THE DYNAMICS OF TASK-RELATED DISCUSSION IN THE PURSUIT OF RADICAL INNOVATION: INNOVATION PROJECT TEAMS AS INTERPRETATION SYSTEMS

by

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ABSTRACT

As global competition is increasingly intensified, radical innovation has become more and more important for corporations in high-velocity industries. Thanks to the advances of information systems and communication media, corporations can easily reach out to experts all over the world and form project teams dedicated to the innovation effort. However, research shows that while some innovation teams are very successful in achieving significant breakthroughs, many struggle to make their collaborations work. In this dissertation, we aim to provide a comprehensive understanding of the collaboration challenges that an innovation team faces. By considering the simultaneous needs for differentiation and integration in the innovation effort and taking a communication/ interpretive perspective, we develop a theoretical model to investigate how the processes of differentiation and integration are shaped through team communication and influence an innovation team's collaboration outcomes. Specifically, we delineate four structural properties of team communication to capture these two processes – the number of issue streams explored, the number of attention switches initiated, the conceptual linkage between issue streams, and the level of deliberation after each attention switch – and identify four categories of factors that influence the development of these two processes – team composition, semi-structures, communication contexts, and communication environments. We conduct a case study as a preliminary test of our theoretical model, and find that the model provides comprehensive explanations for the collaboration dynamics and issues of these teams. We believe such a theoretical model can contribute to a better understanding of the complexity involved in an innovation project and bring fresh insights to the design of information systems for supporting an innovation team.

Key words: Radical innovation; innovation project team; interpretation systems; information systems; communication media; collaboration dynamics

CHAPTER 1: INTRODUCTION

"It convened several internal teams from its different businesses to work on a project, named Connect, that was supposed to come up with a product to counter Apple's. But after a number of years of trying to produce an iPod-killer, Sony admitted defeat and disbanded the connect initiative in 2007." (The Economist 2009)

The continuous pursuit of innovations and breakthroughs is a key survival principle for corporations in high velocity industries, such as electronics. Apple's striking comeback with the iPod in 2001 provides a vivid account of how innovation can change the fate of a once doomed company. While some innovation scholars suggest that innovation can be systematically managed and found, "if one knows where and how to look" (Drucker 1998, p.3), other researchers in the area portray innovation as walking a thin line, full of competing forces and conflicting requirements. Such divergent views on the nature of innovation stem from the increasing reliance on innovation project teams to carry out the innovation effort. Even though innovative ideas may initially come from single individuals, as the idea is being developed and maturing, a team of experts is often required to handle the complexity and interdependence that come with the development process (Van de Ven 1986).

The diversity of team members, in terms of backgrounds and expertise, has been found to help spark different insights and find better solutions. But it may also lead to internal conflicts and political fights because of individuals' different perspectives or interpretive schemes (Dougherty 1992; Jehn et al. 1999; Lovelace et al. 2001). Although imposing a rigid management structure on a project team can stifle creativity, a total lack of management is not helpful either. Instead, managers need to provide their team members with clear responsibilities and priorities, and at the same time supply them with extensive communication and design freedom for improvisation (Brown and Eisenhardt 1997). These competing forces and conflicting requirements create sophisticated entanglements within an innovation project team, and made even Sony, a giant electronic company famous for inventing the Walkman in the 1980s, scramble in its effort to create a revolutionary music player that could cast out Apple's iPod from the market.

Can information systems (IS) help resolve some of these organizational entanglements so that team collaboration for innovation can be smoother and more manageable? Over the years, many new types of collaborative software (e.g., instant messaging, Wiki, and Dropbox) and collaboration forms (e.g., virtual team and crowdsourcing), which can increase the engagement of remote experts in an innovation project, have sprung into being because of the advance of IS and communication media. While some virtual collaborations have been very successful in bringing in different ideas and insights and meshing them into an innovation, many have struggled to make their collaboration work. According to a survey by Govindarajan and Gupta (2001), only 18% of virtual teams considered their performance as highly successful; the other 82% fell short of expectations. Many scholars have leveraged different theoretical lenses to investigate the effects of IS on virtual collaboration (Cummings et al. 2009; Hinds and Bailey 2003; Kanawattanachai and Yoo 2007; Massey et al. 2003; Montoya-Weiss et al. 2001; O'Leary and Mortensen 2010; Paul et al. 2004; Piccoli and Ives 2003). Although their investigation results and implications may vary, one conclusion is consistent – while IS has effects on the way that teammates communicate and coordinate with one another, organizational factors, such as team composition and leadership, still play a crucial role in determining the success of the collaboration. As one business analyst sums it up, "[c]reating collaboration takes more than technology" (Rosen 2010).

In this dissertation, by considering both IS and organizational factors, we aim to develop and test a comprehensive theoretical model for understanding the collaboration dynamics of an innovation project team. We believe such a theoretical model can contribute to a better understanding of the complexity involved in an innovation project and bring fresh insights into the design of information systems for supporting an innovation team. In the development of this model, we focus on two conflicting, intertwined processes in the pursuit of innovation – differentiation and integration – and investigate how various IS and organizational factors promote and shape the development of these two processes. The simultaneous need for differentiation and integration in the process of innovation has been suggested in various ways in the innovation literature. For example, Koput (1997) suggested that although searching for innovative ideas needs randomness and foolishness, implementing the idea requires organization to ensure efficiency and reliability. Dougherty (2001) also posited that in the work of innovation, people with diverse expertise and skills have to be integrated so that they can understand each other's constraints and jointly solve problems. Nevertheless, the simultaneous need for differentiation and integration often cannot be satisfied because of individuals' distinct interpretive schemes. According to Dougherty (1992), collaboration among people with different expertise is like living in different "thought worlds," not able to effectively communicate and comprehend each other's unique perspective for synthesis.

This creates a major barrier for successful innovation and partly explains Sony's failure in its innovation attempt with the Connect project.

By understanding that the tension between differentiation and integration is created by individuals' different interpretive schemes, we take a communication/ interpretation perspective to develop our theoretical model. Specifically, we conceptualize an innovation team as an interpretation system (Daft and Weick 1984) that, through gathering and interpreting information from its outside environments, seeks to make the best judgment call about its innovation effort, and theorize how the processes of differentiation and integration are manifested and shaped in the collective interpretation process during group discussion. This communication/interpretation perspective allows us to (1) have a comprehensive view of the team's developmental process, including its decision making process, developmental transitions, and progress on the project, and (2) theorize the underlying mechanisms through which various IS and organizational factors exercise their influence on the two processes. To perform a preliminary test of our theoretical model, we conduct a case study at the iPlant Collaborative, a cyber-infrastructure initiative for developing innovative computational platforms for the plant science research community. We believe the rich narrative of a case study can give us valuable insights into the collaboration and communication dynamics of innovation projects, drawing significant implications for the management of innovation project teams. Overall, this dissertation is aimed at (1) theorizing how the processes of differentiation and integration are manifested in an innovation team's interpretation and discussion process, (2) clarifying the relationship between these two processes and the team’s collaboration outcomes, and (3) investigating how various IS and organizational factors play a role in shaping the development of these two processes, including the interactions between those factors.

