects on the whole of the system or on as many of its parts (Perrow, 2011).

Understanding how professionals collaborate in these different types of complex adaptive systems can lead to the development of technology and tools that can better support collaboration in these settings. Without understanding the reasons why actors in a system behave in certain ways, individuals tasked with designing collaborative tools are approaching the design process without fully understanding the motivations of the end users. This may lead to the abandonment of a tool which frustrates or works against its target user population. This wasted effort is not only discouraging for all involved, but it may also incur a financial cost; lost productivity while trying to work with an unsuitable tool or completely redesigning said tool can be expensive endeavours. The least expensive option (both in terms of person-hours and actual financial resources spent) is to design an appropriate tool from the very beginning.

This thesis has explored how collaboration is structured in the disaster risk reduction and operating room contexts—each setting respectively providing an example of a loosely- or tightly-coupled complex adaptive system.

1.2 – Clarification of Terms

To better define the scope of this study, several terms related to interprofessional collaboration must be clarified and deconstructed. First and most importantly, a robust definition of the term *collaboration* is needed. Eikey, Reddy, and Kuziemsky (2015) provide a definition that is suitable for the purposes of this thesis:

> *"[Collaboration is] planned or spontaneous engagements that take place between individuals or teams of individuals, whether in-person or mediated by technology, where information is exchanged in some way (either explicitly, i.e. verbally or written, or implicitly, i.e. through shared understanding of gestures, emotions, etc.), and often occur across different roles (i.e. physician and nurse) to deliver patient care" (p.263).*

Although the definition specifies roles in the healthcare sector, it can be used as stated in many other settings. The above definition forms the basis of what is meant by *collaboration* in this thesis. However, there are different ways of looking at the process of collaboration and what a collaborative team may look like.

Steinmacher, Chaves, and Gerosa (2013) indicate that the distinctions between the different kinds of collaboration (and between collaboration and other, related terms) are often arbitrarily decided. This creates difficulties when trying to evaluate how technology supports collaboration because authors use different terminologies to describe the same referents.

First, *interprofessional collaboration* (or *interprofessionality*) broadly relates to how professionals from separate fields of practice (e.g. disaster management, nursing, hospice care, mechanical engineering, institutional psychology) work together to accomplish a shared goal (Barr et al., 2008; Reeves, 2009). The use of the term *profession* could, however, encompass volunteers working for not-for-profit agencies and non-governmental organizations (NGOs). While the differences between paid staff and unpaid volunteers may manifest in the way people (especially paid staff) view volunteers as informal workers (Burbeck, Candy, Low, & Rees, 2014), volunteers in some settings fulfil vital roles in an organization and can take on some of the same responsibilities that paid staff usually fulfil (Overgaard, 2015). Interprofessional collaboration is primarily concerned with how individuals from different areas of practice enhance the function of others they work with.

Interdisciplinarity is a similar term used by D'Amour and Oandasan (2005) to describe how entirely new bodies of knowledge and areas of expertise are created when two or more disciplines are brought together and their strengths combined. "Interdisciplinarity wishes to reconcile and foster cohesion to this fragmented knowledge. As a result, whole new disciplines may emerge." (D'Amour & Oandasan, 2005, p. 9). A distinction here is important: while interprofessionality allows professionals to work across boundaries with one another, interdisciplinarity refers to the creation of a new discipline that exists in the gap between two others. The former relates specifically to practice, while the latter relates to domains of knowledge.

Another concept that is often (and inaccurately) used interchangeably with interprofessional collaboration or interdisciplinarity is that of *multidisciplinarity*. Here, the domains of knowledge are kept mostly separated by professional "silos" when compared to the concept of interdisciplinarity. Professionals collaborate with one another by tackling problems in a piecemeal fashion, with each discipline contributing knowledge from their respective fields. The professionals here work as "independent specialists rather than interactive team members" (Choi & Pak, 2006, p. 355).

The last concept related to interprofessional collaboration is *transdisciplinarity*. This concept not only involves the practice of individuals with different professional roles and knowledge bases but it requires individuals to teach and learn from one another, expanding their role within the team to overlap with that of other members, offering a more holistic approach to a problem (Choi & Pak, 2006). Transdisciplinarity seeks to actively involve groups or people who are affected by the problem (Wickson, Carew, & Russell, 2006). These can include community organizations, residents, policy makers, and a myriad of other groups or individuals, so long as they are being actively engaged in the problem-solving and knowledge-creation processes.

It is important to note that the terms *interdisciplinary*, *multidisciplinary*, and *transdisciplinary* are adjectives used to describe the makeup of a team of collaborators—not the process through which they work, which remains unchanged from the definition given by Eikey, Reddy, and Kuziemsky (2015). This thesis is concerned with all of these types of collaboration—although one type of collaboration may appear more often than others. While the differences between multidisciplinarity, interprofessional collaboration and interdisciplinarity, and transdisciplinarity may have semantic and theoretical differences, this thesis will refer to all forms of collaboration simply as “collaboration”.

1.3 – Research Questions and Objectives

The purpose of this research was to explore how collaboration manifests in different complex adaptive system settings, leading to a better understanding of how actors and components of the system influence one another. This research focused on using the concept of complex adaptive systems to explore how professionals collaborate differently across loosely- and tightly-coupled systems. Specifically, we sought to answer the following research questions:

1) What are some of the core properties of collaboration according to current literature?
2) How do core properties of collaboration manifest in:
   a. Loosely-coupled complex adaptive systems?
   b. Tightly-coupled complex adaptive systems?
3) Using two examples of complex adaptive systems and their common core properties, what are some considerations to account for in designing collaborative tools?

1.4 – Thesis Structure

This thesis is organized into several sections. Chapter 2 is a literature review that provides context for how the research fits within the larger bodies of literature on collaboration and complex adaptive systems. Chapter 3 is an overview of the methodological processes that were used, including an explanation about how the data was sourced and how it was analyzed. Chapter 4 is where the results of the data analysis are presented using quotations from participant interviews. Chapter 5 presents a discussion of the themes by way of introducing two conceptual models and also linking the results to the current body of literature. Chapter 6 discusses the limitations and context while Chapter 7 provides concluding remarks about the contribution of this research to various domains of knowledge, followed by a set of appended documents that were used to support this research.

CHAPTER 2: LITERATURE REVIEW

The importance of collaboration has been recognized in many fields such as patient-centered healthcare (Kern, Edwards, & Kaushal, 2014), disaster preparedness and management (Holmes, Schwein, & Shadie, 2012), and education (Montiel-Overall & Jones, 2011). A Scopus database search for the term "interprofessional collaboration" revealed over 3,600 academic articles in subject areas ranging from business management to engineering. This number is even higher when looking more broadly at "collaboration" and encompasses diverse fields of study, from university-industry collaboration (Ponds, Oort, & Frenken, 2009) and supply-chain management (Gold, Seuring, & Beske, 2009) to tourism (Jamal & Getz, 1995) and governance of water and agriculture policy (Fish, Ioris, & Watson, 2010).

This chapter begins with an examination of several models of collaboration from the literature that address its necessary components. The second section of this chapter provides an explanation of what constitutes a complex adaptive system and how the domains of disaster risk reduction and surgery fall into loosely- and tightly-coupled complex adaptive systems, respectively. The final section presents issues complicating and facilitating the development of electronic tools designed to increase collaboration in different work environments.

2.1 – Collaboration

Collaboration is necessary to deal with complex, multifaceted issues and provides opportunities for individuals with varying professional and personal backgrounds to contribute to solutions to problems. The effective implementation of the collaborative process (defined by Eikey, Reddy, and Kuziemsky (2015) in Chapter 1.2 – Clarification of Terms) relies on understanding what elements contribute positively to collaboration and understanding how to address challenges to it as they appear.

Some of these challenges in the collaborative process occur when professionals approach an issue using different theoretical lenses, and propose divergent solutions. When Deschesnes, Couturier, Laberge, and Campeau (2010) studied how the health and education authorities and the government wanted to implement measures to create healthier schools, each group valued the importance of certain factors differently. The groups of professionals saw the same problem through different lenses and prioritized the various aspects of the project differently as a result. Groups like these must come to a common understanding of the challenges posed by the task, especially in increasingly collaboration-oriented workplaces. At the very least, if complete understanding cannot be achieved among professionals, then dissimilar points of view must be respected so that a compromise of some kind can be reached.

Scopus, PubMed, and Web of Science were the primary databases used in the literature review for this chapter, which used broad search terms (“collaboration”, “cooperative”, “coordinate”, “model”, “groupware”) as well as more narrow terms that referred to various kinds of collaborative teams (“interdisciplinary”, “multidisciplinary”, “transdisciplinary”), and settings where such models might be used (“healthcare”). Search terms were refined and changed as needed, with variations or synonyms of terms being used as substitutes. The terms used to search for applicable models in the literature are shown in Table 1.

Table 1: Search terms used in literature review

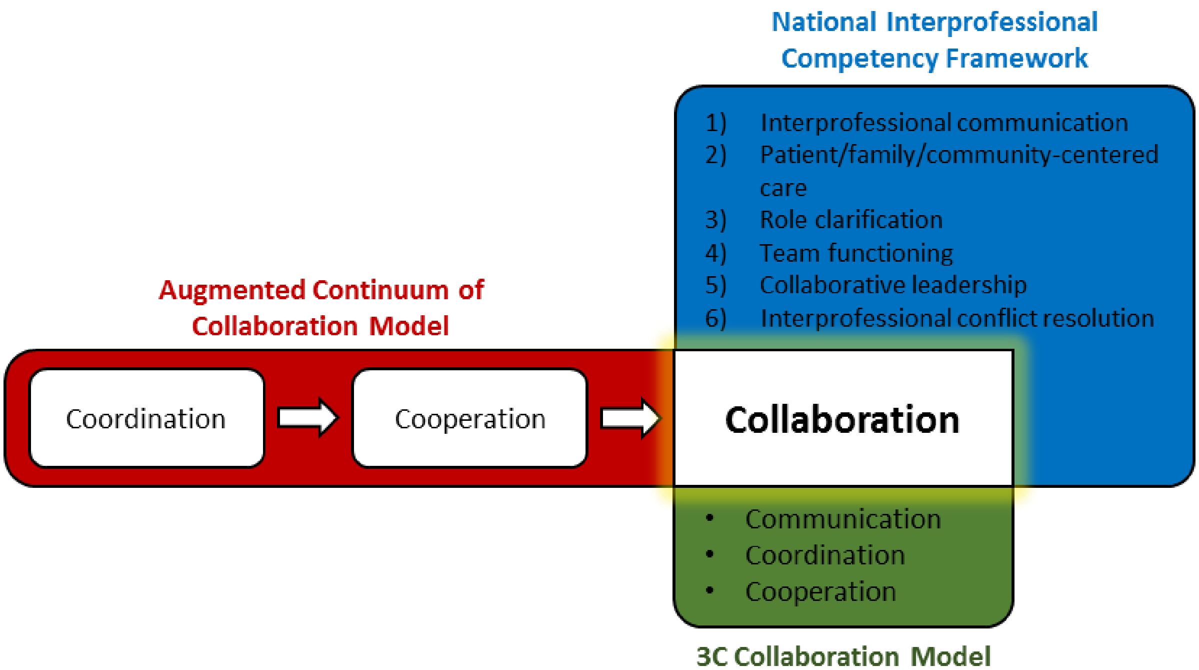
Terms always used	***Terms used in combination***		
Collaboration	Interprofessional	Communication	Elements
	Healthcare	Groupware	Properties
Model	Communication	Computer-supported cooperative work (CSCW)	

Given the scope of this literature base, for this study three models were chosen to serve as a cross-section to demonstrate the different kinds of models that exist in the literature. These models share some similarities but the authors explore the concept of collaboration in different ways.

The three models can be evaluated using different metrics. For example, Hull, Arora, Kassab, Kneebone, and Svedalis (2011) offer a framework that can be used to evaluate the quality of teamwork occurring in an operating room setting—a metric that is particularly relevant to the Surgical Information Management system (SIMs) that was used as a collaborative tool in one of the data sets analyzed as part of this thesis. One of the models presented in the next section—the Canadian Interprofessional Health Collaborative’s National Interprofessional Competency Framework model (2010)—doubles not only as a model but also as an evaluative tool. It is up to the practitioners who are seeking models and frameworks of collaboration to decide what components fit the kinds of collaboration they will engage in.

When referring to *collaboration*, it is important to acknowledge that the term is comprised of many sub-components and the three models discussed in this section present closely-related terms. To depict the different components from the three models, Figure 1 was developed as a conceptual map. It shows how the components of each model fit with one another and contribute to the ultimate goal of collaboration. In addition, while they may sometimes be used interchangeably, the terms *collaboration*, *coordination*, and *cooperation* have distinct meanings, each with their own characteristics (Steinmacher et al., 2013).

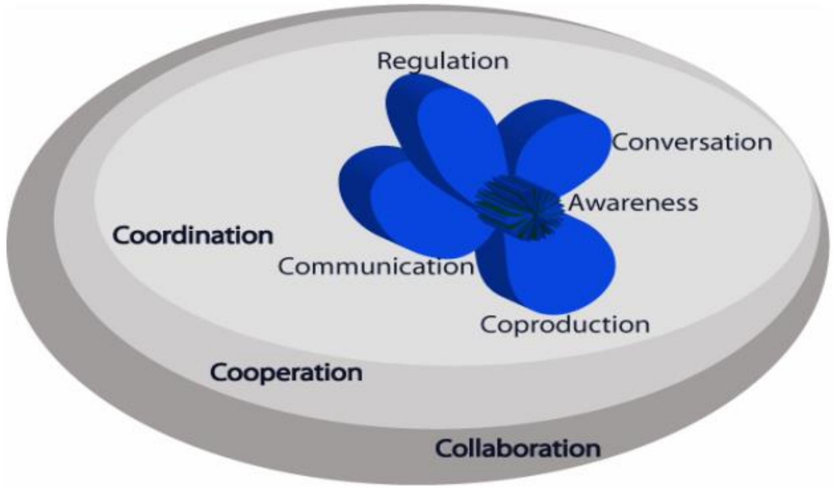
Figure 1: Concept of *collaboration* as it relates to three presented models (Elmarzouqi, Garcia, & Lapayre, 2008), (Fuks, Raposo, Gerosa, & Lucena, 2005), (Canadian Interprofessional Health Collaborative, 2010)



2.1.1 – The Augmented Continuum of Collaboration Model (ACCM)

The Augmented Continuum of Collaboration Model (ACCM) includes four sub-components termed *communication* and *conversation* (how information is passed between members), *co-production* (how members share the products that are created when working towards a shared goal), and *regulation* (how the workspace is mediated through rules and protocols) (Elmarzouqi et al., 2008). It is important to note that the field of second-order cybernetics conceptualizes information as being dependent on the individuals involved in communication; the content of information passed between individuals is highly context-dependent (Brier, 2015). Figure 2 shows the model in its entirety, although this section of the proposal will not focus on the regulation element of the model.

Figure 2: The Augmented Continuum of Collaboration Model (Elmarzouqi et al., 2008)



Note. From "CSCW from coordination to collaboration," by N. Elmarzouqi, E. Garcia, & J. C. Lapayre, 2008, *Lecture Notes in Computer Science*, *Vol. 5236* LNCS, p.92. Copyright 2008 by Springer Science + Business Media. Reprinted with permission.

The *coordination* piece of the model is the least involved in terms of the need to work with other professionals. It "gathers all the shared objects as well as the common objectives" in order to start work on a particular task (Elmarzouqi et al., 2008, p. 93). The work in this part of the continuum is individual in nature and does not include work being done directly with other professionals. These actors are independently working towards a shared goal.

The *cooperation* section of the model is located between the coordination and collaboration ends of the continuum and reflects a balance between independent practice and complete dependency on others. It often requires actors within a setting to use certain tools or procedures to share the results of their work with others. There is a shared understanding among professionals of the goals that need to be achieved. Here, strong, interdependent bonds are not necessary for the completion of the work but there is the need for professionals to be in frequent contact.

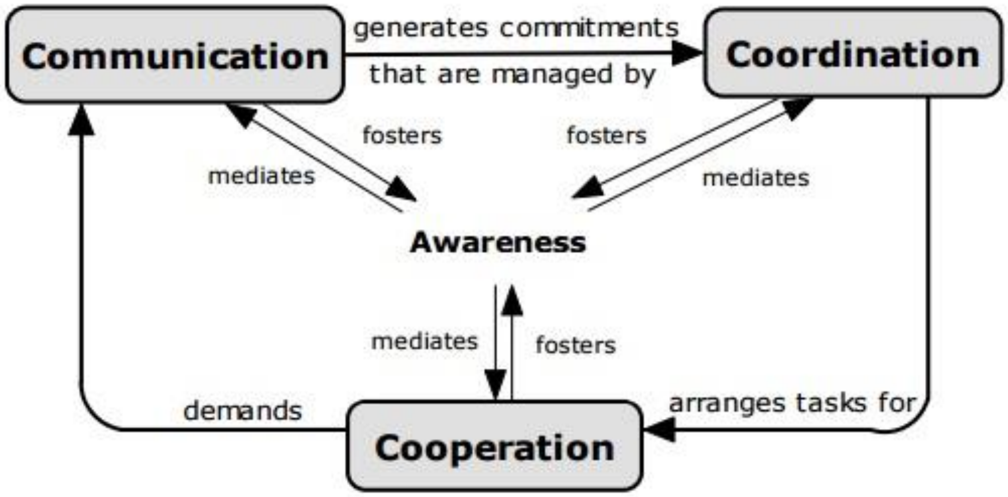
The *collaboration* end of the spectrum represents full interdependency of the actors with one another in order to achieve the desired goal. This kind of interdependency relies on all actors working closely with one another, requiring all members to be involved in the process as a whole and to have a “shared vision” that guides the collaboration (Elmarzouqi et al., 2008, p. 93); the model, therefore, aligns itself with the principles of interdisciplinarity and interprofessional collaboration.

This model expresses collaboration as being positioned at the end of a spectrum that describes how actors relate to each other’s work. The next model presented in the following section focuses on how collaboration is made up of smaller parts that need to work together in order for the shared work to be effective.

2.1.2 – The 3C Collaboration Model

Groupware—referring to the kinds of technologies that mediate collaboration between professionals—has implications for the larger domain of interprofessional collaboration. Within the field of groupware exists a model—the 3C Collaboration Model—that can be utilized to describe how collaboration occurs. The model, shown in Figure 3, consists of three major components that intermingle, leading to awareness among collaborating members and allowing the process of collaboration to take place: *communication*, *coordination*, and *cooperation* (Fuks et al., 2008, 2005; Steinmacher et al., 2013).

Figure 3: The 3C Collaboration Model (Fuks et al., 2005)



Note. From "Applying the 3C model to groupware development" by H. Fuks, A.B. Raposo, M.A. Gerosa, & C.J.P. Lucena, 2005, *International Journal of Cooperative Information Systems, 14*(2-3), p. 301. Copyright 2005 by World Scientific Publishing Co., Inc. Reprinted with permission.