The dissertation is organized as follows. In Chapter 2, we review literature in the areas of innovation, team communication, and team development to delineate the role of communication and interpretation in organizing the effort for innovation. In Chapter 3, with the emphasis on the processes of differentiation and integration, we develop our theoretical model for the collaboration and discussion dynamics of an innovation team. In Chapters 4 and 5, we present our research design for the case study and the analysis results. The dissertation concludes with a discussion of our contributions and the implications of our study for research and practice.

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CHAPTER 2: INNOVATION AND TEAM COMMUNICATION

In this chapter, we review literature to develop a comprehensive understanding of the role of team communication in an innovation team. We first provide a brief review of innovation, centering on the focal type of innovation in this dissertation – radical innovation – and the importance of a project team in the innovation effort. From the idea of creating dramatic changes implied in the radical innovation, we delineate the functions of team communication and interpretation in the process of innovation. Then we consider the dynamics of an innovation project as a series of iteration between two different stages – problem setting and solving, from which the simultaneous need for differentiation and integration is created. Last, we discuss how team communication helps to achieve this simultaneous need by differentiating two elements in the communication – communication content and argument frame.

2.1 The Pursuit of Radical Innovation

Making purposeful, meaningful *changes* in existing entities lies at the heart of innovation efforts. The entities of interest can be technical or administrative, including technologies, products, services, procedures, and policies. Intended changes are introduced through new ideas embodied in an innovation. Depending on the entity of interest, a new idea can be seen as a new combination of old ideas, a unique approach to provide services or manage procedures, a new configuration or formula in technologies or products, or a new scheme for organization (Van de Ven 1986). The ultimate goal behind every innovation attempt is to create new economic or social potential for the innovators or their organizations (Drucker 1998). In the business setting, a significant leap in competitive advantage is expected.

The magnitude of change is often used as a dimension to characterize innovations. At one end of the scale, incremental innovation makes limited enhancement on an entity of interest (e.g., product or service). On the other end of the scale, radical innovation is aimed at introducing revolutionary ideas or designs, or “making a dent in the universe” as Steve Jobs put it. In order to emphasize the essence as well as the complexity of innovation, this dissertation focuses on technical radical innovation. For a specific definition of technical radical innovation, we adopted Henderson and Clark’s typology of innovation (1990) that delineates two dimensions along which changes in a technical entity can take place – (1) linkages between technical components and (2) underlying core design principles implied in a dominant design. According to the typology, incremental innovation refines individual technical components in a system while leaving the linkages between technical components and the core design principles unchanged. Radical innovation, on the other hand, invents a brand new technical layout for a system by overthrowing the established design principles. For example, a smartphone reconfigured a mobile phone with enhanced computing capability and additional electronic components, such as high resolution touchscreen and Global Positioning System (GPS) navigation unit. With the new configuration, the smartphone also challenged the dominant designs of the mobile phone, opening up a whole new area of applications. Accordingly, the smartphone is considered an outstanding example of successful radical innovation.

The intent to change and move behind the dominant design of a technical system renders the task of radical innovation highly complex and uncertain in its process. A dominant design reflects the state of the art in providing certain functionalities, and specifies required technical components and a framework for the way that these components should be integrated (Henderson and Clark 1990). In addition, it embodies a set of design principles that would guarantee particular functional outcomes, making technical issues surrounding the system predictable and analyzable. When an innovation effort is aimed at fundamentally transcending the limitations of a dominant design, the problem to solve becomes open-ended and poorly conceptualized. Various complexities that are not confined to the design framework and principles arise and need to be dealt with. Specifically, innovators need to (1) outline desired ends or outcomes in terms of functionality and market value, (2) search for potential solutions – including alternative new components and their linkages – to meet the desired ends, and (3) resolve uncertainty and complications caused by the unknown interactions of the new components (Campbell 1988). As a result, the pursuit of radical innovation is often characterized as a problem-solving process and as a non-routine and complex task. It heavily depends on individuals' insights, intuition, and experience to clarify means-end connections and requires an enormous amount of information-processing capacity to tackle the complexity and interdependency of the technologies involved (Campbell 1988; Dougherty 1992; Perrow 1967; Van de Ven 1986).

When organizations pursue radical innovation, they often form project teams composed of experts from required technical and managerial areas. This is an efficient and effective means for managing the complexity and interdependence that come with an innovation project. Experts bring in knowledge from their respective domains to the project (e.g., expertise in specific technologies, manufacturing, sales, and marketing) as well as social linkages to potential knowledge sources. Meanwhile, their collaboration enables the processing of a large amount of information in a short time for knowledge development and offers different perspectives to stimulate the search process for innovative ideas. Empirical studies have shown that team collaboration enhances organizations' capabilities for creating breakthroughs in spite of various collaboration difficulties (Dougherty 1992; Lovelace et al. 2001). Particularly, a project team is found to more likely generate novel solutions through better combinations of ideas while avoiding poor outcomes with a more rigorous review process (Singh and Fleming 2010).

2.2 The Role of Interpretation in Radical Innovation

According to two theoretical points of view, team communication provides an essential mechanism for a project team to initiate necessary changes when pursuing radical innovation. First, team communication allows members to envision and communicate desired outcomes that have not yet come into being. From the perspective of structuration theory, people construct and reconstruct social structures known as reality through social interactions and communication (Giddens 1984; Orlikowski 2000). Changes are introduced through "a recursive process of social construction in which new realities are created, sustained, and modified in the process of communication" (Ford and Ford 1995, p.542). To organize the collective effort, the desired future outcomes – a new reality that has not yet been realized – have to be brought into existence and juxtaposed with the current reality to reveal their gaps, which is only possible within the realm of communication (Ford and Ford 1995). After their gaps are revealed, a series of actions can be derived and carried out to achieve the new reality.

Second, team communication enables members to synthesize different points of view and generate novel ideas during the solution search. According to Van de Ven (1986), innovation is “a complex perceptual process that melds together judgments of reality and judgments of value” (p.592). Individuals’ thinking and perception are often heavily influenced by dominant designs that have gained their status of legitimacy in their respective problem domains. The principles embedded in these designs are accepted as the right approach to tackle complex design issues and are incorporated implicitly in individuals’ decision making process (Henderson and Clark 1990; Van de Ven 1986). Novel ideas that defy these principles can appear illegitimate and unworthy of consideration (Bartel and Garud 2009). To break through the bondage of dominant views and make radical changes, a project team needs to engage in dialectical discussion; the dominant thinking acts as the thesis and is challenged by other alternative ways of thinking serving as the antithesis (Bartunek 1984). Through the processes of differentiation and integration, a new, more complex viewpoint can emerge, enabling individuals to generate and appreciate radical ideas that were once viewed as unorthodox and illegitimate (Bartunek 1984).

These two process requirements – communicating future desired outcomes and synthesizing different perspectives for novelty – highlight the role of interpretation in radical innovation. Interpretation is a cognitive process as well as a communication activity during which environmental stimuli are given meaning according to our interpretive schemes for making sense of our surroundings. Interpretive schemes are cognitive structures shaped by our background, experience, and training, and map our experience of the world, recognizing its constituents and relationships and identifying how we come about to understand them (Bartunek 1984; Daft and Weick 1984; Pelled et al. 1999; Ranson et al. 1980). According to Giddens (1984), “[i]nterpretive schemes are the modes of typification …applied reflexively in the sustaining of communication” (p.29). With interpretive schemes operating behind the scenes, interpretation allows us to talk about and understand something unknown by the inference of our knowledge and experience, and gives us the ability to describe what were once our hunches and feelings (Crossan et al. 1999; Schütz 1967). Through the activity of interpretation, we share and discuss our observations and understanding, and collaboratively reduce the conflicting meanings of environmental stimuli (Daft and Weick 1984). In sum, interpretation makes the conversation of desired future outcomes possible and promotes the development of a shared understanding across different perspectives.

Interpretation plays two important roles in the process of radical innovation. First, it enables the gathering of unique insights from individual members. The success of an innovation project is suggested to depend on bringing together a complex array of specific insights to establish means-end connections (Dougherty 1992). Specifically, a vision of future possibilities (or desired outcomes) is created from personal insights to give the team a sense of meaning and purpose (Crossan et al. 1999; Van de Ven 1986). In addition, new patterns or connections are also recognized through personal insights to facilitate the search for novel solutions (Kornish and Ulrich 2011; Simon 1985). Insights are developed on a subconscious level; often precise verbal expressions are not available to effectively communicate them. But through interpretation, individuals are enabled to share their personal insights with others by naming some existing objects to evoke images and the association of desired traits (e.g., the use of metaphors) (Crossan et al. 1999). For example, the development of the Apple Macintosh was guided by the metaphor "household appliance" to convey the visions for the personal computer – simple interface, intuitive to use, and affordable. Once objects are named, listeners' anticipations, expectations, and evaluations are directed toward these objects (Crossan et al. 1999). More explicit connections can then be developed around the named objects to clarify images and the means-end connection.

Second, interpretation helps clarify technological environments and consolidate different points of view. In order to recognize potential new technologies for synthesis, innovation teams need to actively develop a new understanding of technological environments with extensive data collection and interpretation efforts. Data about the technological environment can be collected internally and externally and from impersonal or personal sources (Daft and Weick 1984). For example, an innovation team may seek to understand its parent organization's technical innovation capacities via internal information channels. The team may also collect publicly available reports to investigate competitors' strategies and solutions. Along with the data collection effort, team members need to screen the collected data to identify useful information and form their interpretations. Because of individuals' differences in interpretive schemes, different interpretations of the technological environment are likely to develop. By exchanging and deliberating their unique perspectives, team members have the opportunity to closely examine the basic assumptions underlying their thinking, which can initiate desirable changes in their interpretive schemes (Bartunek 1984; Ford and Ford 1995). A shared language and a shared communication context can also be developed as a result to facilitate collective collaboration (Crossan et al. 1999).

2.3 Communication Activities in the Process of Radical Innovation

Because of its critical role in orienting a project team in the course of change, we use interpretation as the focal point for delineating major communication activities in the process of radical innovation. We focus primarily on task-related communication in regard to the nature of interpretation under the context of innovation. The process of innovation is viewed and analyzed as a series of iterations between two distinct stages – problem setting and problem solving (Dougherty 2001; Koput 1997). During the problem setting stage, an innovation team seeks to establish means-end connections with tangible performance strategies. The major communication activities at this stage are:

- Specifying desired outcomes: Team members define the problem to solve by sharing their interpretations of the task and personal insights about the future possibility. One important product of this activity is the specification of desired outcomes, which provide the innovation team with observable measures to evaluate its solutions and monitor its work progress (Ford and Ford 1995).
- Searching for novel solutions: It is suggested that novelties emerge from new combinations of ideas in different problem domains (e.g., the incorporation of

GPS in the mobile phone design). As a result, the creative search is often characterized as combinational thought trails or an evolutionary search across a combinational space (Bartel and Garud 2009; Kornish and Ulrich 2011; Singh and Fleming 2010). Through the effort to clarify technological environments, an innovation team constructs large spaces of possibilities from which novel combinations can be generated. At the same time, individuals' expertise and insights facilitate the recognition of important patterns, making the creative search more efficient and effective (Koput 1997; Simon 1985). Open forums and brainstorming sessions are often employed as the form of discussion during this search activity to encourage the sharing and synthesis of different ideas (Kornish and Ulrich 2011).

- Screening potential solutions: By carrying out screening activities, team members judge the value of potential solutions according to their interpretive schemes, and identify promising solutions for further development. The more extensive the creative search is, the more costly the screening activity (Koput 1997; Singh and Fleming 2010).

During the problem solving stage, an innovation team implements its chosen solutions in the physical context of operation to receive environmental feedback. Since the integration of new technologies involves many unknown interactions, the physical context provides an essential environment for the innovation team to identify and diagnose technical issues and understand the nature of its innovation task (Dougherty

2001). The innovation team improvises its solutions and obtains new information for further interpretation through the following two activities:

- Collective problem solving: During implementation, the innovation team identifies problems that are unforeseen at the previous stage of problem setting. By conducting investigations and experimentation, team members collaborate to clarify and determine the cause-effect relationship underlying the problem and devise solutions. In addition, the problem solving activity provides a shared communication context for teammates to cultivate a shared understanding of their innovation work (Bartel and Garud 2009; Dougherty 2001).
- Learning by doing: The innovation team creates its new designs and action plans according to its interpretations of the technological environment. During the problem solving stage, the team tries out these plans and puts its theories into action. The action outcomes offer the team new environmental data to assess its interpretations and adjust its action plans (Daft and Weick 1984; Ford and Ford 1995).

These two stages' respective communication activities are illustrated in Table 2-1.

Table 2-1. Communication Activities in the Process of Radical Innovation

Stage	Communication Activity	Example
Problem setting	Specifying desired outcomes	• Clarifying the project's scope and requirements (Ericksen and Dyer 2004; Marks et al. 2001) • Sharing interpretations of the task (Gersick 1990) • Sharing personal insights about future possibilities (Crossan et al. 1999; Ford and Ford 1995) • Outlining desired outcomes or goals (Ford and Ford 1995; Henderson and Clark 1990; Marks et al. 2001)
	Searching for novel solutions	• Gathering contextual information internally and externally (Daft and Weick 1984; Ericksen and Dyer 2004) • Clarifying task-related issues (Gersick 1988) • Surveying alternative new technologies (Henderson and Clark 1990) • Exchanging interpretations of the technological environment (Daft and Weick 1984; Ford and Ford 1995) • Formulating the problem to solve (Ford and Ford 1995) • Open forum or brainstorming session for solutions(Kornish and Ulrich 2011; Woodman et al. 1993)
	Screening potential solutions	• Creating premises and agreements on a basis for collective work (Gersick 1988; 1989) • Examining hypotheses and raising concerns (Ford and Ford 1995) • Laying out action plans and team members' roles and responsibilities (Ericksen and Dyer 2004; Ford and Ford 1995)
Problem solving	Collective problem solving	• Reporting technical issues during implementation (Gersick 1988) • Performing joint investigations and experimentation (Dougherty 2001) • Consulting peer members for advice and feedback (Malhotra et al. 2001; Marks et al. 2001) • Clarifying cause-effect relationships and devising solutions (Ericksen and Dyer 2004)
	Learning by doing	• Receiving feedback from the stakeholder and the outside environment (Gersick 1988; 1989) • Evaluating work progress and the effectiveness of action plans (Ford and Ford 1995; Gersick 1988; Marks et al. 2001)

Because of the high uncertainty and complexity involved in the innovation project, "the process is full of twists and turns, false starts, and dead ends" (Bartel and Garud 2009, p.109). Merely increasing the level of search for novel ideas at the problem setting stage does not guarantee superior outcomes at the end (Earley et al. 1989). Instead, innovation teams often require a number of iterations between the two stages before a final deliverable can be clearly defined (Dougherty 2001; Koput 1997; Marks et al. 2001). Particularly, an innovation project requires team members to explore intrinsically what they want to do and search for a direction that is considered to be worth pursuing (McCaskey 1974). After receiving feedback about their actions and learning about the environment during the problem solving stage, the innovation team may switch to another stage of problem setting and identify a new direction accordingly. Each iteration would increase the clarity of means-end connections and add to the successive formulation of the team's action plans (McCaskey 1974).