Communication involves sending, receiving, and acknowledging the receipt of a message. Fuks et al. (2005) further explain that this communication component of the model also involves the smaller "elements" of: 1) the type of media through which communication is being made; 2) whether or not information is sent continuously and synchronously or in asynchronously-sent "blocks"; 3) the "meta-information" about the message's composition and properties; 4) whether or not a conversation occurs in a linear or branching fashion; and 5) whether or not there is a predetermined way information is allowed to flow through the media of interest. The communication component describes not only the content of the message but its context as well.

Coordination in the 3C Collaboration Model refers to how work is planned and distributed among members of the group working in collaboration with one another (Fuks et al., 2005). This planning component is necessary before cooperation can occur because all actors must understand their role in the collaborative effort so the execution of a task can proceed. This component also works to minimize conflicts between actors by determining a clear plan of action that will be used in the next component (Steinmacher et al., 2013).

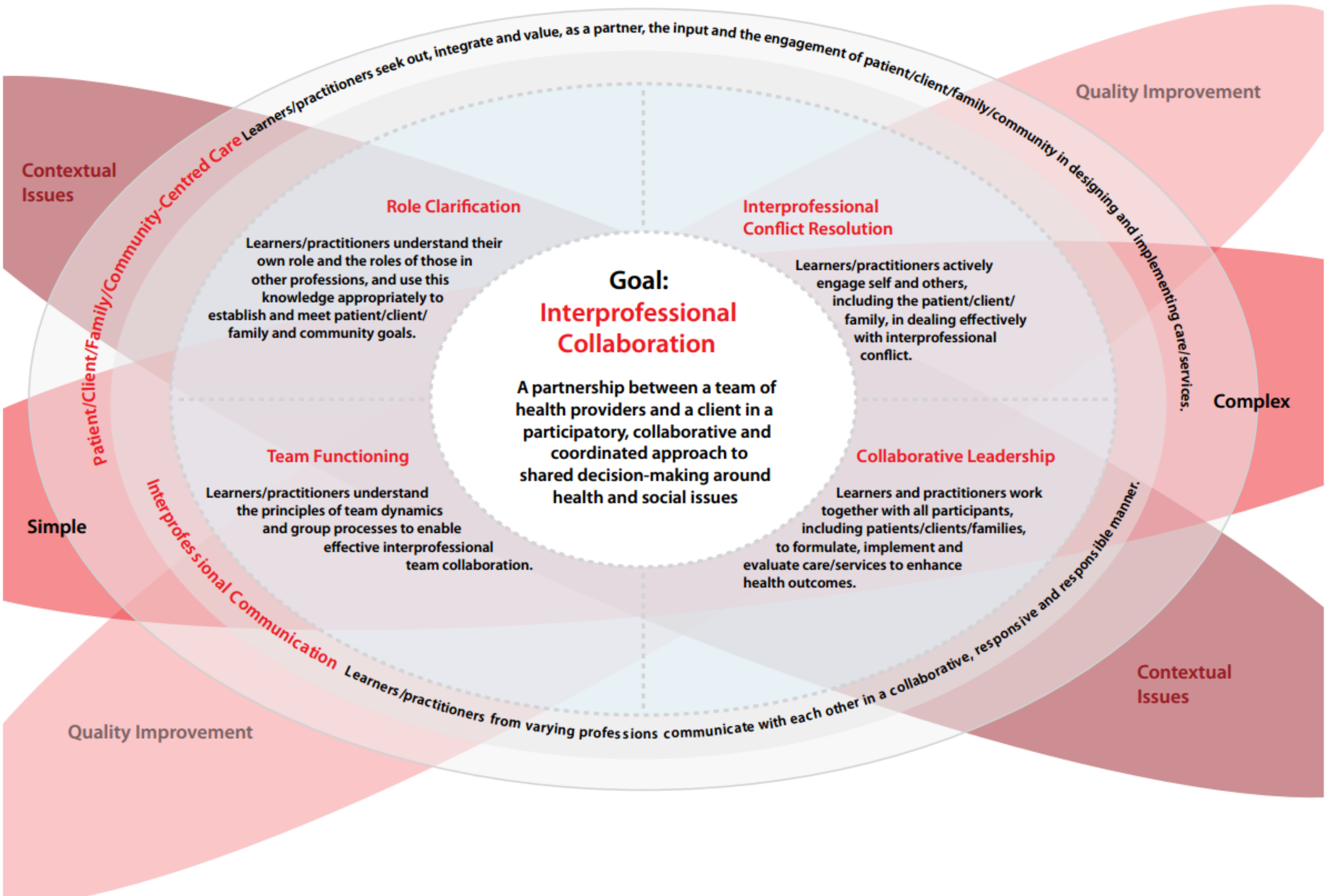
Cooperation refers to the actual work and completion of tasks by multiple actors in the setting of interest. As these tasks are completed, or difficulties and ambiguities arise during this step, the model can be cycled through once more so that additional, clarifying communication can be obtained—information that will then need to be coordinated once more before cooperation can resume effectively (Fuks et al., 2008).

Collaboration can be conceptualized as the holistic summation of the three components of the 3C Collaboration Model in relation to how multiple actors work together. As the authors explain, each component fulfils part of the overall goal of collaboration (Fuks et al., 2005). In this way, *collaboration* is a broader term compared to *communication*, *coordination*, and *cooperation* because it is made up of all three components. In the next model presented in 2.1.3, emphasis is placed on enhancing collaboration between individuals working in the same setting but different professions. This model focuses on the interprofessional aspect of collaboration, which is the predominant kind of collaboration discussed in the healthcare literature.

2.1.3 – National Interprofessional Competency Framework (NICF)

The Canadian Interprofessional Health Collaborative (CIHC) (2010) stated that developing interprofessional collaborative standards—at least in the health professions—is inherently difficult when professions perceive elements of collaboration in different ways. The CIHC elaborated on the importance of six core competency "domains" within their National Interprofessional Competency Framework. These broad domains include: "1) interprofessional communication; 2) patient/family/community-centered care; 3) role clarification; 4) team functioning; 5) collaborative leadership; and 6) interprofessional conflict resolution" (Canadian Interprofessional Health Collaborative, 2010, p. 9). See Figure 4 for a visual representation of their National Interprofessional Competency Framework (NICF).

Figure 4: National Interprofessional Competency Framework (Canadian Interprofessional Health Collaborative, 2010)



Note. From *A National Interprofessional Competency Framework* (p.11), by Canadian Interprofessional Health Collaborative, 2010, retrieved from http://www.cihc.ca/files/CIHC_IPCompetencies_Feb1210r.pdf. Copyright 2010 by Her Majesty the Queen in Right of Canada (2010). Reprinted with permission.

These six core competency domains were found to be the most important competencies in interprofessional collaboration among Canadian professionals surveyed (Curran et al., 2011). As Curran et al. explain, the professionals surveyed were experts in the fields of interprofessional care and interprofessional education in healthcare. Within each of these domains, there are a variety of competencies professionals can demonstrate to allow better collaboration with other professions. While these competencies were developed with the healthcare setting in mind, one can see that the competency domains—with perhaps the exception of *patient/family/community-centered care*—could easily be adapted for use in other professions. Table 2 on the next page further summarizes the nature of the competencies that fall within each of the six domains.

Table 2: Summary of the Competency Domains in the National Interprofessional Competency Framework (CIHC, 2010)

Core Competency Domain	Description
Interprofessional Communication	Professionals use technology to supplement communication within and between teams for the purposes of making decisions and staying up to date with one another. They actively listen to and communicate with other professionals and clients.
Patient/Family/Community-Centered Care	Professionals take into consideration the needs and concerns of the client. They situate given information in the context of the client's knowledge and educate where necessary. The client is involved in all decisions.
Role Clarification	Professionals exchange information with others to inform them of the responsibilities that exist in their roles. This helps professionals take into consideration how actions affect others and what information other professionals require to perform their own responsibilities.
Team Functioning	Professionals establish and actively maintain relationships with other professionals they work with. They are open to contributions from all team members and understand how the bond between team members is strengthened.
Collaborative Leadership	Professionals in leadership positions involve all relevant parties in the decision-making process in order to hear all sides. They set the tone for collaboration and create an environment that encourages collaboration among members.
Interprofessional Conflict Resolution	Professionals address conflicts that arise during the collaborative process rather than ignoring or dismissing them. They engage in effective conflict resolution management strategies that address the root cause of conflicts and that include all members.

Note. Adapted from *A National Interprofessional Competency Framework* (p.11), by Canadian Interprofessional Health Collaborative, 2010, retrieved from http://www.cihc.ca/files/CIHC_IPCompetencies_Feb1210r.pdf. Copyright 2010 by Her Majesty the Queen in Right of Canada (2010). Adapted with permission.

Given the clinical context, the *patient/family/community-centered care* competency domain does not apply to all work contexts or situations (such as when decisions must be made in the absence of the client or when there is not enough time to consult the community); however, the spirit of the domain—its intent to include those affected by decisions being made—has the potential to cross work context boundaries.

The CIHC (2010) makes note of the variation in complexity within a system, collapsing complexity into three categories: simple, complex, and mixed. It does not, however, offer a deep explanation with inclusion criteria to help classify a system as one of the three types, nor does it indicate how the manifestations of the six interprofessional core competencies varies between the three kinds of systems.

2.2 – Complex Adaptive Systems (CAS)

Complex adaptive systems (CAS) can be thought of as systems with numerous parts, each of which interacts with the others in a variety of complex, dynamic ways (Holland, 1992, 2006). These parts also respond, adapt, and self-organize according to changing outside and inside influences. The study of complex adaptive systems falls into the domain of "complexity theory", which itself has been explored in research areas ranging from the social sciences, computer engineering, and environmental sciences to nursing, business management, and pharmacology. In their reflective essay, Funtowicz and Ravetz (1994) conceptualize what they term *emergent complexity* as systems that involve entities whose actions and behaviour cannot easily be predicted by mathematical models and simulations.

The concept of complex adaptive systems have been used in studies to better understand and model how water consumption in urban areas is impacted by policy, consumer demand, and the hydrological cycle (Kanta & Zechman, 2014). It has also been used by researchers to explain the relationship between market conditions and the introduction of innovative products to consumers (Akgün, Keskin, & Byrne, 2014). More closely related in subject matter to this thesis, it has been used to explore how to make cities more resilient in the event of a disaster (Godschalk, 2003), how the clinical environment is understood in relation to preventable clinical incidents (Matthews & Thomas, 2007), and how different parts of an emergency department can integrate with each other to provide flexible patient care (Nugus et al., 2010).

Complex adaptive systems can be tightly- or loosely-coupled or somewhere between the two. Perrow (2011) elaborates on the properties of tightly- and loosely-coupled systems, shown in Table 3, which is used to justify why two particular data sets will be used as exemplars of tightly- and loosely-coupled systems in this research (see section 3.2 – Data Sets).

Table 3: Characteristics of tight- and loosely-coupled systems (Perrow, 2011, p. 96)

Tight Coupling	Loose Coupling
Delays in processing not possible	Processing delays possible
Invariant sequences	Order of sequences can be changed
Only one method to achieve goal	Alternative methods available
Little slack possible in supplies, equipment, personnel	Slack in resources possible
Buffers and redundancies are designed-in, deliberate	Buffers and redundancies fortuitously available
Substitutions of supplies, equipment, personnel limited and designed-in	Substitutions fortuitously available

Note. Adapted from *Normal Accidents: Living with High Risk Technologies* (p.96), by C. Perrow, 2011, Princeton: Princeton University Press. Adapted with permission.

Perrow (2011) conceptualizes tightly-coupled systems as systems with components that are highly interdependent in nature, with one process leading directly into the next with no way to circumvent the necessary steps in the event that materials or personnel are not available. As such, these kinds of systems need to have redundancies built into them; extra personnel and resources or appropriate, pre-approved substitutes need to be on hand at all times in case they are needed (Labaka, Hernantes, & Sarriegi, 2016). In some systems, the substitution of certain components can lead to very different, undesirable outcomes. In addition, some processes that occur within a system may be highly time dependent and cannot be delayed (Mann, 2013; Perrow, 2011).

Perrow (2011) gives the example of power grids as moderately complex, tightly-coupled systems. In these systems, power demands within the grid are routinely managed using both human operators and software that monitor power consumption and re-route electricity accordingly. Ontario and a number of states in the eastern United States of America experienced a massive blackout in August, 2003, reportedly leaving 50 million people without electricity (U.S.-Canada Power System Outage Task Force, 2004). The U.S.-Canada Power System Outage

Task Force—assembled in response to this blackout—indicated that the problem began when a power line was compromised in Ohio. A domino-like cascade of events occurred, stemming from this one incident and compromising a substantial section of the North American power grid. This event is used to illustrate how the components of a power grid are tightly-coupled to one another. While it may appear at first glance that this progression of events within the system was highly linear in nature (and, therefore, the antithesis of a complex system), it is important to note that *multiple* redundancies which should have been in place to prevent this event had, themselves, been compromised (U.S.-Canada Power System Outage Task Force, 2004).

In contrast, a loosely-coupled system naturally allows for various delays and substitutions in the overall process (Perrow, 2011). It is a kind of system in which the end goal can be reached in a variety of ways. Efficiency and rate of progress are emphasized less than the task being accomplished. Perrow used universities as examples of loosely coupled systems. These large, complex organizations have various departments and faculties that are responsible for different tasks and areas of expertise. Students attend universities to learn about specific domains of knowledge—the arts, chemistry, engineering, health sciences—and they progress through the university system by taking an assortment of courses offered from the various departments. While the end goal is to obtain a degree in their chosen field—itself a reflection of the knowledge they have gained—students can take elective courses which fall outside their specific domain of interest. So long as they have the required prerequisites for a course and enough free elective credits available to them, students are free to take any class they choose to fulfil their degree requirements. Students are also free to take more time to complete their degree if necessary; a four-year degree may be extended to five years. Such a system is loosely-coupled, with different components of the system activating at any time.

With the characteristics of both kinds of systems in mind, it is important to acknowledge that Perrow (2011) conceptualized these properties on a tight-loose spectrum rather than as an either-or dichotomy. As such, the following two subsections each describe an example of a loosely-coupled complex adaptive system and a tightly-coupled one. The subsections offer explanations as to why each of these exemplar cases, which provide the focus for this thesis research, are reflective of their respective type of complex adaptive system.

2.2.1 –Disaster Management and Disaster Risk Reduction

An area of particular concern for this thesis research is the field of community-based disaster risk reduction and emergency management. Disaster management is a complex, multifaceted domain; the overall resilience of a community depends on how effectively individuals and organizations within the community prepare for and respond to emergency situations (United Nations Office for Disaster Risk Reduction, 2015). This field would be considered a loosely-coupled system in the sense that the end goal is to make the community better prepared for disaster so that the response and recovery phases can proceed smoothly—with the important caveat that there are multiple ways to go about achieving this goal. In addition, the upstream management of a disaster (the planning that goes into laying the groundwork for a disaster response) (O'Sullivan, Kuziemsky, Corneil, Lemyre, & Franco, 2014) takes place over a long period of time. Olsson, Folke, and Berkes (2004) use the concept of *adaptive co-management* to describe the ways that organizations and individuals learn from each other and their surroundings, tailoring their behaviour to what is happening around them. Arguably, while this term is conceptually broader than the idea of a complex adaptive system, the two ideas are congruent: the system is dynamic and the many actors involved adapt to their environment.

In their study of how global information systems can be used to help coordinate an effective emergency response, Schafer, Ganoe, & Carroll (2007) state that preparing for a disaster is “a continual process of writing emergency plans, reviewing and discussing emergency plans, and exercising and training” (p. 502). This process has many steps, performed by many individuals, and each step is not chronologically locked to another. For example, while it is obviously necessary for an organization to create an emergency preparedness or response plan *before* they are able to review it, the same cannot be said for doing training exercises and building awareness in the community; they can either be done simultaneously or one before the other, though the order in which this is done is not important (Perrow, 2011).

According to Perrow’s (2011) tendencies of loosely-coupled systems (previously shown in Table 3), many disaster risk reduction activities are non-sequential in nature, have multiple ways to achieve community resilience, and make do with what resources are available—even (or perhaps especially) when such resources are scarce. The exact nature of the damage or disruption a disaster imposes on people, buildings, infrastructure, or the environment is almost always unpredictable and—because of this—many disaster response organizations and governments adopt an *all-hazards* approach. The flexibility this approach provides for their plans allows them to respond to a broad spectrum of disasters rather than have individual plans for every specific disaster, which would require first responders to know and keep track of a multitude of operational protocols in the event of a disaster (Caruson & MacManus, 2011; O’Sullivan, Kuziemsky, Toal-Sullivan, & Corneil, 2013).

While an all-hazards approach is a way to limit the amount of information and resources needed for a disaster response, these same organizations do not often have every necessary resource available at their fingertips during an event. Organizations are encouraged to establish memoranda of understanding (MOUs) and/or memoranda of agreement (MOAs) with community partners to secure necessary resources or equipment in the event of a disaster (Hodge, Anderson, Kirsch, & Kelen, 2011). Along with adopting an all-hazards approach, this measure fulfils the '*buffers and redundancies fortuitously available'* and '*substitutions fortuitously available'* characteristics of loosely-coupled systems shown in Table 3 (Perrow, 2011, p. 96). It is important to note that while MOUs are not required to be legally binding, some organizations prefer to establish an unambiguous contract with their partners (Hodge et al., 2011). However, as Hodge et al. indicate, it is the spirit of the agreement that is important, not the details. Legal, contractual obligations during emergencies may place added and unneeded pressure on an organization to comply exactly with the terms of the agreement rather than collaborating in a way that is more appropriate to the event.

Further complicating the accurate prediction of the scale of a disaster is the variety of geographical issues that must be taken into account. Deaths from natural disasters are related not only to the community's capacity to respond, but also to the location and nearby geographical features that may increase vulnerability to disaster (Kahn, 2005). In large cities, such issues may lead to community isolation, relative to other nearby communities or more densely-packed urban centers where resources may be focused during disaster response. Outside of the presence of an immediate disaster, large urban centers may feature some communities (ethnic or socioeconomic) who may be marginalized, isolated, or composed of members who do not identify closely with one another (United Nations Office for Disaster Risk Reduction, 2015). This may make it difficult to build some kind of common ground among members of the larger area, which has been shown to positively influence the way a community prepares for a disaster (Kuziemsky & O'Sullivan, 2015).

Inherent to the field of disaster risk reduction and emergency management is the number of people that must be managed. Each individual may respond in a different way to a disaster, deciding to seek shelter, flee the area, or search out loved ones. Mawson (2005) reduces these responses into a single driving force: the desire to seek out affiliation with individuals, especially those with whom people are already emotionally attached. The movement of people towards loved ones, heedless of all risk, adds another layer of complexity when managing individuals in disasters. When individuals travel across a disaster zone to check on or be with loved ones, it creates difficulties for emergency response crews when trying to keep track of individuals and keep them safe.