2.4 Simultaneous Differentiation and Integration in the Communication Process

Although the two stages – problem setting and problem solving – complement each other in functionality, they impose conflicting requirements on an innovation project team. The problem setting stage emphasizes the infusion of diverse points of view to stimulate the search process with unpredictability and randomness (differentiation). The problem solving stage requires a close integration of work among various specialties to ensure reliability and efficiency in implementation (integration) (Dougherty 2001; Koput 1997). The transition from differentiation to integration is managed through the use of screening activities. The screening activity provides opportunities for team members to elaborate and understand one another's unique perspectives, building consensus toward a basis for collective action (Crossan et al. 1999; Ford and Ford 1995; Gersick 1989).

However, individuals' differences in interpretive schemes, while providing different perspectives in a project team, can stir up internal conflicts and prevent team members from reaching agreement during the screening activity (Fiol 1994; Lovelace et al. 2001). For example, Jehn et al. (1999) found that the differences in individuals' education, experience, and expertise increase informational and value diversities of a team but at the same time cause task and process conflicts, such as disagreements about the task content, action plans, or resource delegation. Dougherty (1992) also suggested that individuals from different functional departments live in different thought worlds, "each focusing on different aspects of technology-market knowledge, and making different sense of the total" (p. 179). The different perspectives often separate rather than combine information, and create interpretive barriers to successful product innovation (Dougherty 1992).

To resolve the collaboration dilemma of promoting both processes of differentiation and integration, Fiol (1994) suggested differentiating two elements in the communication process that simultaneously affect our interpretations – content and frame. The content of communication is reflected in our cognitive categories (e.g., old, new, positive, negative etc.) that define "what" is expressed. The frame of communication refers to "how" we construct our argument regardless of its content. While individuals may strongly disagree over the content of a conversation, they are able to consolidate their different points of view through a frame of interpretation that is broad enough to accommodate those differences (Fiol 1994). By differentiating these two elements, team communication can be seen as simultaneous agreement and disagreement, enabling both processes of differentiation and integration.

2.5 Chapter Summary

In this chapter, we reviewed literature to delineate the role of team communication in the process of innovation. By taking a cognitive/interpretive perspective, we discussed the essential role that team communication plays in facilitating an innovation team to move behind dominant thinking for pursuing radical innovation. We outlined two important functions that team communication/interpretation provide in the innovation process – (1) gathering unique insights for establishing means-end connections and (2) clarifying technological environments and consolidating different points of view. These two functions point out the way that team communication helps weave together the processes of differentiation and integration. Furthermore, by analyzing the innovation process as a series of iteration between two different stages – problem setting and solving – we further discussed how these two stages create the simultaneous need for differentiation and integration. Even though individuals’ different interpretive schemes can cause internal disagreements and prevent an innovation team from progressing towards the problem solving stage, by collectively constructing an interpretative frame during team communication that is broad enough to encompass the differences in perspective, team members can reach consensus on their action plans and, at the same time, enjoy the advantage of having diverse perspectives in finding novel solutions.

CHAPTER 3: INNOVATION TEAMS' COMMUNICATION DYNAMICS

In this chapter, by centering on the simultaneous needs for differentiation and integration, we develop a theoretical model that describes and characterizes the dynamics of team communication in the pursuit of radical innovation. We first introduce the notion of interpretation systems to reiterate the important role that communication/interpretation plays in an innovation project team, and define the theoretical boundaries of our model. We propose four structural properties of team communication to capture the processes of differentiation and integration in group discussion. With these four structural properties and their relationship with differentiation and integration, we further suggest how team communication affects an innovation team's capabilities, and identify four categories of factors from literature to theorize the development of the differentiation and integration processes.

3.1 Innovation Project Teams as Interpretation Systems

To more clearly formulate the relationship between radical innovation and the process of interpretation, we adopt the notion of "interpretation systems" from Daft and Weick (1984) that suggests an organization can be conceptually treated as one individual interacting with uncertain outside environments. By consistently deploying various activities (e.g., regular analyses, surveys, investigations, experimentation, learning by doing etc.) to gather environmental data and feedback, key organizational decision makers try to interpret, in a collective manner, what outside environments are like and determine proper responses or actions based on that interpretation (Daft and Weick 1984). Following this notion, we consider a project team as an interpretation system in which key members engage in intensive data scanning and interpretation efforts in order to deal with the uncertainty and complexity inherited in a radical innovation task.

Departing from Daft and Weick's view that portrays an interpretation system as a coherent unit with a highly developed shared understanding, we emphasize the tension in team communication and group discussion caused by individuals' differences in interpretive schemes, specifically the simultaneous processes of differentiation and integration. The differentiation process enables team members to raise and attend to a large number of diverse opinions and issues regarding the task, and prompts individuals to examine and revisit the assumptions underlying their thinking. The integration process promotes the synthesis of conflicting perspectives into a new, more complete understanding, and provides opportunities to construct a broader frame of interpretation through which consensus on performance strategies can be reached to move the task forward.

Before proceeding with the development of our model, we need to address a few assumptions and conditions that mark the theoretical boundaries of the model. First, the success of an innovation project is typically evaluated in retrospect. Many new products that failed to seize the market from their inferior counterparts were labeled as "mistakes" even though they embodied novel ideas that might have changed our way of thinking (Van de Ven 1986). For clarification purposes, our theoretical model concerns only the effectiveness and constructiveness of team communication in moving the task of radical innovation forward. Whether the end product has significant competitive implications is beyond the scope of the model. Second, we focus on task-related discussion according to the two main roles that communication/interpretation plays in an innovation team as discussed in the previous chapter – it enables the gathering of unique insights for clarifying means-end connections in the innovation effort and helps clarify technological environments and consolidate different points of view. We acknowledge that the analysis of team communication traditionally includes both social and task-related topics and that social communication is important in team processes (Griffith et al. 2003; Jarvenpaa and Leidner 1999; Massey et al. 2003). However, based on our discussion in Chapter 2, task-related discussion more directly helps resolve the complexity and uncertainty involved in radical innovation, pushing the innovation process forward. Therefore, to convey this important relationship between radical innovation and team communication, we focus on task-related discussion.

Third, depending on the scale of an innovation project, the boundary of a project team can be difficult to mark and define. For example, some project teams may include technicians or quality assurance analysts who are not necessarily involved in decision making. As a result, the proposed model concerns only key team members who need to communicate frequently for making major decisions and defining performance strategies. Fourth, because of the advance and wide-spread use of communication media, group discussions can take place under various forms, including face-to-face meetings, emails, conference calls, and discussion forums. In this regard, we do not place restrictions in our theoretical model on the type of communication media used for meeting. Finally, since team communication is a visible manifestation of team interactions, any factor that affects work relationships (e.g., trust, power, personal interest etc.) would have a certain degree of impact on how team communication unfolds. Hence we limit our discussion to factors that have empirically established their direct relationship with the processes of differentiation and integration.

3.2 The Development of Differentiation and Integration in Team Communication

To analyze the dynamics of team communication in an innovation team, we reviewed literature in the areas of IS, innovation, decision making, and team development, and found that two analytical dimensions – issue streams and attention switches – were frequently mentioned and used in various studies (Fiol 1994; Jehn 1995; Koput 1997; Langley et al. 1995; Okhuysen 2001; Okhuysen and Waller 2002; Poole 1983; Sarker and Sahay 2002). An issue steam indicates the development of a topic or an idea over time during the conversation exchange. Accordingly, issue streams can reflect main topics or problems that a group has addressed over time in its meetings or discussions. Tracking issue streams is suggested as a means to help capture the topic of concern at a given point in time and reveals how ideas are transformed into actions through discussion (Langley et al. 1995; Poole 1983). Attention switches, sometimes also referred to as breakpoints or turn-taking, show the beginning of an interruption (or a breakpoint) to the ongoing team communication process. By marking attention switches that take place over time, distinct clusters of activities along the process can be identified to indicate the team's work progress and its developmental transitions (Okhuysen 2001; Okhuysen and Waller 2002; Poole 1983). By associating these two analytical dimensions according to their explicit temporal relationship, the development of task-related discussion over time can be analyzed as in Figure 3-1. An issue stream starts with a conversation contribution that offers a piece of information for the team to consider. Relevant thoughts and suggestions may be provoked and further contributed to the issue stream, increasing the breadth of the original idea. The issue stream continues to develop until it is interrupted and shifted to a new topic by an attention switch.

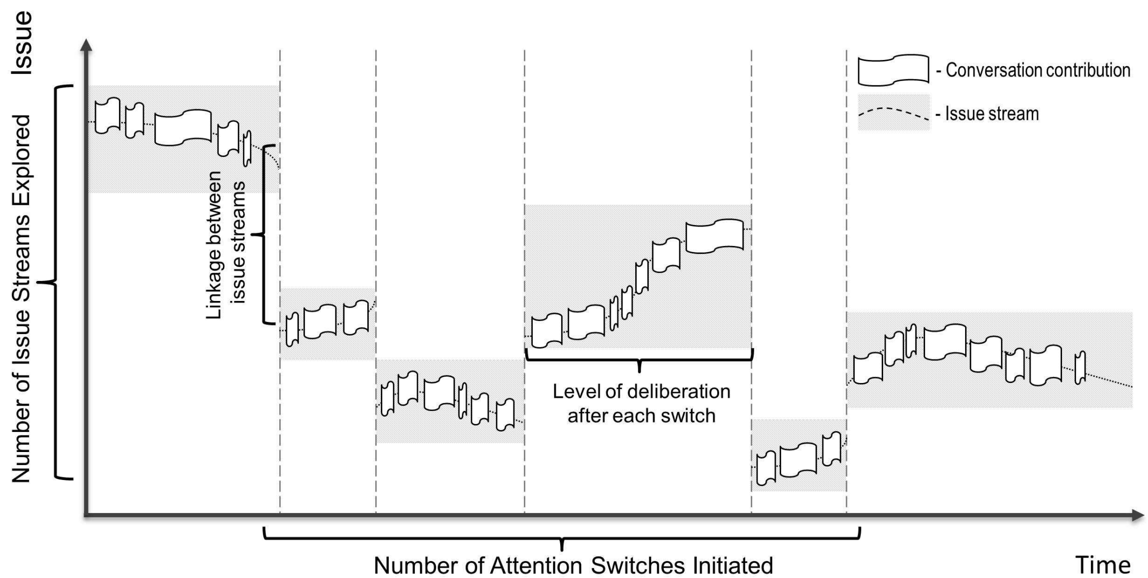

Figure 3-1. The Development of Task-Related Discussion

From the development of task-related discussion in Figure 3-1, which is constructed from the two frequently used analytical dimensions – issue streams and attention switches – we identify four structural properties to evaluate whether or not team communication effectively promotes both processes of differentiation and integration: (1) the number of issue streams explored, (2) the number of attention switches initiated, (3) the conceptual linkage between issue streams, and (4) the level of deliberation after each attention switch.

The first two structural properties – the number of issue streams explored and the number of attention switches initiated – represent the original two analytical dimensions (i.e., issue streams and attention switches). According to the literature (Fiol 1994; Okhuysen 2001; Okhuysen and Waller 2002; Poole 1983), these two structural properties (or the original analytical dimensions) can indicate the degree to which different issues and ideas are considered by the team, thus reflecting the process of differentiation. The other two structural properties – the conceptual linkage between issue streams and the level of deliberation after each attention switch – are also derived from the two original analytical dimensions and provide additional ways to evaluate how issue streams are developed over time and connected with one another. Although the latter two structural properties have not been mentioned by previous studies, we find extensive support from the literature of cognition and consensus development for using these two structural properties to evaluate the process of integration. More detailed reasoning about these four structural properties and their relationship with differentiation and integration are presented below.

The number of issue streams indicates the diversity of interpretations that a project team has attended to for developing new knowledge (Fiol 1994). According to an information processing perspective, the variety of information and opinions has to match the complexity of the task (Campbell 1988; Jehn 1995). For a highly complex task, such as radical innovation, the larger number of different issues a team has discussed, the better its decision quality and solutions (Fiol 1994). For example, Erickson and Dyer (2004) found that the high-performing teams in their study all started with engaging kickoff meetings that allowed these teams to examine their project comprehensively from various angles. In addition, a larger number of different ideas that a team considers can also lead to more creative ideas. For example, Girota et al. (2010) reported that groups organized in a hybrid brainstorming structure (i.e., individuals independently generate ideas first and then work as a group for idea synthesis) can create more and better ideas. Therefore, the number of issue streams indicates the degree to which different issues and ideas are considered and discussed by an innovation team.

The number of attention switches that the team has initiated reflects the intensity of disagreement during group discussion. Individuals direct their attention to certain aspects of the environment regarded as salient according to their interpretive schemes for creating meaning (Giddens 1984; Leonardi 2011). In the process of collective interpretation, if teammates reckon that some important aspects of the project have not been discussed or interpreted properly, they may decide to interrupt the conversation and initiate an attention switch to raise issues, concerns, or new proposals. For example, a team member can initiate an attention switch to make the team aware of the shortage of time resource or expertise (Ericksen and Dyer 2004; Poole 1983). Not only do attention switches help increase the number of issue streams but also provide the team with opportunities to stop and reflect on its progress. A larger number of attention switches has been found to lead to better team performance in problem solving tasks (Okhuysen 2001; Okhuysen and Waller 2002). In sum, the number of issue streams explored and attention switches initiated reflects the process of differentiation that promotes the input of diverse information and opinions into group discussion.