The lack of linearity in disaster preparedness activities, the use of an all-hazards approach, and the establishment of intricate memoranda of understanding all contribute to the complexity of responding to disasters. In addition, various geographical considerations and the unpredictable nature of the movements of individuals in a disaster add to the complexity of the field.

2.2.2 – Collaborative Healthcare Delivery

Collaborative healthcare delivery—specifically the kind of care modeled in team-based surgical interventions—often exists within a tightly-coupled system. Because the field is quite broad, this thesis focused specifically on surgical teams as an example of collaborative healthcare delivery, where the interactions must be highly scripted and closely controlled in order to protect the patient. According to Table 3, this classification using Perrow's (2011) characteristics of tightly-coupled systems means that there cannot be delays in this very controlled process (2011). While there may be multiple ways to achieve the desired goal of a surgery, the team must first decide on which method to use. The equipment used for the surgery will be determined by this method and, therefore, materials, personnel, and contingencies must be built-in to the plan the surgical team will be using. Together, these factors create a tightly-coupled environment.

The composition of surgical teams can vary between procedures. In addition to the surgeon (or surgeons for complex procedures), they include an anaesthesiologist, nurses, medical technicians, medical residents, and can also include specialists like cardiologists, radiologists, perfusionists, and surgical care practitioners (Quick, 2013; Zheng, Panton, & Al-Tayeb, 2012). Each of these professionals must be kept informed during the surgery; communication between members is a major contributing factor to success in surgical interventions, with more adverse events occurring when communication is poor (Davenport, Henderson, Mosca, Khuri, & Mentzer, 2007).

As Bogdanovic, Perry, Guggenheim, and Manser (2015) indicate, communication is very important during surgical procedures because it can help modulate the workloads of the various professionals during unexpected events. However, the more professionals there are in the operating room, the more complex the process of communication and maintaining awareness of the patient's status. In an attempt to control chaos during a surgery, the number of staff involved in the intervention is often limited. In fact, it has been shown that the length of a surgical procedure increases by seven minutes when a single additional team member is added (Zheng et al., 2012). Teams performing together on a more frequent basis, or over an extended period of time, learn to anticipate the actions of their fellow members (Vashdi, Bamberger, & Erez, 2012) but Zheng, Panton, and Al-Tayeb (2012) indicate that there is a limit to this effect when there are too many individuals involved in the process. The relationship between the actors in the system becomes more complex as more parts are added.

Whereas team interaction creates a certain level of complexity in surgical interventions, the patients themselves add another layer. Surgeons will attempt to use the surgical methods that are the most effective and safe for a given condition, but the specific physiology of a patient can complicate surgery. For this reason, information must be gathered about the patient so that the surgical team is able to effectively and safely perform the surgery (Lin & Moore, 2014). Lin and Moore elaborate on this, noting that some medications the patient is taking (such as insulin, anti-coagulants, and medications for heart conditions) can interfere with different aspects of the procedure. Even the scheduling of surgeries must take into account these patients and their specific biological contexts. Lin and Moore indicate that surgeons have many other patient-related factors to consider (allergies, patients receiving dialysis treatment, and others) when deciding on an appropriate course of action. Consultations with the patient beforehand can reveal previously-unknown conditions that could impact the procedure, which will then need to be adjusted to suit that particular situation.

2.3 – Designing to Support Collaboration

In order for collaboration to occur in these complex adaptive systems (whether loosely- or tightly-coupled), collaborative tools are often used to facilitate communication between members, archive decisions and discussions regarding topics of relevance, and provide other kinds of domain-specific supports members might use. There are features of tools that designers have implemented to improve the utility of such systems—which are usually software-based—and some of these features will be described in this section.

At this point, the distinction between the process of collaboration and the tools used to support this collaboration should be reinforced. When designing a collaborative tool, it is important not to overcomplicate or “over-design” a system that is meant to assist with collaboration. The technology must not be more advanced than the knowledge or skills of the people who are expected to use the tool.

2.3.1 – System Interoperability

In an attempt to bridge the gap between different kinds of professionals working with one another, many organizations implement collaborative tools that they encourage their professionals to use. This creates new methods of communication within the workplace. In the medical context, the hope is that the ability of professionals in different roles to properly communicate with one another will create environments where medical care is delivered more effectively (Hartgerink et al., 2014). While electronic health records (EHRs) create and organize easily-accessible information that is used by different professionals collaborating on a task, they are merely documentation tools and were not designed as spaces to carry out collaborative work. New systems must be used to allow for professionals to collaborate in virtual space.

However, even interprofessional collaborative tools that exist do not consider the needs of all types of professionals who are using these tools. For example, the tool may be written in the technical language of one profession that the other professions do not understand. Moreover, tool designers may hold different expectations about how software will be used compared to its end users. These issues can leave these end users frustrated, unsatisfied, and ultimately less likely to use the tool in the first place (Staggers, Clark, Blaz, & Kapsandoy, 2011).

This language issue is compounded by the fact that EHRs and other collaborative technologies may not allow for easy collaboration between professionals in different organizations or divisions; computer-mediated tools are written using different programming languages that may or may not "talk" with one another (Kubicek, Cimander, & Scholl, 2011). This issue of interoperability can manifest itself in two ways: syntactic interoperability (the way different systems use the same language or formatting standards) and semantic interoperability (the ways different systems interpret natural language in the same way) (Kubicek et al., 2011). Whether or not a collaborative tool addresses these two issues can determine if the tool will be successful and implemented, or too cumbersome and abandoned.

2.3.2 – Face-to-Face and Computer-Mediated Interaction

Time is a valuable resource in the busy lives of many professionals, making face-to-face (FtF) meetings time-consuming endeavours if the professionals do not work in the same physical space. This is compounded by the fact that professionals belonging to the same organizations may work from completely different campuses. However, Shneiderman and Plaisant (2010) have developed a matrix that can be used to find technologies that can circumvent this traditional way of meeting. The matrix describes collaborative activities involving group members that happens at either the same or different times, occurring in the same or different place. While FtF meetings are traditionally done using the same-time-same-place paradigm, they can also occur in the same-time-different-place paradigm using applications such as Skype, Google Hangouts, etc… Still, these FtF or remote meetings can be an inefficient use of time in some cases. For example, brief updates on projects do not necessitate full FtF meetings when a simple message can be left somewhere. Likewise, massive amounts of information (such as an entire patient chart) cannot effectively be communicated in an hour-long meeting and may warrant the use of different-time-different-place technologies (Warkentin, Sayeed, & Hightower, 1997).

While Okdie, Guadagno, Bernieri, Geers, & McLarney-Vesotski (2011) show that someone participating in a FtF interaction will feel more positively about the other person than if they were using computer-mediated communication (CMC), they note that these FtF interactions require more energy to maintain than exchanging information through CMC. Sometimes a basic exchange of facts (as opposed to longer conversations) is all that is required in instances like patient care. That said, CMC may not be appropriate in situations that require building trust to form new relationships, such as in disaster management initiatives or other processes involving negotiation (King, Hartzel, Schilhavy, Melone, & McGuire, 2010). Tool designers may need to evaluate whether it is necessary for their solution to incorporate visual (photos, videos, or live video feeds) or audio components, depending on the goal of their tool.

2.3.3 – Synchronicity

When discussing how a tool facilitates collaboration, it is important to consider how messages are delivered and interactions play out. Will users be able to see each other's contributions in real-time? Is it necessary for changes made to the tool be uploaded to a server before being downloaded to the collaborators' computer some hours later? The former defines a synchronous tool and the latter defines an asynchronous one. In some instances, such as leaving short notes or memos, synchronicity is not required; the other collaborators may be busy at the time and the information being shared can be adequately explained in a message without having to contact its writer.

In other contexts, synchronous collaboration tools enable collaborators to correct each other's mistakes and build upon knowledge (Brent Hall, Chipeniuk, Feick, Leahy, & Deparday, 2010). However, as Xu, Zhang, Harvey, & Young indicate (2008) asynchronous tools provide other features that synchronous ones do not. They identify three categories of features (beyond just communication) that such tools provide, including information sharing (file-sharing), project management capabilities, and shared calendars. While not necessary in all contexts, these features may help with coordinating tasks.

2.3 – Summary

In summary, this chapter introduced the literature examining different ways collaboration between professionals can be conceptualized, including several models that elaborate how professionals can interact with one another in a way that promotes collaboration and understanding. This was done by exploring the differences between *collaboration*, *coordination*, and *cooperation*. An overview of the core competencies necessary for collaboration to succeed according to the Canadian Interprofessional Health Collaborative was discussed. These competencies were arrived at empirically, though the context in which they exist may only make them applicable to the medical profession (Curran et al., 2011).

Using these models, the first research question of this thesis relating to the core properties of collaboration can be answered: the core properties of collaboration can vary according to which models chosen to inform the design of a collaborative tool. The task at hand may also change what core properties are of greatest concern. However, clear communication, a shared understanding of the goals of a task, and knowledge of the roles of actors involved in the task are common threads across the three models.

The concept of loosely- and tightly-coupled complex adaptive systems was presented according to Perrow (2011); it situated disaster and emergency management as well as surgical teams—the two fields of study relevant to this thesis—within one type of complex adaptive system or the other. This lays the foundation for the second research question relating to how the core properties of collaboration manifest in both loosely- and tightly-coupled complex adaptive systems.

Finally, the use of technology to bridge the gap between actors within a system was introduced, highlighting issues relating to the interoperability of such technology, the effects of face-to-face versus computer-mediated interactions, and whether design takes into consideration the needs of all individuals and roles involved. This final point underpins the third research question that aims to answer how collaborative tools can be designed with the core properties of collaboration in mind. Table 4 provides a brief overview of questions that have been answered in the literature and areas that have yet to be addressed.

Table 4: Overview of topics addressed by literature review and issues that remain unanswered

<table>
<tr><th colspan="2">Issues Addressed by the Literature</th></tr>
<tr><td colspan="2">There are models that exist in the literature that can be used to demonstrate how the concept of collaboration can be broken down into its constituent “core properties”.</td></tr>
<tr><td colspan="2">The core properties of collaboration could change or interact with one another in different ways in a loosely- or tightly-coupled complex adaptive system.</td></tr>
<tr><td colspan="2">There are criteria that a system must meet for it to be considered a loosely- or tightly-coupled complex adaptive system.</td></tr>
<tr><td colspan="2">Disaster risk reduction and emergency management can unfold in ways that fulfil the criteria of a loosely-coupled complex adaptive system.</td></tr>
<tr><td colspan="2">Surgical teams operate in ways that fulfil the criteria for tightly-coupled complex adaptive systems.</td></tr>
<tr><td rowspan="3">When designing a collaborative tool, it is important to consider the technological aspects of tool design such as:</td><td>a) System interoperability</td></tr>
<tr><td>b) The benefits of FtF versus CMC interaction</td></tr>
<tr><td>c) Synchronous and asynchronous ways to collaborate</td></tr>
<tr><th colspan="2">Issues that Require Further Investigation</th></tr>
<tr><td colspan="2">How do the core properties of collaboration manifest in loosely-coupled complex adaptive systems?</td></tr>
<tr><td colspan="2">How do the core properties of collaboration manifest in tightly-coupled complex adaptive systems?</td></tr>
<tr><td colspan="2">How can we design systems in such a way that incorporate these core properties?</td></tr>
</table>

CHAPTER 3: METHODS

This thesis follows a multiple-case study design (Yin, 2009) where two datasets were examined and analyzed separately to answer the research questions. This chapter provides a detailed explanation of the cases, including data sources, protocol for data collection, and the steps that were used for analysis.

3.1 – Case Study Design

A multiple-case study design was chosen to assist in answering the research questions. According to Yin (2009), case studies lend themselves well to exploring issues not previously discussed in literature—issues that need to be explored further. The concept of collaboration in loosely- and tightly-coupled CAS requires further investigation; because a case study design is an exploratory method of scientific inquiry, it is most appropriate to exploring the inner workings of each of these kinds of systems. Whereas single-case designs focus on one “case” (a specific environment studied during a specific time period), multiple-case designs study the same phenomenon at multiple sites, thereby creating multiple cases (Creswell, 2013). Specifically, this thesis research has examined how collaborative teams (the unit of analysis) used collaborative tools in three different cases, making this a multiple-case study design.

3.2 – Data Sets

Two datasets were used to develop a model for this thesis. The first represents an example of collaboration in a loosely-coupled complex adaptive system in the field of disaster risk reduction in two communities. The second dataset is focused on the interactions of a surgical team in a hospital surgery unit, representing a complex adaptive system which is tightly-coupled.

3.2.1 – Loosely-Coupled System: Disaster Management and Disaster Risk Reduction

The data set representing a loosely-coupled system was collected for *The EnRiCH Project*—a research project that focused on enhancing resilience and preparedness of high-risk populations living in five communities across Canada, by engaging emergency management organizations and facilitating partnerships between community organizations (O'Sullivan, Corniel, Kuziemsky, Lemyre, & McCrann, 2013). The five communities from which data was collected were: Truro, Nova Scotia; The Region of Kitchener-Waterloo, Ontario; Gatineau, Québec; and Québec City, Québec. The full protocol for the community intervention is available online at www.enrichproject.ca (O'Sullivan, Corniel, et al., 2013).

These partnerships were facilitated using a technique called *asset mapping* whereby each organization within a community created a spreadsheet outlining the services and resources they could provide in the event of an emergency or disaster. This spreadsheet was to be used as a coordination tool; with it, participants could determine who in the group they could contact for specific services. This activity used the free, cloud-based Google Sheets software (part of the Google Drive suite of programs, which include the much better-known Google Docs word processor). This cloud-based spreadsheet software allowed all the participants in a given community to log in and contribute to the spreadsheet in real time—a feature that was used to great effect during the orientation session where group members helped each other understand the software's capabilities and explored its value as a coordination tool.

While the exact makeup of the groups varied across the different communities, organizations involved in responding to disasters or emergencies were contacted and asked to participate. In addition, regional authorities were invited to contribute, as their input into the project would be invaluable. Organizations that ran food banks and community centers, as well as members of the chambers of commerce in the various communities, transportation administrations, mental health organizations, and long-term care facilities were also asked to participate.

The English data from Truro and The Region of Waterloo were used for this study. The data sources used in this thesis research included one-on-one, semi-structured phone interviews that were recorded in an audio-only format and then transcribed verbatim. There were 38 interviews, each lasting between 30 minutes and one hour. The purpose of the interviews was to determine how participants felt about the collaborative group they were taking part in, and to what extent the group influenced their perceptions of preparedness (see Appendix B for the full interview guide).

The first set of interviews were collected before the groups met, to establish a baseline of opinions and feelings about the collaborative activity that was planned. Subsequent interviews were collected after they met for an asset-mapping activity and discussed how the community would respond to a disaster. Although baseline interviews were conducted, these occurred before participants met with one another and, therefore, did not gather information about how the group was collaborating. Therefore, the interviews used for this thesis were conducted *after* participants met one another and had begun to collaborate.

The EnRiCH Project obtained approval from the University of Ottawa Research Ethics Board and participant consent was obtained before any information was collected. Ethics approval from the same review board was obtained for this secondary analysis (see Appendix D for ethics certificate).

All transcripts were double-checked by a second researcher to ensure accuracy. I was personally involved in the transcription and accuracy-checking aspects of the original research project.

3.2.2 – Tightly-Coupled System: Surgical Teams

The data used to analyze collaboration in tightly-coupled complex adaptive systems was collected from two integrated Canadian hospitals in a large, urban setting as part of a larger study (Kuziemsky & Bush, 2013). The larger study focused on observing the transformation and overhaul of both hospitals' peri-operative information system and how professionals interacted with this new system.

SIMs (the Surgical Information Management system) is an electronic medical record software suite used by various professional groups involved in the management and care of patients undergoing surgery. It tracks patient progress and keeps all healthcare providers updated on the status of the patient. It was deployed to better support the continuity of patient experience from pre-operation consultation and admitting to post-operation discharge and recovery. Developed and sold by a third-party health information technology vendor, it was necessary for software such as SIMs to integrate with existing hospital infrastructure and workflow. Not only did SIMs track patient progress and interact with the hospitals' existing health information technology but it also has the capability to provide hospital administrators with statistical data relating to various workflow- or patient safety-related issues.

The dataset used for this study included six one hour-long, audio-recorded, semi-structured interviews (in English) occurring at various stages of the implementation process; the scope of this original study captured a short period of time in the longer implementation period of this new peri-operative system (see Appendix C for the full interview guide). At the time data was collected, the initiative had begun roughly two and a half years prior. Ethics approval was obtained for the study from both the hospital ethics committee and the board of ethics for the university; participants also freely consented to the research process.

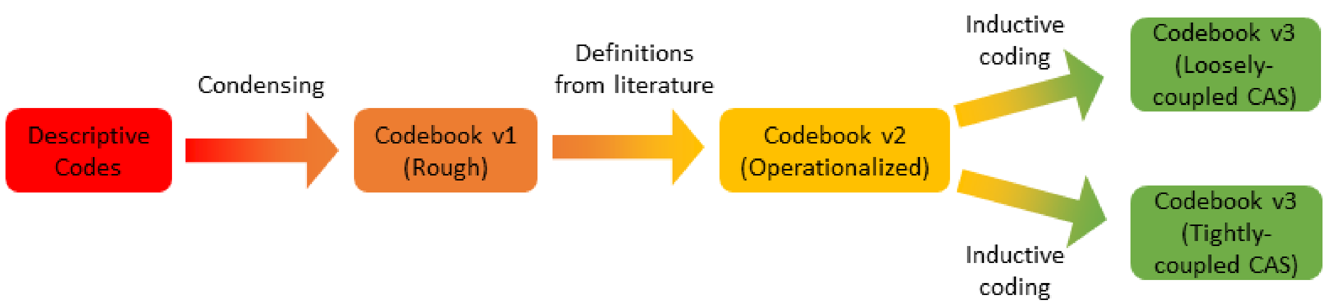
The interviewees included registered nurses, anesthesiologists, and nursing administrator/managers. The interviews were transcribed verbatim using a transcription service and checked for accuracy by Dr. Kuziemsky. For this thesis, we analyzed the six interviews from the study.

3.3 – Data Analysis

The units of analysis used in this study differed between datasets. For the disaster risk reduction and emergency management dataset, the unit consisted of individuals from various community organizations (and the group they formed as a result of *The EnRiCH Project* intervention). For the surgical team dataset, the unit of analysis was individuals from the various professions (anaesthesiologists, nurses, and other operating room personnel) who use the SIMs software.