The conceptual linkage between issue streams indicates the degree to which two different issue streams are conceptually related and considered under a shared context.

According to the innovation literature, sufficient connections among different knowledge domains are a necessary condition for innovative ideas to emerge (Cohen and Levinthal 1990; Dougherty and Dunne 2011). But often individuals fail to recognize the relevance of ideas from other fields to their own work because of the filtering effects inherent in our interpretive schemes (Fiol 1994; Leonardi 2011). One way to overcome this innovation barrier is to create a shared language with boundary objects, such as common models or standardized repositories, which helps teammates identify the differences and dependencies among their respective knowledge domains (Bartel and Garud 2009; Carlile 2002). Through using a shared language to frame their arguments, team members create conceptual linkages between discussed issues and develop a shared communication context that helps consolidate their different points of view (Fiol 1994; Langley et al. 1995). These conceptual linkages can further enable team members to see how various issues are linked together and lead to a more holistic view of the project.

The level of deliberation after each attention switch indicates team members' engagement in constructing a broader frame of interpretation that can encompass the differences in perspective. Because of its incompatibility with our interpretive schemes, a different idea or opinion brought up to discussion through an attention switch may appear strange and illegitimate (Bartel and Garud 2009; Bartunek 1984; Van de Ven 1986). To recognize its merits, careful, continuing deliberation on the idea is important. "Through listening to other members clarifying ideas and providing rationales for their interpretations, members may proceed from understanding the different perspectives of others to accepting the legitimacy of alternative points of view" (Mohammed 2001, p.418). Engaging in this deliberation process can transform individuals' frames of thinking, leading to greater cognitive consensus and deeper shared understanding (Crossan et al. 1999; Mohammed 2001). In sum, the conceptual linkages between issue streams and the level of deliberation after each attention switch indicate the process of integration, promoting the construction of a boarder frame of interpretation for consensus building.

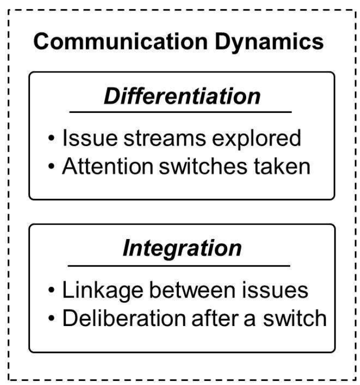

Figure 3-2. Innovation Team's Communication Dynamics

Overall, we develop and propose four structural properties to capture the dynamics of team communication and evaluate the processes of differentiation and integration as shown in Figure 3-2. The number of issue streams explored and the number of attention switches initiated indicate the degree to which different ideas and opinions are considered and discussed by an innovation team, reflecting the process of differentiation. The conceptual linkage between issue streams and the level of deliberation after each switch promote the construction of a broader frame of interpretation that can encompass different points of view, and encourage the development of a shared language and a shared communication context in the team, reflecting the process of integration. With these four structural properties and their relationship with differentiation and integration, we theorize how the dynamics of team communication affect the team capabilities as follows.

3.3 Team Communication Dynamics and Team Capabilities

According to previous research in team development (Ericksen and Dyer 2004; Gersick 1989; Okhuysen 2001; Okhuysen and Waller 2002), we suggest that the process of differentiation in team communication affects an innovation team's capabilities to manage team process and unexpected situations. Specifically, the number of issue streams explored affects a project team's flexibility to adapt to changes. For example, if a project team has comprehensively examined its project and explored potential issues, it is found to be more capable of improvising and reorganizing when unexpected problems arise (Ericksen and Dyer 2004; Gersick 1988). Additionally, a larger number of attention switches prompts team members to consider more areas of the team process, and provides the team with greater opportunities to notice and resolve emerging problems (Okhuysen 2001; Okhuysen and Waller 2002).

We also propose that the process of integration, as reflected in the conceptual linkage between issue streams and the level of issue deliberation, affect the degree to which a project team has consensus on its course of action. "Convergence around a broader frame of interpretations provides the common understanding needed to move toward collective action" (Fiol 1994, p.415). It is commonly found that an innovation team failed to make significant progress because team members were unable to close debate and agree on an action plan during the screening activity to move forward to the problem solving stage (Gersick 1988; Gersick 1989; Lovelace et al. 2001). Furthermore, the effect of the number of issue streams and attention switches on team capability has to be established under the condition that different points of view have converged around a broader frame of interpretation. More information is useful to a team *only* after a common view of what sorts of information are relevant to decision making is developed (Fiol 1994; Gersick 1988). Once linkages between various issue streams are comprehensively constructed to allow more information to be processed, the team is more likely to arrive at unique combinations for novel solutions and evaluate its solutions critically. Accordingly, we suggest the following proposition and summarize the relationship between team communication and team capabilities in Figure 3-3.

P1: The processes of differentiation and integration in team communication affect an innovation team's capabilities.

(a) The process of differentiation, as reflected in the numbers of issue streams explored and attention switches initiated, affects an innovation team's capability to manage team process and unexpected problems.

(b) The process of integration, as reflected in the conceptual linkage between issue streams and the level of issue deliberation after each attention switch, affects the degree to which an innovation team has consensus on its action plan.

(c) The effect of the differentiation process on team capabilities has to be established on the condition that diverse perspectives have converged around a broader frame of interpretation by the process of integration.

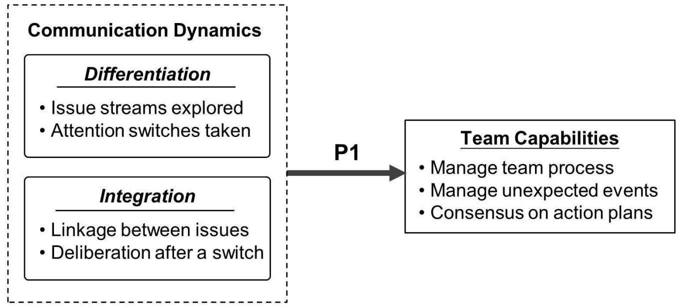

Figure 3-3. Effects of Team Communication on Team Capabilities

In the following sections, we take three theoretical perspectives – interpretation system (or organization), communication, and information systems – to theorize the development of the differentiation and integration processes in task-related discussion. These three theoretical perspectives are selected because each of them offers a different angle to investigate how an innovation team can gather various opinions and ideas while consolidating the differences into coherent collective actions. For example, from an IS perspective, we can examine the use of information systems and communication media to connect remote experts for virtual collaboration, and suggest specific IS capabilities to promote constructive discussion environments. Despite their different angles, these three perspectives together provide a complete understanding of the developmental process of team communication. We address each of the perspectives as follows and discuss important factors identified from the perspective.