The transcribed interviews underwent directed content analysis, adapted from Hseih and Shannon (2005). The coding process (shown in Figure 5) began with a list of descriptive codes relating to the concept of *collaboration*—a list that was arrived at using the articles from the models in Chapter 2 (Canadian Interprofessional Health Collaborative, 2010; Elmarzouqi et al., 2008; Fuks et al., 2005). Descriptive codes and concepts emerged from the articles, which were assembled and used to initially code the data. A full list of descriptive codes can be seen in Appendix A. This extensive list of descriptive codes was then condensed into a more manageable rough codebook (Codebook v1) with broad terms that were shared by both datasets. The codebook was further refined (Codebook v2) by operationalizing the categories that were emerging using definitions found in the literature relating to the models of collaboration discussed in Chapter 2.1 – Collaboration. The shared codebook then branched into loosely- and tightly-coupled versions (Codebook v3) so that each of the systems would have a separate codebook. Rather than contrast the two datasets using the same codebook, it was decided that each dataset should be given its own, uniquely-tailored codebook to work from. Future changes to the codebooks were informed by an inductive coding process unique to each dataset.

Figure 5: The data analysis process



To ensure rigour in the coding process, a second coder was involved in the data analysis procedure once Codebook v3 was found to be sufficiently developed to capture points of data that were emerging inductively from each of the datasets. 10.5% (four out of 38 interviews) and 16.6% (one out of six interviews) of the loosely- and tightly-coupled data, respectively, were coded by this second coder. To avoid bias, this individual did not have access to the coded version of the interview which they had been asked to analyze (i.e. the second coder had no prior knowledge as to how the principal investigator coded the very same interview). Once the coding of an interview was finished, the second coder and principal investigator's coding were compared sentence by sentence. Discrepancies between coded segments of the interviews were discussed at length and changes to the codebook were made as necessary to clarify the operational definitions of each of the categories for subsequent interviews. For example, if the second coder pointed out the emergence of a new code in an interview, this coding decision was explored, and a discussion ensued relating how distinct this potential code was from existing coding categories. If there was enough evidence to support the new code, an operational definition was given to it to separate it from other codes. Likewise, similar discussions took place when blocks of data were coded by both the second coder and principal investigator but the codes used to identify the data differed. Coded sections of interviews that had been looked at previously were then re-examined and codes were moved to different categories if they no longer fit the revised definitions.

The coded interview transcripts were transferred to NVivo10 software to facilitate the process of thematic analysis (QSR International, 2013). By the time the coding process had finished, notes and memos indicated that some categories could combine to form themes discussing a specific topic, while some categories used during the coding process could became themes in their own right.

3.4 – Strategies to Ensure Rigour

Authors such as LeCompte and Goetz (1982), and Lincoln and Guba (1985) have suggested standards to which qualitative research should be held—standards that take into account the impossibility of qualitative studies to achieve statistical representation of a population. Creswell (2013) offers a summary of the many kinds of different validation criteria that qualitative studies can employ to validate their results. For the purposes of this research, rigour was ensured by following the standards suggested by Lincoln and Guba (1985), which are explained in Table 5. Miles, Huberman, & Saldaña (2014) explain these four criteria further and add an additional one—*application*—to their evaluative framework. The third column of the table references other authors who have expanded on the work done by the seminal authors.

Table 5: Lincoln & Guba (1985) and Miles, Huberman, & Saldaña (2014) Standards for Validation

Lincoln & Guba's Terminology	***Quantitative Equivalent***	***Definition***
Credibility	Internal Validity	"Credibility (…) is the extent to which the findings represent the beliefs/feelings and values of the participants" (Viney & Nagy, 2011, p. 56)
Transferability	External Validity	"If Context A and Context B are 'sufficiently' congruent, then working hypotheses from the sending originating context *may* be applicable in the receiving context." (Lincoln & Guba, 1985, p. 124)
Dependability	Reliability	"Dependability will demonstrate the appropriateness of methodological shifts that occurred during the emergent process." (Rodwell & Byers, 1997, p. 124)
Confirmability	Objectivity	"Confirmability refers to the extent to which conclusions are able to be verified by others" (Viney & Nagy, 2011, p. 56)
Application	N/A	The research should be "worthwhile, ranging from consciousness raising and the development of insight or self-understanding to broader considerations-—a theory to guide action, or policy advice. Or it may be local and specific—corrective recommendations or specific action images." (Miles et al., 2014, p. 315)

3.4.1 – Credibility

To verify the credibility of the findings, it is important to make sure the views of the participants are accurately reflected (Viney & Nagy, 2011). Because the data were not gathered first-hand as part of this thesis, gaining access to the original participants would have been problematic and impractical to acquire—for this reason, member checking was not possible. However, the principal investigators of the studies from which the data comes were supervisors for this thesis; they collected the data for each data set and were able to provide one type of perspective for confirming the findings.

3.4.2 – Transferability

Because the findings of all research are constrained to similar contexts to those found where the research was conducted, rich, thick descriptions of the settings are provided so that those evaluating the research can better determine if the findings apply to other locales or spheres of practice. Additionally, the loosely-coupled dataset consists of two communities and, where the findings from each community are in agreement with one another, transferability to other settings is increased. The similarities emerging from both the loosely- and tightly-coupled datasets also add a degree of transferability to the results, while the differences reveal when the core properties of collaboration differ within specific settings.

3.4.3 – Dependability

To enable replication, the research process was recorded in detail (as explained in 3.3 – Data Analysis) and notes were taken to explain why various data analysis decisions were taken at certain points in time. As Shenton (2004) states, “the research design may be viewed as a “prototype model” (p. 71). General memos from the data analysis phase were kept and can be used to show transparency of the decision-making process. Smaller, more specific memos and annotations were used when uncertainties and conflicts arose during the coding process (Miles & Huberman, 1994).

3.4.4 – Confirmability

Confirmability was established using the principles of triangulation. Before the coding process began, it was decided that a minimum of 10% of the interviews from each dataset would be coded a second time by another person for accuracy. A second coder who was familiar with *The EnRiCH Project* dataset confirmed the results of the coding process for that dataset and coded a sample of 11% of the 38 interviews. This second coder also assisted in confirming the coding results for the SIMs-related dataset, coding a 16% of the six interviews from this dataset.

Once preliminary themes emerged from the data, they were presented to the two thesis supervisors for confirmation. They reviewed the coding procedures, assisted in development of the emerging themes resulting from the coding process, and supported the development and revision of the models. Because each supervisor was very familiar with their respective dataset, the results of the thematic analysis could be confirmed.

3.4.5 – Application

Because the practical purpose of performing research is to examine and create documentation that explains a phenomenon, experience, or an observation, it must be useable in some form so that findings positively contribute in some way to society. The purpose of this research—to determine what core properties of collaboration are present in loosely- and tightly-coupled systems—will help organizations determine what kinds of supports these interprofessional interactions require to function optimally. The discussion section of Chapter 5 will address the practical applications of this research more in depth.

CHAPTER 4: RESULTS

The following two sections are dedicated to explaining the major themes that emerged during data analysis for the loosely-coupled complex adaptive system and the tightly-coupled one, respectively.

4.1 – Loosely-Coupled System: Disaster Management and Disaster Risk Reduction

The themes presented for the loosely-coupled system emerged from a project that was meant to be proof-of-concept. The barriers presented are not obstacles that cannot be overcome—rather, they are considerations that can inform other collaborative efforts to maximize the potential benefits of any project.

The most important thing to note about the *EnRiCH Project*, and by extension every locale, is that each community is a unique environment. Each community features different actors, different government or regulatory policies and laws, different cultures, and—most importantly—different people who view the world with unique perspectives.

4.1.1 – Theme 1: Engagement

During the data analysis process, it was clear that one of the most important aspects of collaboration in the context of disaster preparedness and management was the concept of *engagement*. Many of the themes in this chapter directly relate to participant engagement in some way. Engagement relates to *investment*: how invested the members of a group are in a task or project. The more engaged they are, the more willing they are to put effort into making the project a success. Without engagement, members simply would not have participated in the activities that were aimed at increasing community resilience, such as contributing information to the cloud-based tool the EnRiCH coordinators created to facilitate collaboration between members. In a loosely-coupled system, engagement must manifest *intrinsically*; motivation to collaborate must originate from inside participants. This investment in the project is especially needed in these kinds of systems because of the inherent flexibility in the way tasks can be accomplished. The abundance of choice with regards to how a goal can be completed means that every individual or organization in the system could approach the goal differently. There must be internal motivation to collaborate and ensure that these different ways of working help the group as a whole to arrive at the same goal.

If participants feel like the collaborative tool belongs to them, they are more likely to feel invested in the process. The end users need to feel like the tool was not imposed on them and that they were not forced to use it. One participant notes,

> *"I guess the impetus will be on the folks around the table and whether they're willing to take this tool to the next level and own it. And that'll be the real issue. If they decide to own this and say, 'You know what? This is really useful,' it will move forward and it will be successful." (Participant 8, Waterloo)*

The perception of usefulness is dictated by how engaged the participants feel in the process. Tool designers must maintain participant engagement by involving them in the design and implementation of the tool, understanding that end users know what processes work best in their unique context. The more engaged or invested collaborators are in the tool, the more likely they will be to use it.

Engagement, however, is not just mental investment in an activity and it must be supplemented with clear direction, commitment, and action. A lack of direction can leave users wondering what to do next, with each user waiting for the others to make the first move, ultimately stalling any collaboration. Additionally, it was noted by participants that interest wanes over time, as one participant indicated.

> *"The group represented at the Truro meeting did have a high level of commitment. The question is, however, if that level of interest can be sustained over time. The challenge for the group will be to keep and build on the initial momentum started at that meeting." (Participant 21, Truro)*

Maintaining momentum and interest can be as challenging as the original goal the collaborators are trying to address. In a loosely-coupled system, timelines may not be as concrete as those found in tightly-coupled systems, meaning that there needs to be strong internal motivation from partners to keep the project moving. These kinds of collaborative projects benefit from feedback loops where interest is gauged, and motivational factors are adjusted, so participants continue to be engaged and invested in the process. Tool designers should incorporate some kind of system that gauges the interest levels of collaborators: when interest begins to wane, steps can be taken to increase engagement. This may be done by tracking the frequency of collaborator logins to the tool or by looking at the average length of time the tool is being used per partner.

Although it is discussed separately in the next theme, communication can help to increase engagement in loosely-coupled systems. Communication through the spreadsheet in *The EnRiCH Project* was associated with feelings of increased engagement in the initiative. Participants described feeling invested in the collaborative activity when information about the activity (such as roles and responsibilities) was being actively exchanged. One participant expanded on this, stating

> *"I've found in anything that I try to do in the community, awareness is always the biggest issue. Like, if you can make your group perfectly aware of any issue, there'll be a percentage of that group that will be interested in that issue. There'll probably be a huge part of that group that won't be interested in that issue but you go with what you got and you build it. […] If we increased the awareness, then, there'd, there will be a certain percentage of our population who will pick it up and carry it." (Participant 5, Truro)*

Communication and interest in a project are directly related to one another: projects that are engaging get people talking and the more people talk about a project, the more interested they and others become. In loosely-coupled systems, engagement is an important factor that is necessary to bind together organizations that have widely varying but sometimes overlapping mandates, areas of practice, and irregular contact with one another. Tool designers should make it easy for users to communicate with one another and for them to branch out and engage other stakeholders. So long as sensitive information is not being shared, tool designers could even create a “guest mode” where people who are interested in the project can see what kind of work is being done before they commit to joining the group.

4.1.2 – Theme 2: Communication

Communication is a critical component to collaboration in any context. This theme for the loosely-couple system deals less with the *content* of the message, however, and looks instead at the *process* of communication. With *The EnRiCH Project*, there was some confusion among the participants about the purpose and expectations of the project itself. This could be attributed to communication and the way participants were brought together through invitations from other participants who themselves had been contacted by the research team. In Truro, the disconnect between some participating groups and the goal of the project were more pronounced, which left some other participants feeling frustrated.

> *“I got the impression from the people who attended—the ladies at our table — that they [...] didn’t understand the purpose of what it was, and they certainly had no concept of how they were going to bring any of this kind of information back to their own organizations. So [...] I was confused by the configuration of people that were there.” (Participant 4, Truro)*

The issue facing these groups was not that they did not belong—after all, the project was meant to bring together various kinds of community organizations together—but that the purpose was not clearly communicated. This could be attributed to the fact that the leaders of these organizations had been informed about the project (by either the research staff or by other participant organizations) but asked a representative to attend the sessions in their place. Tool designers need to be clear when explaining the purpose of their collaborative activity, but they also need to make it clear to partners that using the tool is not the reason for collaborating—the tool is just a method to achieve whatever the overall collaborative goal is. Information about the project should be stored near the working documents where the end users can easily refer to it. One participant had an excellent suggestion about having something prepared that could be easily shared with anyone new joining the group.

> *"We need to become better at—in a couple sentences—being able to tell people, 'This is what the project's all about and this is where we see you having a role.' " (Participant 8, Waterloo)*

Communication between members also fosters a sense of belonging among the participants. When communication is sporadic or unclear, it can leave members of a collaborative group feeling uninformed. The use of Google Docs created a medium through which participants could share their thoughts with one another informally and asynchronously. In this way, in-person and phone contact between the participants was supplemented by an online tool.

> *"I think utilizing Google Documents could become a very powerful communication and collaborative tool. I also suspect there will be communication and interaction between community groups and agencies within the immediate Truro area that will be "offline", and not accessible outside." (Participant 21, Truro)*

The asynchronous nature of Google Docs works especially well for loosely-coupled systems because of the loose ties between organizations. Although they may operate on different schedules and work in different sectors, the blog-type tool allows for responses to be left whenever there is a free moment, rather than participants having to be available at the same time. This is also very useful when several different tasks make up a single project and any of these tasks can be worked on at any time—a hallmark of a loosely-coupled system. Tool designers in these kinds of systems should allow for easy asynchronous communication between end users.

The environment in which end users communicate needs to also be considered. The Truro group had some older members than the Waterloo group did. Truro also had participants with functional limitations (vision, speech, mobility, other accessibility issues) that were accommodated. In this community, there was some hesitancy to using Google Docs as a method of communication because of some of these factors. While the technology aspect itself will be discussed in another theme, it should be noted that alternative forms of asynchronous communication like e-mail or Facebook groups would work just as effectively and may be more accessible to people with functional limitations, or those who are less comfortable with technology in general. In this particular system, collaboration using Facebook groups was not possible because some participants were government employees and certain policies prevented them from using Facebook for work purposes.

4.1.3 – Theme 3: Leadership

Although some participants looked to the EnRiCH organizers as the leaders of the group, it is important to reiterate the fact that the EnRiCH research team was only meant to be a facilitator in bringing the community together; they were not the ones pushing the group to pursue certain agendas. The participants realized that there would not be a one-size-fits-all approach to the research project. The structure of the group, and therefore its leadership, was highly dependent on how much time participants were given by their organizations to contribute to *The EnRiCH Project*, the willingness of any given participant to step up and become a leader, and who the participants came to view as key players in their community. Additionally, the cultural values of each community likely influenced the way that the group was organized. This left each community with a different leadership structure. In the case of this loosely-coupled system, a top-down command structure was not used; rather, leaders worked to create interest in the task and maintain the momentum of the group. This theme, therefore, is closely tied to the theme relating to engagement and motivation. Leaders should also be able to provide the resources that others in the group need, either by directly giving them what is needed or by coordinating how to acquire what is needed.

In Waterloo, "the region" was looked to as a leader in the community to be a catalyst in how *The EnRiCH Project*'s goals were pushed along because their mandate included disaster management elements. It was expected that the region would maintain the group's momentum and push the other organizations along to make progress, as one participant explains.

> *"We know that it's difficult to sustain any kind of group long-term when it's pretty sizeable. […] I think it will just depend on whether or not this becomes a priority from the region's end. From what I was able to observe, they've indicated that they're going to be taking on some leadership in driving the project here locally. I think really it will depend on them." (Participant 1, Waterloo)*

While the region felt a bit overwhelmed that so much responsibility was being placed on its shoulders, it understood why other participants looked to them for direction. In Truro, the situation was much the same for one particular disaster management organization that the participants looked to for guidance. They indicated that they stepped up to the plate not necessarily because their mandate lined up with the EnRiCH goal but because of a personal belief about leadership. Just as in Waterloo, the participant representing the Truro organization was a bit reluctant to take hold of the leadership position but appreciated why others thought the initiative fell to them.

> *"I am doing this off the side of my desk. […] My philosophy is if you want it done right, you gotta do it yourself! I don't see anybody else stepping up or connecting with me to say, 'Hey, look through this, look through that.' Unfortunately there is only one of me. Will this fall to the wayside? I'm hoping it won't, 'cause I think it's a very important tool for me reaching my goals within this organization. Could I use an extra hand on it? Absolutely, yeah." (Participant 22, Truro)*

When creating a collaborative tool in loosely-coupled systems, designers must consider how their tool can be used by group leaders to facilitate the building of interest and maintaining engagement. However, leaders are often also responsible for helping to obtain resources for those they are leading. Loosely-coupled actors in a system are not closely bound to one another so leaders may not always be immediately aware of resources that are needed. Leaders should be able to use collaborative tools to check in on end users and see if there is any additional support that is required. Likewise, users should be able to easily communicate with their leaders about any concerns they have so that these leaders can address them before it becomes a bigger issue.

In the context of loosely-coupled systems, it is possible for coupling between actors to be *too* loose. If there is not enough internal motivation to collaborate, the group members will cease to work with one another. In that case, some external pressure may need to be added to keep the group on track and to prevent it from drifting apart over time. In the context of disaster risk reduction and disaster management, the perception is often that the goal is simply to prepare to respond to a disaster rather than building community resilience. If participants perceived the task as a simple preparedness activity, they may not have been as engaged in the process to begin with. A leader must be able to either motivate the other partners to participate by building internal motivation or they must be able to add some kind of effective external pressure. It must be restated, however, that each system exists within a unique context and leaders will face different challenges that may influence how they decide to keep a group working together.

4.1.4 – Theme 4: Role Clarity

A clear understanding of which participants in a group fill which roles is key to collaboration. This prevents members from stepping on each other's toes. In a loosely-coupled system, actors are not necessarily in close contact with one another and may be less aware of the actions of other group members as a result. When roles are clearly outlined by the group, members know who has the responsibility of performing certain tasks. The EnRiCH organizers allowed the participants to determine what the roles and responsibilities of member organizations would look like. Participants in the loosely-coupled system were asked to add their organization's contact and response information to a spreadsheet created by the EnRiCH research team using the Google Sheets spreadsheet. It was up to the group to decide what kind of information would be shared there.

A goal that the participants of both communities independently arrived at was to use this spreadsheet to replace a paper-based (and therefore likely obsolete) resource list or resource binder that was formerly used. This new spreadsheet could become a real-time resource list that would accessible to all members of the collaborative group. For it to be effective, however, the roles of the participants needed to be solidified. This loosely-coupled system was created as a result of *The EnRiCH Project* and did not exist previously, so some negotiation among the participants was involved. The roles within the group and the parameters or characteristics of this environment were initially undefined and needed to be discussed. Although the mandates of member organizations indicated that they offered certain services, some members of the group noted that competing organizations who were asked to cooperate for *The EnRiCH Project* should come to a common understanding of which organizations would be responsible for which services during an emergency, thereby reducing conflict.

> *"I mean, we could have an agreement that we all do everything. We would all provide food, clothing, shelter, first aid, and we have an army of people all doing that. I'm not sure if that would be very efficient, though. […] On a day-to-day basis for a revenue source, we are in competition with those people. And I don't want to be in competition with them when there is a disaster or an emergency. I want it clearly defined. 'This is all we do. It's all we do.' " (Participant 3, Waterloo)*

In environments where collaborators provide similar services or fall under the same umbrella for funding, it can be difficult for partnering organizations to put aside these very real financial concerns. If, for whatever reason, the results of the collaborative group are credited to one partner over another, it may affect future funding. Additionally, there may be other barriers for some organizations collaborating to their fullest extent; these organizations may have conflicting roles between their usual day-to-day functioning and the role that they play in the group. In some cases, these two roles may directly oppose one another. One organization may be under the impression that their own capital is not going to be used for the collaborative venture while other partners may be pitching in to cover the costs of tool development. This may put one organization at an advantage over the others in their field of practice. While there is no way to eliminate these role conflicts outright, tool designers need to consider the kind of investment that organizations will need to put in to the tool to collaborate effectively and these investments need to be presented as accurately and as early as possible.

The group was supportive in the idea of organizations having pre-defined roles during a disaster situation. This helped people know where they stood in terms of responsibilities during *The EnRiCH Project* meetings. One participant indicated that this delineation of responsibilities could allay fears about an organization's role being usurped if another organization with a similar mandate stepped in:

> *"I think challenges to collaboration are people's perception that by collaborating, they will lose their autonomy—That by collaborating they might lose their place in the world, and by collaborating, others might step in and try to do it better […] I think that when you start collaborating, what you have to do is have along with that a good dose of respect for the roles [those organizations] play, so that you can reassure them that the collaboration, in fact, doesn't usurp them, but enhance them." (Participant 9, Waterloo)*

This willingness to discuss concerns up front is necessary if members are to collaborate effectively with one another. The participants recognized the risk of some roles overlapping but they understood that respect for each other's roles would allow responsibilities to sort themselves out within the group. Organizations that recognize and respect the roles of other entities in the community can enhance collaboration. This is especially important in a loosely-coupled system where many actors could fill several, overlapping roles in the community. The more information participants had about their own roles and that of other members, the more invested they seemed to be. Tool designers for loosely-coupled systems should allow users to very clearly define their own roles so that there is no confusion and very little overlap in responsibilities, which may lead to certain users feeling like they are redundant as opposed to a valued member of the collaborative activity. In addition, a loosely-coupled system may feature roles that evolve and change frequently because these are initially not defined within this kind of system. Tool designers must allow for flexibility with the role structure that the user group settles on in order to accommodate this.

4.1.5 – Theme 5: Awareness

In this loosely-coupled system, *The EnRiCH Project* was heavily focused on building relationships and making connections. *Who* participants knew, rather than *what* they knew, was equally important to the overall functioning of the group because the task of creating community resilience can be solved in a myriad of ways. Linkages between organizations in the community have the potential to enhance community resilience by expanding the pool of resources and personnel that can be mobilized in the event of a disaster. The organizations that attended the EnRiCH sessions had varying levels of awareness about one another. A simple meeting to put a name to a face went a long way for participants.

> *"I mean, I didn't know that some of these partners existed and I'm in emergency planning. So just knowing that they're out there, regardless of what happens with this, I really learned a lot about our region. Going through this process was a real benefit because […] I really felt, at that human level, that I'm gonna gain because I know the partners. I've got some business cards." (Participant 4, Waterloo)*

Because the pieces in a loosely-coupled system are not as closely bound to one another as in a tightly-coupled system, organizations have limited opportunities to connect. In the context of disaster preparedness and response, however, it is better for organizations to be aware of the different resources available within the community that could be mobilized to help—which is the essence of asset literacy. Tool designers can facilitate this type of connection and simplify processes so end users can learn about one another and their roles in the specific context of interest. For examples, short biographies about each collaborator could build awareness among the working group and the kinds of resources available.

An increased awareness of other organizations in the community also promoted opportunities for training and education. Exposure to other organizations involved in disaster preparedness and management brought ideas of how to prepare for a disaster and strategies to include individuals and organizations not normally involved in these kinds of activities. As one participant noted,

> *"One thing that we did, I think it was [a ground search and rescue organization] that we brought in to talk to all of our clients who live here about preparedness for short term disasters: power outages, floods, hurricanes, stuff like that. And we did bring them in and did an afternoon session on that so. If nothing else, we've accomplished that, and I'm sure other organizations have done the same thing." (Participant 10, Truro)*

The opportunities for cross-training and collaboration allowed organizations to learn about different subjects; this information could be passed on to clients who make up the population in a community. For tool designers, it is important to recognize the importance of supporting collaborative efforts between end users that may be spinoff projects of the current venture. Contact between collaborators outside of the tool should be encouraged or facilitated within the collaborative tool. This can be done through a forum-like module that allows participants to schedule networking or team-building social activities in order to build familiarity. While this would involve some extra effort when designing the tool, the personal linkages created through group social events involving the end users would serve as excellent networking opportunities.

These occasions can serve to increase the users' overall awareness of who is a part of the group and what they have to offer—both things that are crucial in loosely-coupled systems.

In a loosely-coupled system, a relationship with an individual person is very important and supports many of the core elements of collaboration. If a relationship exists with someone who then changes workplaces, a new collaborative opportunity is created with that person's organization because of the established association. In this way, familiarity between collaborators is important. This was especially true in Truro, which is a small town where personal connections between agencies are already deeply ingrained. One participant indicated that *The EnRiCH Project* provided valuable networking opportunities to meet people, stating,

> *"I know now that if I now have a contact at [the association of disabled individuals], I now have a better working relationship with [an emergency health service] so I know that if I had to open up a shelter through [my organization] and I have a high rate of folks with medical issues, I know I can pick up the phone and call [another EnRiCH participant], who I met here at the EnRiCH group and say, 'I need this, this, this. How can I do it?' And he'll say, 'Leave it with me. I'll get it done.'"* (Participant in Truro)

It is important for tool designers to create networking opportunities using their tools so that participants can form bonds and become familiar with one another. The EnRiCH research team did this by teaching the participants in a group setting how to use the collaborative tool, which created an atmosphere where everyone was going through the learning process together. This served to build common ground among participants, and became an experience they all shared while being able to network at the same time. Education sessions that teach users how to use the collaborative tool could be used as networking events where common ground can also be built.

4.1.6 – Theme 6: Time

While this theme explains a phenomenon that is generally understood by most professionals, it is expanded on here because of how deeply it saturated this dataset. The time participants could spend on the EnRiCH asset-mapping task was determined by their regular workload and the support their organizations provided for their participation in this project. When asked about whether participants were being given enough physical or financial resources to work on *The EnRiCH Project*, they overwhelmingly indicated that it was not money or equipment they needed. As one participant noted,

> *"I think that time is the ultimate resource, right? I mean, collaboration doesn't cost a lot of money from what I can tell of it is need [to develop] training material and things like that but that's a small piece compared to the time resource." (Participant 11, Waterloo)*

While engagement and participant buy-in were important factors when assessing the ability of participants to take part, it was *time* that determined if participants could be a part of the process at all. In loosely-coupled systems such as this, tool designers must consider that 'time' itself is a resource that has to be budgeted and acknowledged as a finite resource. If the tool takes time to learn, then time needs to be budgeted for. If the process of creating or using the tool requires multi-hour meetings, this is important to account for. Tool designers must be sensitive to the responsibilities users already have and plan around this. Certain times of the year may be busier for some sectors than other times of the year, so implementing a new collaborative tool may add to an already-sizeable workload. One participant echoed this, stating,

> *"One of the things I identified at the meeting was that this is a very busy time for long-term care facilities now. So being able to carve out time to put to the project is a concern for me." (Participant 18, Waterloo)*

Tool designers must consider current and upcoming workloads of the users and be able to anticipate cyclical changes to these workloads. However, users have a role in the assessment of time as well. When they commit to a new project, it can put strain on other parts of their workload. In the EnRiCH Project, commitment was voluntarily for all participants; therefore the perceived value of the task had to be weighed against other competing interests. One participant notes,

> *"It's great to say, 'I'll look after that, but I think in the end people gotta be honest and say 'Well, you know, I'd like to look after that but I think you'd better go looking for someone else to look at this end of things because I don't have the time' or 'I can't make the time commitment.' "(Participant 25, Truro)*

In loosely-coupled systems where one process is not tightly integrated into the next, setting deadlines can be challenging given the different factors that can influence organizations involved. That being said, not setting a deadline at all can be problematic – as the tasks become open-ended with less structure and other projects or tasks can override them due to actual or perceived urgency. As one participant shared,

> *"When we're calling a meeting to talk about emergency preparedness, it's there. People attend the meeting, people participate in the meeting. But when we walk away from it, it's like there's always something else to do—whether it's from my perspective, when I leave a meeting from EnRiCH I may not get back to that Google Doc for another three weeks because I've got other things that I have to do that take precedence over emergency preparedness. I have a staff to manage, I have reports that need to be done, I have payroll that needs to be done, I have a parent-teacher this afternoon. So it's not always front-and-centre." (Participant 22, Truro)*

For organizations or individuals who work from one deadline to another, the absence of a deadline for one project signals that there is no rush to complete it—that it can be worked on at their leisure. Even if a deadline must be pushed back, the simple presence of an impending due date can extrinsically motivate people to act if they are not intrinsically motivated. If a tool can be linked to a scheduling program such as Outlook or Google Calendar, notifications of approaching deadlines can serve as reminders for users to reflect on their progress relating to an upcoming due date and adjust their workload accordingly.

4.1.7 – Theme 7: Technical Skills and Knowledge

Technology is used to support many collaborative endeavours; it makes it possible to view what other contributors are doing (often in real-time) and can provide virtual meeting spaces when face-to-face meetings are impractical. The *EnRiCH Project* was no exception to this. A key feature of this intervention was providing participants from different organizations a virtual meeting space to collaborate in creating the asset database in the form of Google Sheets and Google Docs.

For activities where different organizations come together and work on a project using technology, it is important that technology-based tools have a simple learning curve and are sensitive to varied levels of technology literacy among group members. For *The EnRiCH Project*, some individuals who were involved in the collaborative asset-mapping exercise did not have access to computers or the Internet (many were volunteer-based organizations); some members of the group did not own computers or have experience using one.

> *"Like I say, in our particular group, I'm not sure probably more than 15% would even have a computer or access to a computer. So even if you wanted to have some help made available for them, you probably would have to figure out: 'Okay, where are we going to be able to do this because who's gonna go to whose house and where can we meet and who's gonna have access to the computers or computer storage [to] be able to achieve what we want?" (Participant 25, Truro)*

Accessibility for certain participants was a factor in how collaboration evolved. The EnRiCH group in Truro had more representation of participants with functional limitations than Waterloo and the collaborative process was adapted to the varied levels and experience with technology. Tool designers should consider any functional limitations that might impact usage of the tool. Different screen-reading programs are available, for example, for people with reduced vision, but the file formats being used by a collaborative tool might prevent the use of a screen-reader. Certain file formats may also prevent re-sizing the screen or zooming-in on text. These factors have to be considered when making decisions regarding the implementation of a collaborative tool. Because loosely-coupled systems offer a variety of ways to achieve a single goal—effective collaboration in this case—it may not even be necessary for everyone to participate using the collaborative tool. Instead, users can collaborate and exchange information on behalf of other participants who may be unable to contribute because of functional limitations, which is what happened in Truro. Members of the community stepped forth and offered solutions that would enable those who were less fluent with the use of technology or had physical or cognitive limitations to participate fully in the group activities. In this way, the participants used adaptive coping strategies to deal with the challenges that the tool presented for their specific context. They prioritized the engagement of their fellow participants over being rigidly efficient with the collaborative tool.

Despite the ease-of-use aspect that most of the group seemed quite pleased with, there were issues with the tool that made it difficult to use for collaboration. One of the problems that emerged related to privacy and security. The firewall systems in some organizations prevented users from accessing the Google Drive suite of programs from their offices. In at least one case, the organization's IT department blocked access to the Google Sheets and Google Docs webpages. When asked how likely it would be that they would participate using the online collaborative tool, one participant explained,

> *"It's probably gonna be unlikely for the main fact that I can't access the online component through our firewalls of our user system. I've done some at home and I've entered a few things and updated the [spreadsheet]. However, besides from being able to do it from home every once in awhile, it's very difficult because I can't access it. [...] The biggest issue that I saw was the fact that the way that it's set up online. I think it's a great idea that everybody can—in theory—can get there. It's the fact that its hampered by the firewalls I think will be the biggest hurdle because then people might start to lose some interest if they can't participate." (Participant 20, Truro)*

The barrier created by a corporate firewall is symptomatic of a larger issue that affects loosely-coupled systems. With many possible interactions, due to the way the actors are loosely associated with one another, it would be impractical for designers of the IT infrastructure in each organization to anticipate the IT infrastructure used by every *other* organization. IT systems encounter difficulties when one system attempts to bridge over to the next, blocking attempts at collaboration. The EnRiCH participant (quoted above) was able to use a workaround to continue participating from another location without such a stringent firewall protocol in place; but tool designers need to take into account the physical location where their users are accessing the tool. For example, it is important to consider whether users will be limited to using the tool inside a corporate Wi-Fi network or whether they able to access it from a home office or another offsite location. This may involve discussions with IT personnel at all participating organizations, but it is a factor that needs to be considered as more organizations implement robust Internet security policies.

4.2 – Tightly-Coupled System: Surgical Teams

The themes that emerged from the analysis process are focused in different areas of concern between datasets. With the *EnRiCH Project*, the tool was designed be amorphous and amenable to alteration by the participants as they determined what would work best for them; everyone was involved in the development of the tool, so fostering engagement in the process was paramount to a successful intervention. How the SIMs would be implemented, on the other hand, was decided by the hospital and proceeded despite the objections staff had to certain processes that would be changed. A key group of people were asked to participate in the implementation process and to give feedback on how SIMs would be used; most staff at the hospital did not have any input into how the system was designed.

4.2.1 – Theme 1: Engagement

Professionals working in tightly-coupled systems require motivation and engagement, similar to their loosely-coupled counterparts. In this kind of system, however, much of the motivation originates extrinsically, from outside pressures and motivators. That is not to say that a person working in a tightly-coupled system cannot be motivated by internal factors (such as wanting to help people or wanting to feel fulfilled in a career) but the pressure from outside sources is certainly much higher in systems where parts are closely interconnected. In this particular setting, there was pressure from other units in the hospital to push work their way and the prospect of slowing another unit down can put a lot of strain on some of these professionals. One of the extrinsic motivators to perform well in this system, however, is the threat of medical malpractice suits. In fact, when asked whether or not there was concern with being *too* thorough while charting during a procedure, one participant indicated,

> *"Hmm . . . some people would say that. I guess by new standards and by medical-legal standards, maybe not. By CPSO [College of Physicians and Surgeons of Ontario] standards, maybe not. So maybe it's that people are not in the same thought process as the people from CPSO for what should be on the chart or what is required on the chart and what is not." (Participant 6)*

The possibility of being vulnerable to lawsuits kept physicians engaged in the process. Patients expect high performance from their doctors. Tool designers in systems where litigation is a possibility need to implement cataloguing or recording methods that accurately track the participation of its users to forestall lawsuits claiming negligence. The SIMs tool took care of this issue by automatically charting patient vitals during surgeries, providing the hospital with evidence that the physicians were practicing medicine using the best techniques available. As one participant noted,

> *"In a situation where there is perhaps a bad outcome—medical-legal concerns regarding the care of patient during an anesthetic—when it gets to a court of law, [the anesthesiologist's report] is not what anybody should be looking at. They*

> *should be looking directly at the electronic record, what's showing here, because that is 100% accurate. That is archived forever." (Participant 5)*

The pressure on physicians is relentless. If a physician is listed as being the care provider for a patient and an adverse event occurs while the physician is on break, they may still be held responsible for whatever happened. This "always on" type of responsibility can be taxing so there needs to be a way of distinguishing when the physician is or is not responsible for a patient at a certain point in time. The SIMs had a way of addressing this issue, however.

> *"And what is very nice about SIMS compared to paper is that when you do go to break or finish your shift, there's an icon you can press on and say, 'I'm leaving for my break.' […] So for safety, it's good. Because we had no protection on paper. We didn't write 'I'm going for break. I'm coming back from break.' So if an incident happened while I'm at break, well I may be responsible but I'm not giving care to that patient at that moment, or I've gone home. So this helps me specify when I'm at the bedside and when I'm not, and when I'm responsible for this patient or not." (Participant 2)*

The designers of the tool understood that advances in technology allowed for the implementation of an on—off switch that physicians can toggle when they are not actually responsible for patient care. In other systems where there is constant external pressure to perform, collaborative tools can allow for a check-in and check-out function where partners can indicate whether they are available to use the tool at a given moment. This could help prevent other users from pushing tasks to someone who is not currently available. Otherwise, time-sensitive tasks would be waiting for the arrival of someone who is not present, obstructing the smooth flow of the system as it waits for a user to deal with the backlog.

4.2.2 – Theme 2: Communication

Working within a hospital involves a constant exchange of information between health professionals working in different units, performing a wide variety of tasks relating to assisting patients. The primary method of communication in such a tightly-coupled system is medical chart documentation. These charts need to be as accurate and complete as possible so that patient safety is not compromised. The SIMs tool was no different, with physicians and nurses communicating asynchronously using this particular collaborative model.

This specific system required substantial patient information; scarcity of information could cause the whole system to back up while it waits for information. With electronic systems that allow for documentation or filling out of forms, there are often *required* fields that indicate to users what minimum information is needed to progress. If left blank, these required fields will prevent the application/program/webpage from advancing to the next screen or submitting other information the user has entered. While SIMs had some required fields, the tool designers decided to allow for some flexibility in areas where free-text comments and notes could be entered. They did not want end users to feel they had to write notes for every patient, especially if the case was straightforward.

> *"[SIMs] could be done more like instead of just selecting things, it can lead you down paths and so on. But we were sure people would complain that they were being railroaded into doing things. Like if it said you could not proceed any further with your anesthetic or anything until you've answered these questions, then you might not be able to get the patient to sleep, get everything set up—45 minutes later—because the way the program setup is that you have to enter these things as you do." (Participant 1)*

The designers of the tool ensured the documentation process would not negatively impact activities in the operating room, such as holding up a procedure simply to transcribe something into the SIMs. While communication is important, it should not stall other processes.