3.4 Interpretation System Perspective – Organizational Factors that Influence the Development of Team Communication

When a group of individuals is conceptualized as one interpretation system, it is important to recognize (1) the differences in individuals and (2) the role of the organization in consolidating individuals' various interpretations into coherent organizational ones. According to Daft and Weick (1984), "[m]anagers may not agree fully about their perceptions, but the thread of coherence among managers is what characterizes organizational interpretations. Reaching convergence among members characterizes the act of organizing and enables the organization to interpret as a system" (p. 285). Following this insight, we identify two categories of organizational factors that play an important role in influencing such a convergence process: (1) team composition and (2) semi-structures. The team composition has been a main category of factors for investigating team process and dynamics, especially in its effects on team conflicts and competency (Ericksen and Dyer 2004; Jehn 1995; Jehn et al. 1999; O'Leary and Mortensen 2010). The concept of semi-structures is used by many researchers to explain how organizational control and design freedom can be simultaneously achieved by certain types of organizational facilitation (Brown and Eisenhardt 1997; Okhuysen and Waller 2002). These two categories of factors are discussed as follows.

3.4.1 Team Composition

It is generally asserted that a project team's competence and creativity are largely determined by its composition. The characteristics of membership thus provide basic indicators for assessing a team's capacity for innovation. In this regard, two dimensions of team composition are found to have a profound effect: (1) the heterogeneity of membership and (2) the mapping between task requirements and team members' expertise. The heterogeneity of membership refers to the differences in individuals' background, education, and experience from which team members develop different opinions on task content and process (Dougherty 1992; Jehn et al. 1999; Pelled et al. 1999). Heterogeneity promotes the process of differentiation by increasing information and value diversities within a project. The information diversity concerns the differences in knowledge bases that members bring to the team and increases the number of issue streams that the team would attend to. The value diversity creates different interpretations of what the team's real task, goal, or mission should be (Jehn et al. 1999). When team members have different judgments on value, they are more likely to disagree with one another and initiate attention switches to raise issues or concerns. Therefore, the heterogeneity of membership promotes the process of differentiation by increasing the number of issue streams explored and the number of attention switches initiated.

The mapping between task requirements and team members' expertise concerns whether or not a project team has full access to required information, knowledge, or skills in order to move the innovation task forward (Ericksen and Dyer 2004). The access to required knowledge and skills is typically ensured by recruiting members with corresponding expertise into the project. In some cases, it is also achieved by exploiting team members' social connections to locate domain experts with which to consult. A task-expertise mapping enables an innovation team to explore task-related issues more effectively and see how different issues and ideas can be linked together, as members supply the team with critical pieces of information that would fill the gap. This contributes to a better coverage of issues (or a larger number of issue streams) and more comprehensive linkages between issues, promoting both processes of differentiation and integration.

Nonetheless, the effects of the two team composition factors are contingent upon team members' time commitment and timely responses. Many empirical studies found that team progress and productivity would seriously suffer if team members simply do not have the time comment to participate in group discussion (Ericksen and Dyer 2004; Gersick 1988; Malhotra et al. 2001). For example, Ericksen and Dyer (2004) attributed one key factor for causing the low performance in a project team to the time commitment issue: "the team had no full-time participants, and only the team leader was even part-time, which meant that all eight of its members were left to participate when they could find or make the time" (p.461). On the other hand, in a case study of a radical innovation project, having devoted team members' immediate feedback about the feasibility of a design saved the team weeks in the design process (Malhotra et al. 2001). Therefore, team members' time commitment is considered as a moderator in the team composition that affects the effects of heterogeneity and task-expertise mapping on task-related discussion. Overall, considering the effects of team composition on team communication as summarized in Figure 3-4, we provide the following proposition.

P2: Team composition factors affect the development of the differentiation and integration processes in team communication.

(a) The heterogeneity of membership promotes the process of differentiation by increasing the numbers of issue streams and attention switches.

(b) A good mapping between task requirements and team members' expertise facilitates both processes of differentiation and integration by increasing the number of issue streams and the conceptual linkages of issues.

(c) Team members' time commitment moderates the effects of team composition factors on team communication.

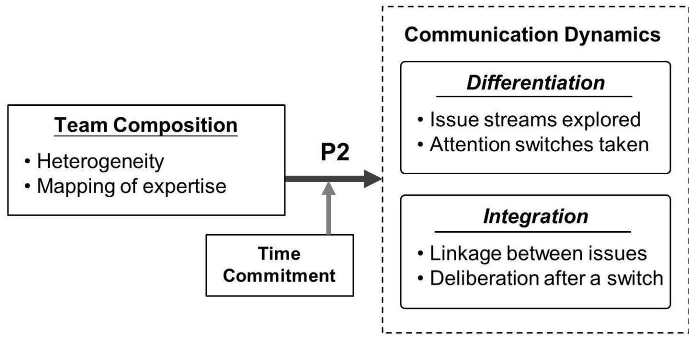

Figure 3-4. Effects of Team Composition Factors on Team Communication

3.4.2 Semi-structures

Semi-structures are related to "the act of organizing" that helps consolidate individuals' differences, allowing a project team to interpret as though it is a coherent whole. The idea of semi-structures is derived from empirical studies that found successful innovation projects to be neither completely chaotic for creativity to flourish, nor rigidly structured so that steady production can be ensured. Instead, the team process was regulated by semi-structures that serve as interaction templates to reduce the level of task uncertainty without restricting the team to a defined solution path (Brown and Eisenhardt 1997; Okhuysen and Waller 2002). Semi-structures provide clear rules and responsibilities and at the same time encourage extensive communication and design freedom.

We identify a total of eight such semi-structures from the literature of team process and decision making. These semi-structures have been frequently suggested by previous studies to have significant impacts on regulating team coordination and communication. While striving to be comprehensive, we acknowledge that the list may not be complete. The semi-structures that promote the process of differentiation are:

- Familiarity: Familiarity indicates the degree to which social interactions have been established among members. Social interactions can be deployed as a way to manage professional disagreement when team members are engaging in confrontation behaviors (Okhuysen 2001). For example, teammates who are familiar with one another are more capable of using jokes or daily conversation topics to properly bring up opposing opinions or break up severe arguments. Accordingly, familiarity can promote the process of differentiation by increasing the number of attention switches.
- Openness norm: Openness norm is a group norm that perceives task conflict and disagreement as normal and beneficial. When the openness norm exists, team members do not feel the pressure of self-censorship and are willing to engage in open communication to express their doubts, opinions, and uncertainties (Jehn 1995). As a result, different ideas can be considered and incorporated into product design; task-related issues are more likely to be discovered and resolved early (Lovelace et al. 2001). Based on this reasoning, the openness norm increases the number of attention switches and enhances a project team's capacity for innovation.
- Project management framework: Project management (PM) framework, such as project schedule, deadlines, milestones, and action items, is suggested to serve as a process structure to regulate the tempo and pace of team communication and

activities (Massey et al. 2003; Montoya-Weiss et al. 2001). The project management framework creates a sense of time for the teamwork and gives team members legitimate reasons to interrupt the ongoing activity and initiate an attention switch (Okhuysen 2001; Okhuysen and Waller 2002). For example, a member can call the team's attention to the shortage of time and discuss the effectiveness of a current task approach.