Another issue that should not hold other processes back in such a tightly-controlled system is the legibility of handwriting on paper documentation that is often still used for specific tasks. This paper documentation is usually sent to a hospital department that will transcribe the information and enter it into the hospital's EMR, but it is likely that several other people will need to see the information before it gets transcribed. Illegible notes and information have no value other than to show a certain piece of documentation was filled out. The contents of this, however, are often crucial for other health professionals to understand what is happening with a patient's course of treatment. One participant stated,

> *"I don't know if you've had a chance to actually look at hand-written anesthetic records. They can go from being very legible, and well-documented, to completely illegible, extremely poor documentation, and of no help to anybody. [...] So I mean, as far as communication goes, everybody can understand or read what you've done [in SIMs]. So I think for communication and patient safety, it works very, very well, on those two fronts." (Participant 5)*

Adverse events that occur during surgery are recorded within some of these anaesthetic records, so if they are not legible, other staff may be unaware of any complications resulting from the surgery. The solution to problems of legibility in these situations is to have everything done electronically through the collaborative tool from the start—which is how SIMs has handled charting. However, it may be difficult to do this in some other system contexts, such as fields where having a computer nearby is unfeasible and mobile devices may be slower than writing things down on paper. In difficult environments like this, tool designers can do very little to force end users to practice penmanship.

The method of communication in this system was described as particularly challenging in terms of maintaining the confidentiality of any notes that are appended to a patient's chart. With paper-based systems, sticky notes that are tacked-on to charts can fall off during transport or when something brushes against them. Using an EMR that can only be accessed through a hospital-issued account is one way of ensuring patient files are kept confidential and at the same time easily-accessible when they are needed. In the following exchange a participant goes into more depth by stating,

> *P: We'll put memos in, addendums in, notes for the nurses in the surgical daycare unit who'll be the next to see the patients. There are notes there, and I put them in regularly.*

I: Okay. And you're pretty sure that they always see what you put in?

P: That's one of the first things they do, is they read our nursing history. And the nursing history is what I generate in SIMs in the preadmission unit. So they read that. It's part of their responsibility, to get to know the patients. So any memo that I would put in there, they would see. So they read that. Because they're in a specific area, so you know where to look for them.

I: Whereas in paper they could have been anywhere.

P: Lost, or Post-It falls off the chart. And it's confidential this way too because it's in SIMs. (Participant 2)

This approach to severely restricting who can and cannot access information about a patient's chart is mandated by hospital policy. This limits the method of communication that can be used and requires staff to log in to the system any time that they want to see a patient's chart. Confidentiality can, in cases like this, slow the process of collaboration down in tightly-coupled systems. Tool designers must ensure that their collaborative tool is not only secure but also easily accessible. It may not always be possible to have a computer at hand so accessibility can present a challenge. In hospital settings, tablet computers are often used to look at patient information on-the-go but there are trade-offs associated with using smaller devices that must be considered.

4.2.3 – Theme 3: Leadership

Just as in the theme relating to role clarity within this tightly-coupled system, the base characteristics of this system provide clear boundaries for the roles of the various actors. A leader would not "step up to the plate" and take charge here; instead, a leader for a particular unit or department is chosen by other leaders who are higher up the chain of command. The decision to promote someone into a leadership position is based on the would-be leader's past performance—and in some cases, their relative prestige within their particular field of practice. Because of the complex interactions within this tightly-coupled system, it needs to run as efficiently as possible. There cannot be unanswered questions about who is the leader of any given unit or department, so the hospital is managed using a hierarchical structure.

The hospital's board of directors represents the topmost level of leadership in this environment, though one member will be designated as the hospital's CEO. They make decisions that affect the overall direction of the hospital and all of the departments within it. The chiefs or heads of these departments, in turn, have the responsibility of making sure that departmental functioning falls in line with what the board of directors want. These departments may be further divided into specialized units that deal with specific fields of practice, each of which has its own leader; the emergency department within a hospital may have a burn unit, for example. Though the exact terminology used to refer to a department or unit may change from region to region, the overall concept is the same. In the hospital environment, professionals turn to their most proximal leader for guidance. Because this is taken for granted in systems like these, this meant that participants did not speak about the leadership structure relating to how SIMs was implemented, except to say that the Ministry of Health mandated the use of electronic medical records as a way to look maintain accountability in some departments. The hospital board had to quickly follow this mandate, which in turn meant that the whole hospital would be implementing an EMR system. As one participant states,

> *"Originally, when we proposed this to the hospital, IT said they wanted to develop this in-house, and that it was going to take eight years. Suddenly the whole calendar agenda changed when the Ministry of Health in Toronto started saying, 'The OR is a black box; it's money in, we don't know what comes out. We want accountability.' And we needed that, so that's how we ended up getting it." (Participant 1)*

Tool designers that are creating tools for tightly-coupled systems must respect the chain of command and work with this hierarchical structure. Those who are not in positions of leadership should not be given permission within the tool to overstep their bounds and thereby complicate the system. Tool designers in tightly-coupled systems must limit the ability of users to cause problems by issuing orders or interposing themselves in situations that would call into question the established command structure that allows the system to run smoothly. If there is a question of authority in a tightly-coupled system, tasks may be sent to the wrong people or these tasks may remain stationary in the system until the professionals are sure that whoever is in charge wants them to be completed.

An additional consideration relating to leadership focuses on how SIMs was designed and implemented. While it is discussed further in the Technical Skills and Knowledge theme later in this chapter, making someone responsible for the design of the tool takes thought and consideration. Choosing a physician who has a great deal of experience working with technology to lead the design process may seem like a sound choice but the tool will be operated by individuals of varying skill when it comes to technology. Leaders must be individuals who understand that not all end users will have the same background using computers; tool designers should take this into account when designing tools under the supervision of a leader who has more experience in working with technology than the average user. Leaders should also be able to manage the disruption in day-to-day functions that the implementation of a new tool will create.

4.2.4 – Theme 4: Role Clarity

In this dataset, role conflict is managed quite effectively due to the way tightly-coupled systems are structured. Because the moving parts within these environments can dramatically affect other actors within the system, roles and their related responsibilities are carefully defined. It is taken for granted in this environment that there are relatively clear boundaries separating the work different professionals do in relation to one another. Though not unique to healthcare, the various professionals who work in the system belong to professional societies or associations that license or regulate the roles and responsibilities that they have. The College of Physicians and Surgeons of Ontario, for example, provide best practice guidelines and are able to review and revoke medical licences in cases where medical ethics or professional standards were violated because they are the regulatory body for physicians in Ontario. Likewise, the Ontario College of Social Workers and Social Service Workers performs a similar function for social workers and the College of Nurses of Ontario does the same for nurses. Within Ontario hospitals, these three professions (and others) work together on a regular basis, with the boundaries between each role being defined not only by their regulating bodies but also by hospital policy. Regulatory bodies do not allow social workers or nurses to prescribe medications and hospital policy may prefer that social workers be the ones to refer patients to community-based programs for various issues.

These two elements—regulatory bodies and hospital policy—work together in a tightly-coupled system to control who is doing what, which limits the possible treatment paths a patient can take. Flowcharts describing a patient's path through the system—called *clinical pathways*—help to delineate the responsibilities of the various professionals within a healthcare system, ensuring that patients are not able to move to parts of the system that are not ready to treat them yet. This keeps the system moving smoothly and predictably. In a tightly-coupled system, this predictability is invaluable and tool designers must ensure that the tools they are creating work with the existing roles of its users. The implementation of a new tool must not circumvent the regulatory bodies that are responsible for the professions using it. The best way to ensure that it does not give professionals privileges that they do not already have is to get them involved in the design of the tool, as one participant noted.

> *"I think the best thing that was ever done was they took one person from each area and made a corporate document. They took into consideration everybody's*

> *situation—and that's by far the best thing that was ever done because you have people that know what goes on and what is necessary from their point of view, and their department. […] And it probably was a little more expensive than just having one person do it all. It's the people that are doing the hands-on that need to be the ones that are kind of behind the implementation, the build of it." (Participant 4)*

If tool designers can consult not only information provided by regulatory bodies and formalized hospital policies but the professionals themselves, the tool will better support the roles of these professionals in that unique context.

4.2.5 – Theme 5: Awareness

Awareness in this dataset centered on *what* participants knew about the system rather than on *who* they knew, which contrasts with the findings from the loosely-coupled system. In a hospital, being aware of role responsibilities is crucial part of the job; staff support one another by making sure the information they pass along is relevant and timely. Staff need to know where they fit in the larger picture of the hospital so they can determine who to collaborate with and what kind of information those partners will need.

Discussions regarding who would be receiving information did not focus on specific individuals, but instead focused on the *position* of the person receiving. It did not matter whether the nurses from the pre-admission care unit knew the surgeon personally, because the patient would proceed to see the surgeon next, regardless. In this tightly-coupled system, it was the role of the recipient that influenced the kind of information forwarded. The focus of the information exchange was to ensure the next health provider had the information required, and the collaborative tool was used to facilitate information transfer.

Sometimes information would not smoothly transfer over from one unit to another, however. When the nurses in the pre-admission care unit (PACU) logged in to the EMR to check patient information after an operation and they were not being shown all the information recorded during the procedure. This stemmed from the fact that different modules exist within SIMs and they do not always transfer information properly; the data from the operating room manager module did not parse nicely into the module used by nurses in the PACU.

> *"[In] PACU, the nurses don't seem to have access to all the information in anesthesia manager that they could have access to. […] Sometimes I've actually gone onto the PACU record and wanted to see if they could see what I was doing in the operating room and some of the things just aren't there. Some of the fields just aren't there. […] The big key there is to know what you can and cannot see. That helps you out at least with the thinking process. 'Well they don't know that so it's not on there.' " (Participant 3)*

In a tightly-coupled system, it is especially important for all relevant information to be made available to those who need to see it; what defines "relevant" should err on the side of providing more information than is needed. One caveat to this is that tool designers need to avoid "information overload" and overburdening staff with information that they have to sift through to find the information that is relevant to them. A careful analysis should be carried out to determine the kinds of information that each position needs to see so that the design of a tool can revolve around making that information displayed more prominently. While it would be unfeasible to completely customize how information is displayed on a per-user basis, it may be possible for different user *roles* to have certain types of information displayed forefront.

The designers of the SIMs tool prioritized efficiency across all units interacting with the tool. The staff implementing SIMs in the hospital could pre-program a list of medications that healthcare providers could choose from when administering drugs. However, this medication list had to be comprehensive enough to accommodate most users but not so exhaustive that opening the medication list would flood the screen with hundreds of choices. This required the tool designers to populate the list based on common medications someone in a given role would use rather than the personal healthcare provider's preferences.

> *"The nurses didn't want to see the list of medications ten miles long. Because what happens is when that patient goes from the operating room to the recovery room, that same medication list would then populate their screen. The vast majority of drugs and fluids they don't use. So they wanted us to create a very streamlined list, which would then follow the patient into the recovery area." (Participant 5)*

In tightly-coupled systems, the part of the system responsible for executing a certain task is indicated with a role title, not a specific name. If the person filling a certain role is not present, someone who has the same title should be able to step in and assume those responsibilities. This is where it is important for tool designers to build redundancy in to their collaborative tools but this requires the designers to be aware of the roles that are present in the system and how they interact on a regular basis.

4.2.6 – Theme 6: Time

In tightly-coupled systems, delays in the completion of one process can have a domino effect and bring the system to a crawl but there is very little that can be done to change this from a process design perspective. In this case, the decision to implement SIMs was imposed on its users from hospital management so the end users are required to make do with what they have been given to work with.

Severe delays in the context of surgeries can result in cancellation of patient appointments if issues cannot be resolved quickly. Time is of the essence in a tightly-coupled system because the sequence of events cannot be altered; if there is a delay in the admission process on the day of a patient's surgery, the surgical team cannot send a patient to the recovery unit in the meantime. Tool designers must consider the critical paths and associated timelines in these systems when designing a new means for collaboration. Redundancies become important to off-set detrimental impacts associated with delays.

In the hospital, a certain number of staff is booked relative to how many surgical procedures will be done in a given day. Because this is a tightly-coupled system, delays during the surgical procedures can create time management issues that ripple backwards and forwards through the system. If a surgery has to be prolonged, the surgical preadmission unit cannot admit new patients until they have cleared some from their current queue—which they cannot do because of some issue that arose during an operation. Surgeries scheduled for later in that day may have to be cancelled. Further down the line, the recovery unit is expecting a certain number of patients but they may find themselves to be overstaffed if only a fraction of those patients come through. Likewise, the operating room cannot begin work on another patient if all of the recovery unit's beds are full. The ripples created by these delays can then affect the staffing levels of other units, the resources other units have access to, and any number of other factors.

Newly-designed collaborative tools should reduce the workload for end users, or at the very least make their workload more manageable. In the case of SIMs, more time spent working on a computer is less time spent interacting with a patient. One of the participants noted this, stating,

> *"Whenever you have a problem, the answer isn't always to increase the number of checklists because that can be counter-productive. So the SIMs can be like that, too. It can be counter-productive. It's designed to increase safety, but there's two sides to the coin—where if it's so complete, so thorough, you're losing focus on the major issues with all the minutia." (Participant 6)*

The easier it is to quickly perform frequent tasks while charting, the more time a physician or nurse has to interact with a patient and deliver care. Designers must ensure that a tool is not more labour-intensive or time-consuming than the method it replaces. If the collaborative tool increases time spent in a certain area of the system, it should reduce the time spent elsewhere. For example, if the tool requires a significant investment of time to gather information, then the likelihood of an adverse event should be lowered considerably. Preventing adverse events has a net effect of speeding up the system relative to a system that spends more time dealing with the fallout of unintended consequences.

Another area where valuable time is potentially wasted is during the information-gathering phase of a surgical intervention—the period of time where patient history is gathered and pre-existing conditions that may complicate surgery are assessed. One participant mentioned that a potential solution to this is a SIMs add-on module that allows patients to enter their own history into a web-based form, thereby giving nurses more time to interact with other patients who need care.

> *"One of the things now that they have is a module called Pre-optimize. It's a web portal that patients can go in and give their history before they even come here. […] The questions [it asks] are keyed to the database fields that are already in the system so that when the patient finally does come here, or the nurse calls them up on the phone, it pops up and things are filled in. […] So this would improve the nurses' time. […] I think that it might cut their job in half in terms of time for the nurse." (Participant 1)*

In addition to this, time spent avoiding software bugs is an investment toward using the collaborative tool effectively. When a software bug disrupts system use, the time spent *fixing* the problem creates an even larger drain on system resources because of how tightly-integrated the software can be. With an electronic medical record system, workflow can be dramatically altered if certain features are modified. Because of this, a hospital's IT department may take a long time to review and test fixes to software bugs to avoid creating new issues. As one participant stated,

> *"We're paying a hefty maintenance sum to run this software. The problem is an IT/IS problem, in that any time there's a version upgrade, tremendous amount of time and resources—weeks and months—have to be spent by them to ensure that all the data from the previous version comes over. That everything works the way it's supposed to work. Even if the new version is doing very little but addresses some of these, what we consider, very aggravating concerns." (Participant 5)*

Tool designers must alpha- and beta-test their software as thoroughly as possible; it is not enough to run a simulation within an ideal *version* of the system in which it will be implemented.

There will always be unexpected issues when moving such a tightly-integrated system from a simulated environment into the real-world environment. These issues can create a pile-up of tasks that depend on the tool functioning as expected, which in turn wastes valuable time to sort out.

4.2.7 – Theme 7: Technical Skills and Knowledge

An electronic medical record (EMR) system was already in place and being used when the SIMs was implemented, meaning that some staff were familiar with how to incorporate an electronic tool into the way they provide care. However, this was not the case in the operating room, which had always been using paper-based medical records. For some, the principles behind using an EMR were taught in medical school or nursing school but for others, the advent of EMRs precedes their formal medical school education. Some participants started with very little experience in terms of using computers, especially if they had been involved in the healthcare industry for a lengthy amount of time and were trained using a paper-only system. Because some of these electronic systems are expensive to adopt, hospitals may have held off investing in an EMR system for many years and have only recently made the switch to electronic records. The Surgical Information Management system goes above and beyond what a basic EMR system can do and so it presents an additional challenge to those with little experience using computers.

> *"There were a surprising number of people who were not as computer savvy as I thought they'd be. So that was a bit of a hurdle too—getting them up to speed on just navigating the screen and things that I would consider totally logical. 'Yeah you just press this and that,' and they'd said, 'How'd you do that?' So yeah, some of them are really starting from zero. So that was a challenge, too" (Participant 1).*

In a tightly-coupled system, the implementation of a tool that requires a fair amount of experience using computers can be difficult to manage. The time required to get everyone working with a minimum level of proficiency can impact other parts of the system and mistakes made during the acclimatization period can also have an effect on the system. What's more is that because it is a tightly-coupled system, accommodations cannot be made for those who prefer to work exclusively with paper records; the impact of one part of the system moving much more slowly and being less tightly integrated with the other parts would slow the entire system down. Tool designers need to take into consideration both the time it will take the average user to adjust to using the new tool and the time involved in teaching someone who has very little experience using technology in general. This is not to say that it is a daunting task; the participants in this group handled it quite well and the differences in experience levels were managed throughout not only the implementation process but the design process as well. During one of the interviews, a participant shared how one nurse with very little experience in using computers was involved in the design and implementation process.

> *P: I know one of the nurses that was called in […] She knew nothing about computers, and she was brought in on the nursing side. So that was a good example of bring someone in that can—You know, if she can do it, then everybody else can do it. She didn't know how to turn on a computer. Her family would not let her touch the computers at home. So, that was over at the eye care centre. She became one of the team to—*
>
> *I: One of the super-users?*
>
> *P: Yes.*
>
> *I: Wow, that's quite a progression.*
>
> *P: Yeah, yeah, no, now she's very proud of herself, too, and quite rightly so. But that was actually a good—Like you said, get someone who's not at the high-tech level. It can be at the tech level, but not at the highest tech level, so that they're sort of—Maybe one of each: one high-tech, one mid-tech, and maybe one low-tech. (Participant 6)*

Beyond general differences in comfort levels related to using certain pieces of technology, the younger residents were able to pick up on different software features or "tricks" that different physicians or nurses were using. They then took this knowledge and would share it as they rotated around the hospital, creating an informal training network.

> *"You have to remember that a resident moves from room to room to room to room. So that resident could have been in my room, and then I went on a whole tirade about how bad the record keeping was and how I think it should be done, and they get that. Or how I picked up a certain drug, or showed [them how] protocols are powerful. Instead of [selecting drugs] one at a time, they just simply go in, and the staff go, 'How did you do that?' Or we'll see residents using a technique or using drug combinations that I don't use, because I've my own way of doing things […] So you sort of learn from them as well. So it's that cross-educational component. But in general, these young kids who are twenty-five, I mean they've grown up with laptops so for them, it's not a big stretch." (Participant 5)*

In a tightly-coupled system such as this, ongoing training is crucial to make sure that everyone is using the software to its fullest extent. If a shortcut known by a single physician could speed the whole system up, then the dissemination of these tricks by the residents should not only be encouraged but designed for. Tool designers must leverage younger generations who are more comfortable with technology in teaching those who are not comfortable with using computers. The cross-generational trade of wisdom and experience in exchange for learning how to use complex software and technology creates a positive working environment that will benefit the system as a whole.

CHAPTER 5: DISCUSSION

This chapter will discuss the creation of two new parallel models of collaboration (one for each of the loosely- and tightly-coupled CAS contexts) based on the relationships between the core elements of collaboration from Chapter 4. The components of each of these models will be explored in depth before they are discussed in relation to the three models presented in the literature review from Chapter 2.

By investigating the relationships between each of the core elements of collaboration, it was possible to create a conceptual model to assist with visualizing these relationships. Figure 6 and Figure 7 in the next sections present two variants of a new model of collaboration called the Elements of Collaboration in Complex Adaptive Systems (ECCAS) Model. One variant of the ECCAS Model exists for each of the loosely- and tightly-coupled complex adaptive systems being studied. Additionally, each of the ECCAS Models contains considerations for tool designers that fall within one of the seven core elements of collaboration. On the next page, Table 6 presents these considerations as they appear in the ECCAS Models.

Table 6: Considerations for each core element when designing for loosely- and tightly-coupled complex adaptive systems (CAS)

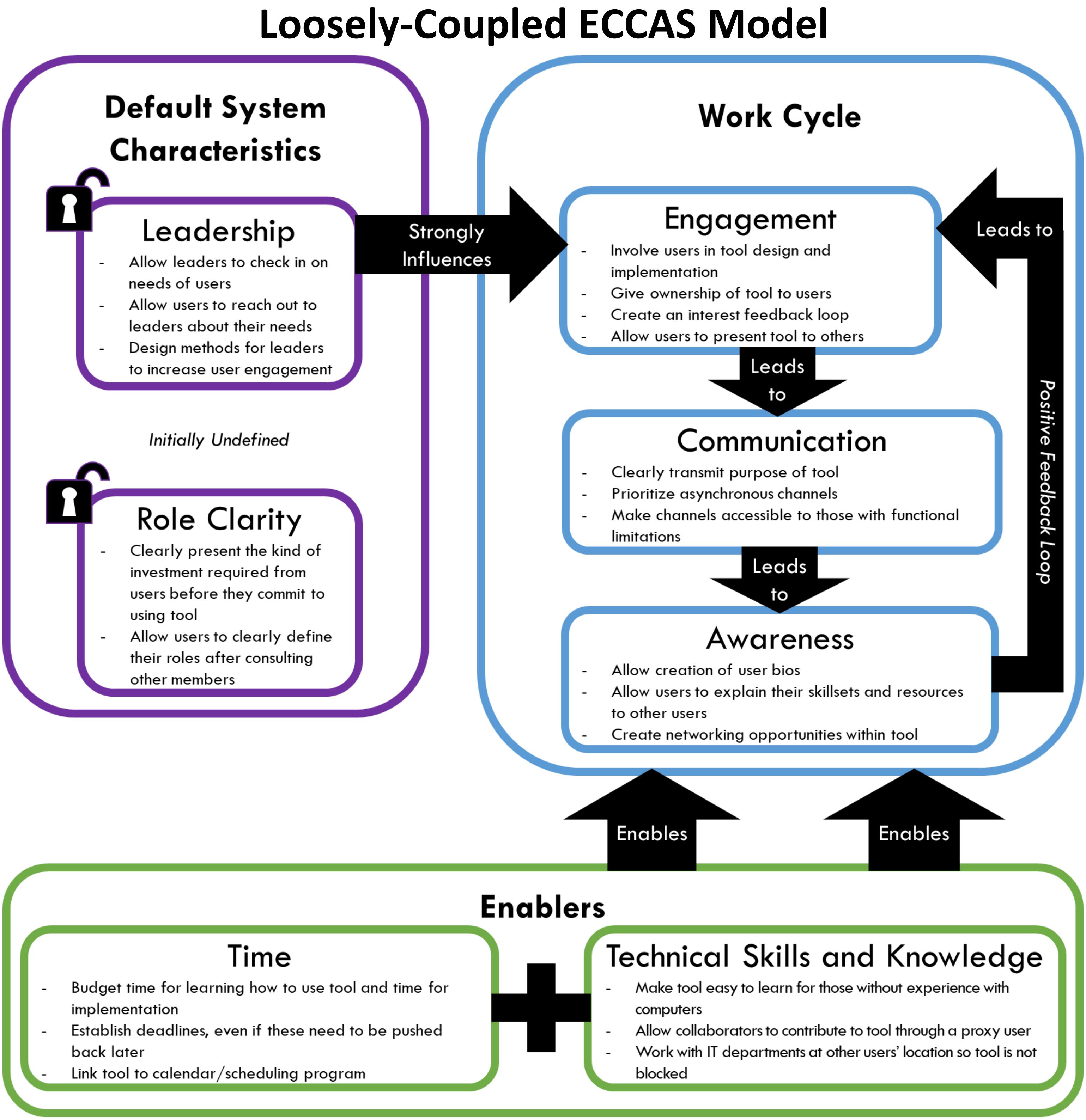
Core Element	*Considerations for Loosely-Coupled CAS*	*Considerations for Tightly-Coupled CAS*
Engagement	• Involve users in tool design and implementation • Give ownership of tool to users • Create an interest feedback loop • Allow users to present tool to others	• Track user participation to forestall legal repercussions • Create check-in and check-out functionality to protect users
Communication	• Clearly transmit purpose of tool • Prioritize asynchronous channels • Make channels accessible to those with functional limitations	• Do not force communication onto users • Make communication channels legible or easy to interpret without needing specialized training • Balance client privacy with user accessibility
Leadership	• Allow leaders to check in on needs of users • Allow users to reach out to leaders about their needs • Design methods for leaders to increase user engagement	• Respect established chain of command • User permissions in tool should reflect actual user responsibilities • Balance design leader's vision with end users' actual skill levels
Role Clarity	• Clearly present the kind of investment required from users before they commit to using tool • Allow users to clearly define their roles after consulting other members	• Learn which organizational and regulatory policies will affect tool use • Respect role boundaries within tool • Do not enable users to circumvent regulations and policies
Awareness	• Allow creation of user bios • Allow users to explain their skillsets and resources to other users • Create networking opportunities within tool	• Give users access to enough information to make decisions but beware information overload • Learn how different roles/titles in organization interact *in vivo* • Create redundancy by allowing users with similar titles to take on an absent user's workload
Time	• Budget time for learning how to use tool and time for implementation • Establish deadlines, even if these need to be pushed back later • Link tool to calendar/scheduling program	• Create redundancies to meet timeline if normal processes are delayed • Reduce time spent using tool relative to old processes being replaced • Thoroughly alpha and beta test tool outside simulated environments
Technical Skills and Knowledge	• Make tool easy to learn for those without experience with computers • Allow collaborators to contribute to tool through a proxy user • Work with IT departments at other users' location so tool is not blocked	• Budget for time/effort it takes to adjust to tool for both average users and users without much experience working with technology • Facilitate ongoing tool training and skill-building opportunities • Leverage younger users to teach those not comfortable with technology

5.1 – Discussion of the Loosely-Coupled ECCAS Model

The ECCAS Model for the loosely-coupled system featured on the following page in Figure 6 consists of the *Default System Characteristics*, the *Work Cycle*, and the *Enablers*. Both the *Default System Characteristics* (which initially define how the collaborative task is coordinated) and the *Enablers* (which provide support in accomplishing the overall goal of the group) influence what occurs in the *Work Cycle*, where the majority of the collaboration occurs. Each of the core properties that make up the model contains recommendations for tool designers based on participant feedback during *The EnRiCH Project*.

Beginning with the *Default System Characteristics*, the two core elements of *Leadership* and *Role Clarity* serve to define the direction of the loosely-coupled working environment. Initially, these two components were undefined; no leader had been assigned or chosen and there were no clear role boundaries. The lock symbols next to *Leadership* and *Role Clarity* reflect the way these elements were left open to discussion at the beginning of *The EnRiCH Project*. This meant participants had to deliberate on both of these components and define the structure they wanted to work within. The leadership model they chose and how they determined what each person would contribute defined their unique contextual parameters. In addition, *Leadership* had a strong influence on one of the core elements of collaboration within the *Work Cycle*: *Engagement*.

Figure 6: Elements of Collaboration in Complex Adaptive Systems (ECCAS) Model for the loosely-coupled complex adaptive system



The *Work Cycle* consists of the components of collaboration that had immediate effects on the participants' work, namely *Engagement*, *Communication*, and *Awareness*. The core element of *Engagement* related to how participants were actively involved in *The EnRiCH Project*—the degree to which they were invested. The core element of *Leadership* strongly influenced overall engagement; a more personable leader was believed to positively influence *Engagement*. High levels of *Engagement* supported *Communication*, with participants generating "hype" and excitement about the project. This, in turn, led to networking and people becoming more aware of the services other organizations offered. This *Awareness* fed back into the *Engagement* core element; as participants networked and understood what other organizations offered, they started to think of ways those services could be used in tandem with those offered by their organizations. This formed a positive feedback loop within the model, further motivating participants to contribute to the collaborative tool.

The core elements within the *Enablers* section of the model acted like catalysts to the *Work Cycle* process by making activities simpler. They did not interfere with the *Default System Characteristics* but instead facilitated other core components. Without enough *Time* to work on the collaborative project, the *Work Cycle* would fall apart. Additionally, when participants were not able to use the collaborative tool (or if using it was too difficult), they encountered problems when trying to communicate or engage with other participants who *were* making use of the tool.

It is important to note that this ECCAS Model was created as a result of the interactions of these core elements in this *specific* context. Not all loosely-coupled complex adaptive systems will follow this model, though there should be some similarities in overall structure.

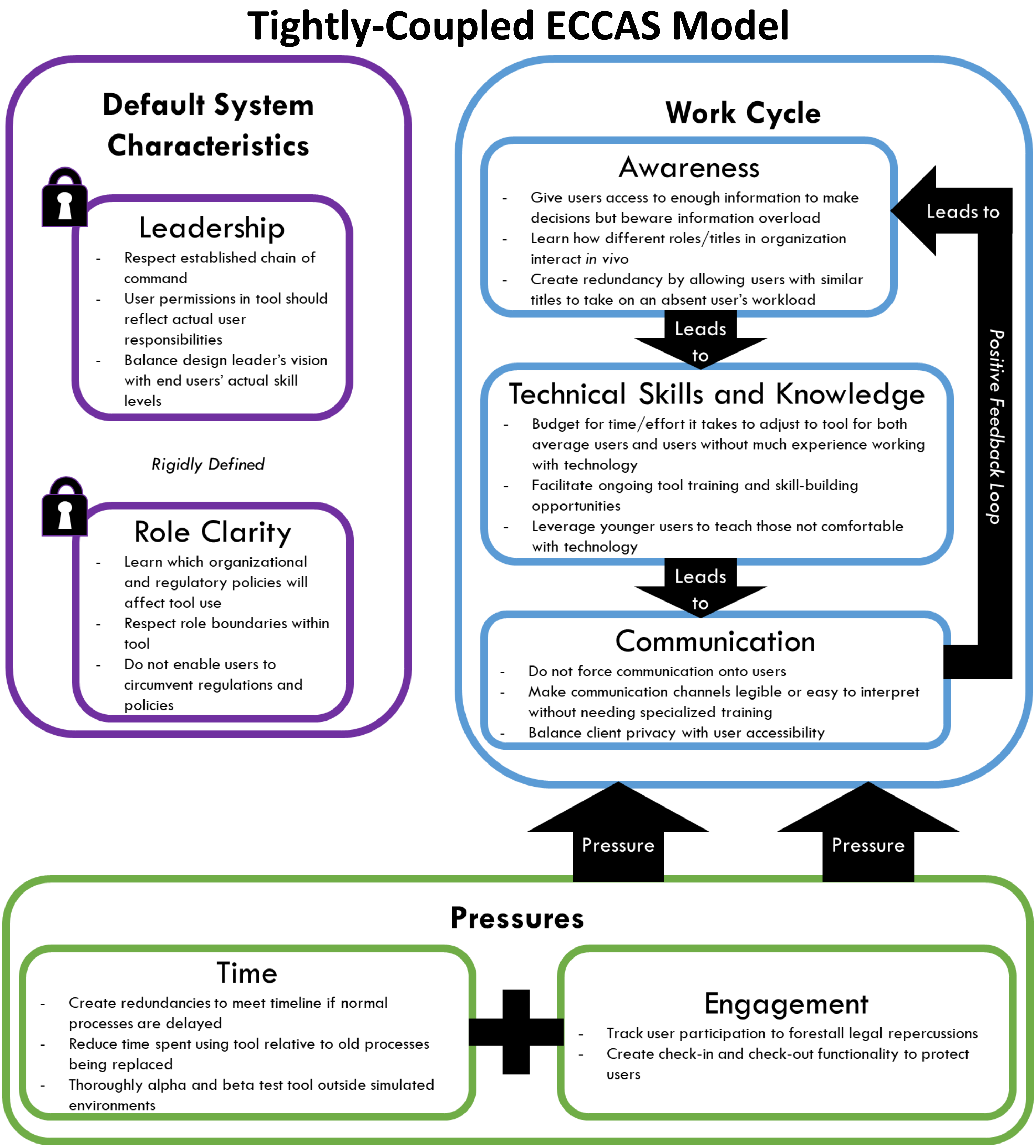
5.2 – Discussion of the Tightly-Coupled ECCAAS Model

While the ECCAS Model for the tightly-coupled system in Figure 7 on the following page was created in the same way as the loosely-coupled variant, the relationships between the core elements are different. Notably, *Engagement* is in a different place and is reversed with *Technical Skills and Knowledge*. The *Enablers* from the loosely-coupled model have also been relabeled as *Pressures*, reflecting how the actors in tightly-coupled systems are pressured by other actors to keep things moving.

The *Default System Characteristics* in this particular system are rigidly defined and left little opportunity for the participants to create new roles or redefine the leadership structure within the hospital. Because of this, the lock symbols next to the core element names have been locked down and are fixed in place. The focus in this area of the model was for tool designers to mirror participant roles within the tool; the actual roles of users within an organization or collaborative groups should be maintained.

The *Work Cycle* of this system is similar to the loosely-coupled system; improvements to the quality of *Communication* between collaborators also enhance *Awareness* in the workplace through the use of the tool. This *Awareness* is not limited to information about the patient, however. Physicians, nurses, and younger residents exchange information relating to different or new ways to use the collaborative tool, which leads to increases in the core element of *Technical Skills and Knowledge*. As participants become more proficient with the tool, they are better able to communicate information to colleagues using various tool functionalities and features.

Figure 7: Elements of Collaboration in Complex Adaptive Systems (ECCAS) Model for the tightly-coupled complex adaptive system



The core properties of collaboration in the *Pressures* section of this ECCAS Model are ever-present issues in a system where end users are short on *Time* and their full *Engagement* in the work process is required. With the risk of sanctions due to medical malpractice becoming a growing reality in the healthcare industry, medical professionals are encouraged to become as engaged as possible in patient care, affecting the *Work Cycle*. Interactions with patients are logged and attending physicians are considered to be responsible for patients even when they are not physically in the immediate vicinity. This creates implications for how staff communicate with one another, how they use and learn about the tool, and how aware they must be about not only the status of the patient but of the capacity of their own unit. *Time* in this system was not a catalyst but a source of pressure. Because the system must ensure patients are steadily moving through the hospital care pathway, providing staff with an unlimited amount of time to see a patient is not particularly helpful or beneficial to the system as a whole. These *Pressures* were useful to motivate participants to use SIMs in a way that was not only efficient but also appropriate to the specific context of the system.

5.3 – Relevance to Current Literature and Practical Applications

The creation of the ECCAS Models addressed the second research question for this thesis, which focused on how core properties of collaboration manifest in both loosely- and tightly-coupled complex adaptive systems. The third research question focused on issues designers must be aware of when implementing a new tool. The ECCAS Models in Figure 6 and Figure 7 show these considerations in relation to other elements of a loosely- or tightly-coupled CAS. Each of the ECCAS Models presented here share important features with the other three models that were presented in Chapter 2.

Communication as a core element of collaboration is reflected in each of the three models presented in Chapter 2. General consensus supports the notion that good communication is critical to effective team functioning (Bogdanovic et al., 2015; Davenport et al., 2007). While the Augmented Continuum of Collaboration Model by Elmarzouqi et al. (2008) conceptualizes *Communication* and *Conversation* as two different pieces of collaboration, *Conversation* occurs bidirectionally instead of unidirectionally. Additionally, both the 3C Collaboration Model (Fuks et al., 2005) and the National Interprofessional Competency Framework (Canadian Interprofessional Health Collaborative, 2010) describe the importance of communication and refer to communication being supported by technology. In the ECCAS Models, *Communication* is bidirectional and can occur either synchronously or asynchronously as well as occurring face-to-face (FtF) or through computer-mediated communication (CMC). Because the loosely-coupled ECCAS Model emphasized relationship-building as an important part of collaboration, FtF communication could be considered a "must" in this kind of system—meeting with collaborators and getting to know them is as important as understanding their role in the group (Okdie et al., 2011). In this system, the relationships participants had with one another were just as important as the information being exchanged.

The group primarily communicated through CMC, which reduced difficulties associated with coordinating meetings for such a large group. The system that influenced the design of the tightly-coupled ECCAS Model, on the other hand, was better served by computer-mediated communication than face-to-face interactions. In fact, the tightly-coupled ECCAS Model shows that proper utilization of technology leads to better communication. Tightly-coupled systems such as this cannot wait for all professionals in the patient circle of care to be available at the same time (Warkentin et al., 1997). In this way, the specific context of a system shapes the way information is communicated between group members, what information will be shared, and when it will be shared (Brier, 2015). Tool designers need to consider the specific context in which their tool will be used. For example, implementing a CMC-heavy collaborative tool in a loosely-coupled system—where building trust between individuals is crucial—would be an idea worth reconsidering.

The authors of each of the models from Chapter 2 also include a piece of their framework that is dedicated to the coordination of work. Whereas the models by both Elmarzouqi et al. (2008) and Fuks et al (2005) provide a more general description of this concept, and label this piece as *Coordination*, the Canadian Interprofessional Health Collaborative (2010) has three separate model components that work together to accomplish the same function: *Role Clarification, Collaborative Leadership, and Interprofessional Conflict Resolution.* In the ECCAS Models, the coordination piece is found in the *Default System Characteristics* component, which includes *Role Clarity* and *Leadership*. These core elements of collaboration create an environment where work is coordinated by one or more leaders who direct tasks towards other areas of the system based on the roles the individuals there possess. These roles are either arrived at during the early phases of collaboration in a loosely-coupled system or they are mostly pre-defined in the case of a tightly-coupled system. In both kinds of systems, many different types of professionals came together to work on a shared goal; the literature has established that when individuals from different professions collaborate, they often have different agendas (Deschesnes et al., 2010). A series of discussions to coordinate group workflow is important to determine what will be worked on and when the work will occur. It is important when designing a collaborative tool to consult all collaborators and take into account the various roles they have (or will have in the future) and determine what tool features best support those roles.

With the Augmented Continuum of Collaboration Model and the 3C Collaboration Model (Elmarzouqi et al., 2008; Fuks et al., 2005) situated within the “groupware” literature, it is evident that technology can play a crucial role in the process of collaboration. In addition, the third model (the National Interprofessional Competency Framework) (Canadian Interprofessional Health Collaborative, 2010) contains a component that explicitly discusses the use of technology for communication purposes, making it very clear that technology is a critical piece of the collaboration puzzle. In the loosely-coupled ECCAS Model, the ability to effectively use technology is classified as an *Enabler* to the *Work Cycle*; it facilitates collaboration even in an environment where repeated face-to-face contact may be the preferred way to work together and establish trust. In the tightly-coupled ECCAS Model, meanwhile, technology has been integrated into the *Work Cycle* so strongly that the whole process revolves around using technology. While this can create problems related to software interoperability, technology that supports collaboration has become so important to many work environments that programmers actively seek methods to accurately translate information sent from software using different computer languages (Kubicek et al., 2011).

The positive feedback loops in both ECCAS Models function as methods to re-evaluate the state of the work process and make adjustments accordingly. These complex systems need to be able to respond to the changing nature of their environment. For example, both Schafer et al. (2007) and Hodge et al. (2011) note the importance of emergency management plans or memoranda of understanding to be flexible and responsive to changing conditions. Should new members join the collaborative group, the resources and talent they bring can become a source of engagement for other members, opening opportunities for cross-training and awareness building. Likewise, as team members communicate in the context of patient surgical care, they learn more about the patient's history and the outcome of a procedure, facilitating better response to patient needs and communication within the team.

One of the practical benefits of being able to differentiate between the kinds of coupling is to provide appropriate support to team members. Because collaboration has distinct ways of manifesting itself in either a loosely- or a tightly-coupled system, tool designers can avoid wasted time by designing supports to collaboration that are congruent with the way the system functions. It is important to know if a tool that is being created will never be used or—worse—if the tool features will actively work against the way a system naturally behaves.

One contribution of this research is that it provides direction for tool designers that can be used to prompt questions related to the overall functioning of a collaborative tool. For example, does the tool inadvertently allow end users to circumvent company policies or the chain of command? Does the tool allow networking opportunities among end users? Did the design of the tool involve input from the end users? Asking the right questions during the conceptualization and implementation phases of a new collaborative instrument allows designers to consider whether the operation of the tool goes against the expected flow of the system, or whether it will effectively work alongside it. It is not enough for tool designers to understand what the core elements of collaboration are and how these manifest in the specific system within which they are working—they must also design effective supports for these core elements.

CHAPTER 6: LIMITATIONS

When interpreting the results of this research, it is important for readers to note several things that constrain the scope of these findings. The first is that the three models presented in the literature review chapter were purposefully selected to display both the differences and the similarities between the kinds of models that were found in the literature. Many other models of collaboration exist, however, and they come in a wide variety of forms that each focus on different aspects of collaboration. This could have influenced which core elements of collaboration were present in the first version of the codebook, which in turn could have placed more focus on other aspects of collaboration instead. However, the use of inductive coding during the coding process should have extracted these hidden core elements from the data if they were present.

Another of these limitations relates to the sample sizes for each of the datasets, limiting the transferability of these results. While the loosely-coupled dataset consisted of 38 interviews—each of which lasted less than one hour—the tightly-coupled dataset was made of six longer interviews from key informants that lasted upwards of an hour in length. The availability of hospital staff to participate in long interviews undoubtedly contributed to the limited sample size; hospitals are busy working environments and being away an hour or more to do an interview may disrupt such a tightly-coupled system. The sample size for both datasets limits the kinds of contexts that these results can be transferred to. However, the context from which both datasets emerged has been described in detail, which should allow for some transferability to other environments sufficiently similar in nature.

The generally rapid pace of technological progress means that the intervening time between when interviews were conducted and analyzed has provided the opportunity for technology to develop further than the kinds of tools that were being used in these datasets. The technology available in each context has undoubtedly improved since interviews were conducted; the recommendations and considerations for tool designers are based on the tools that were in place at the time in these working environments. It is possible that many tools now being implemented in these areas will—by default—incorporate some of the considerations that were presented in Chapters 4 and 5. For example, when the loosely-coupled interviews were taking place, the Google Drive suite of programs (including Google Docs and Google Sheets that were used in *The EnRiCH Project*) were relatively new. However, as of the writing of this thesis, Google Drive is being replaced by Google's new Backup and Sync app, which will almost certainly offer more features for collaborative endeavours.

Finally, it is possible that additional considerations tool designers should implement may not have been mentioned in any of the interviews. These considerations could have been *so* well addressed by the tools the participants were using that they were taken for granted and never brought up in the interview process.

CHAPTER 7: CONCLUSIONS

Broadly, the purpose of this research was to determine core properties of collaboration in loosely- and tightly-coupled and how tool designers can use this knowledge to design better collaborative tools for working in these environments. Understanding how collaboration manifests in certain kinds of systems can lead designers to better support the different aspects of collaboration that end users require. More importantly, this research aims to prevent wasted time, effort, and funds from being used to support the design and implementation of collaborative tools that work against its intended end users. More specifically, this research answered three primary research questions:

1) **What are some of the core properties of collaboration according to current literature?**

Chapter 2 provided a literature review of three models of collaboration, each of which incorporated various properties that their authors indicated were central to the concept of collaboration. This review revealed differences and similarities across the three models, each existing in a different context and used for different purposes. In addition, this chapter described the differences between loose and tight coupling in the context of complex adaptive systems (CAS). It also provided justification for why each of the datasets presented in the methods chapter and chosen for analysis were examples of either a loosely- or tightly-coupled CAS. The literature review section also outlined current issues that tool designers face when creating new collaborative tools, laying the foundation required to answer the final research question later on in the thesis.

2) **How do core properties of collaboration manifest in:**

    a) **Loosely-coupled complex adaptive systems?**

    b) **Tightly-coupled complex adaptive systems?**

The results chapter answered both of these questions using two datasets, independently analysing each of them using qualitative content analysis. The core elements of collaboration consisted of *Engagement*, *Communication*, *Leadership*, *Role Clarity*, *Awareness*, *Time*, and *Technical Skills and Knowledge*. How the specific manifestation of these core properties of collaboration differed between datasets and evidence to support the findings were presented. The relationship between the core properties was presented in the ECCAS Models at the beginning of the discussion chapter.

3) **Using two examples of complex adaptive systems and their common core properties, what are some considerations to account for in designing collaborative tools?**

While the results chapter outlined the considerations tool designers must take into account, the discussion section answered this research question by presenting these considerations within each of the two ECCAS Models. Additionally, the discussion chapter reviewed the relationship between the ECCAS Models and the current literature, examining how the answer to this research question could provide practical benefits to organizations and collaborators.

Beyond answering the three research questions posed as part of this research, it is important to reflect on three key points that flow from this research. The first is that there are core elements to collaboration; while these elements may vary in the way they manifest across different environments, they are indeed present and cannot be ignored. The second is that the end users of a particular tool are in a much better position to provide feedback about how it is being used than the tool designers themselves. Because of this, tool design should be iterative in nature so that feedback about its performance can be used to improve future versions. The final key point is that context is everything—the tools a team uses should be highly dependent on the specific context they are working in. Designing a tool that works in all contexts is impossible; some trade-offs must inevitably occur in order to accommodate one feature in lieu of another. A one-size-fits-all approach to collaboration will miss the intricate ways it progresses in different kinds of systems.

Future research into the core properties of collaboration in loosely- and tightly-coupled CAS may reveal different relationships between the core components in other contexts. Notably, it would be valuable to learn if additional core properties exist for systems situated in the middle of the loose-tight coupling spectrum. Future research could also validate the recommendations given to tool designers for creating collaborative tools.

As businesses and other organizations increasingly incorporate team-based work models, they will come to depend more heavily on technology-based solutions to keep these units operating smoothly. It would be beneficial if organizations incorporated collaborative technologies that properly support the activity of collaborative teams, based on the specific type of complex adaptive system in which their organization exists, whether it be a loosely- or tightly-coupled one. It matters not whether the collaboration in question is interprofessional, interdisciplinary, multidisciplinary, or transdisciplinary in nature; it matters only that the tool being used to assist in the collaborative endeavour has been designed for use in a specific context of a complex adaptive system.

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APPENDIX A: LIST OF DEDUCTIVE CODES

Codes from Elmarzouqi et al. (2008)

- Tools for communication
- Tools for group awareness
- Workspace considerations
    - Taking into account several actors
    - Making sure actors can communicate with one another
    - Ability to manage several levels of collaboration and contribution to achievement of collaborative task
    - Making it easier to complete the required work
- Competition between collaborators
- Disturbances from working with other group members
- Workspace issues
    - Personalization/arrangement of windows on screens
    - Synchronous tasks vs asynchronous tasks
    - Sub-groups to complete transitory tasks
    - Congruence of views
- Collaboration Spaces
    - Co-production space
    - Communication space
    - Regulation
    - Awareness
- Continuum of Collaboration:
    - Coordination space
        - Shared tasks
        - Scheduling
        - Temporization of the contributions
    - Cooperation space.
    - Collaboration space
- Awareness space
    - Time
    - Space
    - Population
    - The task
- Awareness of:
    - The knowledge
    - The activity: Who does what? With which goal? How (synchronous vs asynchronous)
    - The context
    - The participation

Codes from Fuks et al. (2005)

- Collaboration: The combination of:
    - Communication
        - Media
        - Transmission mode: Synchronous, asynchronous. Continuous or in blocks.
        - Restrictions policy
        - Meta-information
        - Category
        - Conversation structure: Linear (one to one), hierarchical (evolutionary tree), networked (evolutionary tree/interconnected nodes).
        - Conversation paths
    - Coordination
            - Pre-articulation
            - Management of tasks
            - Post-articulation
        - *Loosely* integrated collaborative activities
        - *Tightly* integrated collaborative activities
        - Object-level coordination
        - Temporal-level coordination
    - Cooperation (production)
        - Iterative process involving feedback from actions

Codes from The Canadian Interprofessional Health Collaborative (2010)

- Role Clarification
    - Appropriate language
- Patient/Client/Family/Community-Centred Care:
    - Engaging the client in the collaborative activity
    - Supporting client in being involved.
    - Sharing information
    - Give client support and education that will enable them to be involved
    - Respectful listening
- Team Functioning
    - Set of principles that respects the values of all members
    - Facilitate discussions/interactions.
    - Establish and maintain healthy relationships
    - Trust and mutual respect
    - Open communication to share information
- Collaborative Leadership
    - Shared decision-making with individual accountability
    - Interdependent working relationships
    - Shared leadership: Based on the specific kind of leadership and skillset needed at that moment in time
        - Task-orientation

        - Relationship-orientation
- Interprofessional Communication
    - Establish communication principles before/during collaboration
    - Active listening
    - Common understanding
    - Develop trusting relationships
    - Using technology to improve team effectiveness
    - Verbal methods of communicating:
        - Negotiating, consulting, interacting, discussing, debating
- Interprofessional Conflict Resolution
    - Setting guidelines.
    - Conflict providing opportunity to engage team members
    - Role conflict
        - Role ambiguity
        - Role overload
        - Accountability
    - Goal conflict
        - Dissimilar philosophies
- Other issues
    - Complexity
        - Simple system
        - Complicated system
        - Complex system
    - Contextual issues
    - Quality improvement: Reciprocal relationship with interprofessional collaboration.

APPENDIX B: *THE EnRiCH PROJECT* INTERVIEW GUIDE

Reference scale for questions where participants are asked to provide a rating (1 = lowest; 5 = highest)

1) Please describe the organizations you work with in your community.
    a. *Probe*: In your work, do you do any direct care for people with functional limitations?

2) Please indicate the number of community organizations you work with on a daily basis (Weekly? Monthly?) in the context of performing the duties for your work (paid or unpaid).

3) Connectedness has been defined as *(give definition)*. On a scale of 1-5, how would you describe the extent of your connectedness in your community?
    a. *Definition of connectedness:* the extent to which you feel connected or linked with a web of people, organizations, resources and information in your community.
    b. *Probe*: Are you satisfied with this level of connectedness? If not, how would you like to change it?

4) On a scale of 1 to 5, please rate how your organization supports or encourages collaboration.
    a. *Probe*: Please explain your rating.
    b. *Probe*: What type of support is provided for collaboration?
    c. *Probe*: What challenges have you encountered in trying to collaborate? Can you provide a specific example?
    d. *Interviews 2-4:* Has this changed since your last interview?

5) Using the same rating scale, how confident do you feel about your ability to fulfill your responsibilities in a disaster response in the event of a community disaster (such as an ice storm, flood or fire)?
    a. *Probe*: Please explain your rating.

6) On a scale of 1 to 5, how would you describe the potential of this collaborative group who are participating in the EnRiCH Project to sustain its activities over the next year?
    a. *Probe*: Please explain your rating.

7) Using the same rating scale, how would you describe the political climate in your organization with respect to supporting collaboration with the participants in this EnRiCH group in your community?
    a. *Probe*: Please explain your rating.

8) On a scale of 1 to 5, would you say you have the resources (equipment, money, people) you need to sustain collaboration with this group?
    a. *Probe*: Please explain your rating.

9) On a scale of 1 to 5, how likely is it that you will participate in the online component of the collaborative task over the next month?

    a. *Probe*: Please explain your rating.

10) What do you hope to get out of your participation in the EnRiCH session?

11) *(Interviews 2-4)* Please rate your sense of belonging to this EnRiCH collaborative group in your community using the same 1 to 5 rating scale.
    a. *Probe*: Please explain your rating

12) Please describe how this collaborative group has structured itself.
    a. *Probe*: What type of leadership has evolved within the group?
    b. *Probe*: Has it been effective?
    c. *Probe*: What are the relationships like?
    d. *Probe*: Does this group have the right mix of people?
    e. *Probe*: What, if anything, would you change about the structure?

13) Has your participation in the project influenced the way you work?

14) Please describe whether your perceptions of preparedness for disasters has changed or remained the same over the course of this project.
    a. *Probe*: Have you done anything differently in terms of your own preparedness for disasters?

15) Has the group identified any common goals after the EHRIT Mapping Session?
    a. *Probe*: How was this process accomplished?

16) Does this collaborative group have the right mix of people?

17) Please describe the level of commitment among the group.

18) Have any new people joined the group?
    a. *Probe*: How were they integrated?
    b. *Probe*: What were the challenges that new members faced in integration?

19) Please explain any relationships between this group and the connectedness in the community at this time.

20) Have there been any major changes in the community within the past month?

21) How does this collaborative group make decisions with regards to the contingency plans?

22) How does this group communicate internally? Externally? Informally? Formally?

23) Do people with functional needs participate fully in contingency planning with this group?
    a. *Probe*: What accommodations are made to facilitate this?

24) In the past month, have there been any major changes in the direction this collaborative group is going?

25) Please describe the process that has evolved to develop the contingency plans in your organization and in the community.
    a. *Probe*: Do you feel your viewpoint is reflected in the contingency plans (or the work that has been accomplished to date)?
    b. *Probe*: Is anything missing from the plans?

26) Has the work of this collaborative group had any influence on the resilience of this community?

APPENDIX C: SIMs STUDY INTERVIEW GUIDE

1) Can you please describe how you use SIMs (Surgical Information Management system) in your typical work day?

2) **More work/New work**
    a. Can you describe how SIMs has impacted your work?
    b. What processes has it enhanced?
    c. Are there any processes that it has made more difficult?
    d. Did you have to adapt or change any of your work processes after SIMs was implemented?

3) W**orkflow**
    a. When clinical information systems are implemented, it can alter how people do their work. Has SIMs changed the way you do your day-to day work processes?
    b. Have certain processes changed from the paper system to SIMs?
        i. *Probe:* Can you give an example?

4) **Communication**
    a. Communication is an important aspect of the peri-operative pathway. Has SIMs changed the way you communicate with other clinicians or with patients and families?
        i. *Probe:* Can you give an example?

5) **New functionality**: Now that SIMs has been in use for a while, are there any functionalities that have emerged through system usage (i.e. does it give you functionality that was not planned but that has enhanced your ability to provide care)?

6) **Information access**
    a. A key aspect of the peri-operative pathway is the efficient exchange of information. How has SIMs impacted your ability to get the information you need to do your job?
    b. Does SIMs provide the information you need in the format you need it in?
    c. How does it impact your ability to track a patient over the continuum of their surgery?

7) **Impact to patients**: Has SIMs changed your interaction with patients and/or families?

8) **Outcomes**
    a. Has SIMs had an impact on quality or efficiency of care delivery?
    b. Has it impacted patient safety?

9) Are there features of SIMs that you would like to change or revise?

10) Are there functions missing from it that would enhance your ability to use it?

APPENDIX D: ETHICS APPROVAL CERTIFICATE

Continue to next page for full ethics document.

Université d'Ottawa University of Ottawa
Bureau d'éthique et d'intégrité de la recherche Office of Research Ethics and Integrity

Ethics Approval Notice

Social Sciences and Humanities REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

First Name	Last Name	Affiliation	Role
Craig	Kuziemsky	School of Management / School of	Co-Supervisor
Tracey	O'Sullivan	Health Sciences / Others	Co-Supervisor
Nathaniel	Leduc	School of Management / School of	Student Researcher

File Number: 05-16-23

Type of Project: Master's Thesis

Title: Collaboration Properties in Complex Adaptive Systems

Approval Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
05/12/2016	05/11/2017	Approved

Special Conditions / Comments:
N/A

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This is to confirm that the University of Ottawa Research Ethics Board identified above, which operates in accordance with the Tri-Council Policy Statement (2010) and other applicable laws and regulations in Ontario, has examined and approved the ethics application for the above named research project. Ethics approval is valid for the period indicated above and subject to the conditions listed in the section entitled "Special Conditions / Comments".

During the course of the project, the protocol may not be modified without prior written approval from the REB except when necessary to remove participants from immediate endangerment or when the modification(s) pertain to only administrative or logistical components of the project (e.g., change of telephone number). Investigators must also promptly alert the REB of any changes which increase the risk to participant(s), any changes which considerably affect the conduct of the project, all unanticipated and harmful events that occur, and new information that may negatively affect the conduct of the project and safety of the participant(s). Modifications to the project, including consent and recruitment documentation, should be submitted to the Ethics Office for approval using the "Modification to research project" form available at: http://research.uottawa.ca/ethics/submissions-and-reviews.

Please submit an annual report to the Ethics Office four weeks before the above-referenced expiry date to request a renewal of this ethics approval. To close the file, a final report must be submitted. These documents can be found at: http://research.uottawa.ca/ethics/submissions-and-reviews.

If you have any questions, please do not hesitate to contact the Ethics Office at extension 5387 or by e-mail at: ethics@uOttawa.ca.

Hoda Shawki
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