The semi-structures that facilitate the process of integration are:

- Problem definitions: Problem definitions are premises and agreements that team members have arrived at for comprehending the situation and defining what they are trying to accomplish with the project. Problem definitions are thought to be part of the team behavioral framework that is implicitly formed during the first few group meetings, defining a team's subsequent interaction patterns and approaches toward its task (Ericksen and Dyer 2004; Gersick 1988; Gersick 1989). Problem definitions set the main themes of group discussion and tighten the conceptual linkage of the issues to which the team attends. However, premature problem definitions may hinder the effectiveness of team communication. For example, Gersick (1988) reported that a project team consistently rejected useful ideas because these ideas did not fit into the agreed problem definitions; the stagnation elevated after the team revised its initial behavior and problem framework.
- Shared language: A shared language is developed around certain technical terms and analogies that are commonly understood and at the same time central to the

argument. These commonly shared terms allow team members to more effectively explore and identify their similarities and differences in perspective (Carlile 2002). That is, a shared language creates conceptual linkages between issue streams that enable team members to comprehensively trace and follow the discussion. For example, Fiol (1994) found that when a shared language was developed, the group discussion evolved in a similar focus on particular organizational aspects (e.g., internal operations, customer needs, and marketing concerns). Even though team members might use the shared language to argue for their opposing positions, they disagreed in a progressively shared context.

Three semi-structures are proposed to improve both processes of differentiation and integration:

- Unanimous decision structure: Decision structure affects the dynamics of group discussion by indicating the degree to which individuals' opinions are equally counted and considered in the decision making process. When decisions are required to be made unanimously, team members are more likely to bargain for their own positions and at the same time, be sensitive about others' different views, which prompts the close examination of underlying assumptions and premises (Mohammed 2001; Poole 1983). This leads to increases in the number of attention switches as well as the level of deliberation after a new issue is brought up for consideration.
- Effective leadership: When a project team is tackling a highly uncertain task such as radical innovation, (1) initiating structure and (2) consideration are found to be

two important dimensions of leadership that affect the team's morale and satisfaction. That is, the leader should properly structure team members' roles and interactions towards goal attainment while showing consideration of their different ideas (Kerr et al. 1974). In the context of team communication, effective leadership is demonstrated via moderating the discussion for members to express whatever differences they may have and helping them find a way to resolve these differences (Lovelace et al. 2001; Madhavan and Grover 1998). In other words, effective leadership encourages the initiation of attention switches, promotes the level of deliberation, and helps tighten the linkages between different issues.

- Communication protocols: Communication protocols refer to the collaboration mechanisms established for increasing information sharing among individual members, including information sharing policies and the arrangement of frequent, regular group meetings. These communication protocols are found to be important in mitigating the negative effect of subgrouping when team members are disproportionally separated in locations. Subgroups are often formed among members who are collocated or have similar interests so they are more likely to engage in individual conversation outside of the group discussion. This would reduce the number of issues that the team would explore as a whole and create the problem of information asymmetry or even subgroup biases towards one another. To manage the negative effect of subgrouping, Malhotra et al. (2001) found that the best practice was *not* to forbid informal subgroup meetings, but to create information sharing mechanisms for members to document and share with the group what they had discussed. Such information sharing mechanisms increased not only the number of discussed issues but also a shared understanding. For example, by browsing and reviewing others' documentation in a central repository, team members became increasingly knowledgeable about different design issues and were able to comment on all aspects of the design process (Malhotra et al. 2001).

We contend that a semi-structure is not "fixed" in its existence and effect, but rather evolves with team communication over time. This view is consistent with the theory of structuration that "structure exists, as time-space presence, only in its instantiations in such [social] practices" (Giddens 1984, p.17). Team communication, as structural properties in social systems that give hints to prompt a certain social practice to reproduce, provides essential conditions for a semi-structure to emerge, develop, and exert its influence. For example, familiarity often appears in a more relaxed atmosphere to facilitate discussion, but its effect diminishes as conflict intensities. Overall, for the effects of semi-structures on team communication as shown in Figure 3-5, we provide the following proposition.

P3: Semi-structures affect the development of the differentiation and integration processes in team communication. At the same time, the dynamics of team communication also affects the development of semi-structures.

(a) Familiarity, openness norm, and project management framework promote the process of differentiation by increasing the number of attention switches.

(b) Problem definitions, shared language facilitates the process of integration by increasing the conceptual linkages between issue streams and the level of deliberation after a new issue is brought up to discussion.

(c) Unanimous decision structure, effective leadership, and communication protocols improve both processes of differentiation and integration.

(d) Semi-structures evolve and develop with team communication over time.

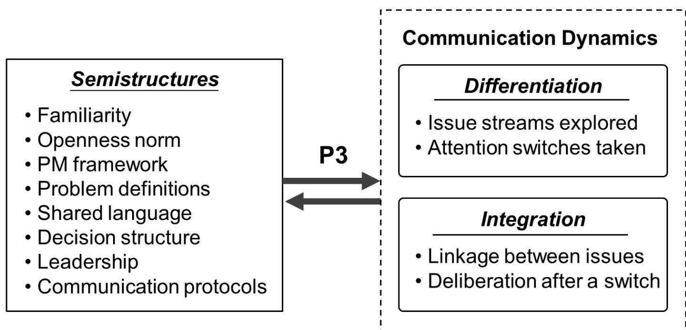

Figure 3-5. Effects of Semi-structures on Team Communication

3.5 Communication Perspective – Factors related to Communication Contexts

In the studies of communication, it is widely accepted that a shared context is a fundamental element for communication to be meaningful. It allows individuals to comprehend what has been said and determine what would be appropriate in response (Krauss and Fussell 1988; Krauss and Fussell 1996). One key principle of creating and maintaining a shared communication context is by reciprocal perspective taking. Communicators take the perspective of their addressees, assume what they share in common (e.g., background knowledge, beliefs, experience, and surroundings), and tailor their speech accordingly (Fussell and Krauss 1992; Krauss and Fussell 1988). By updating and accumulating the information they share, individuals create mutual understanding for their collective action (Clark and Brennan 1991). Based on the principle of reciprocal perspective taking, three important factors are suggested to affect the processes of differentiation and integration: the size of discussion, shared artifacts, and the input of contextual information. These three factors have been suggested and investigated in various research areas, including communication, cognition, team behaviors, and information systems. They are discussed as follows.

The size of discussion affects how much *unique* information individuals would suggest to their group in the discussion. In a large group setting, individuals tend to bring up already shared information instead of unique information in order to maintain the level of consensus that the group already has (Dennis 1996; Stasser and Titus 1985; 1987). Research also shows that as the group size increases, the discussion pattern is more likely to change from an interactive dialogue to a serial monologue (Fay et al. 2000). Therefore, the size of discussion affects the number of different issue streams that the team would attend to and the number of attention switches that team members would initiate.

Shared artifacts are physical substances that can be used to facilitate communication. When presenting design ideas, individuals constantly need to take account of what their addressees can see and make use of visualization tools available in their joint physical context, such as a whiteboard or a piece of drawing, to facilitate the conceptual exchange. In this regard, shared artifacts – working documents, modeling diagrams, or prototypes that team members can all see – are found to be useful in conveying design concepts and creating a shared communication context, even when the joint physical context is absent (Malhotra et al. 2001; Olson and Olson 1991). Specifically, shared artifacts enhance the process of integration by tightening the conceptual linkages of different issues. For example, Ericksen and Dyer (2004) reported that working together on a causal diagram helped a team resolve two incompatible views. Malhotra et al. (2001) also found that the use of shared artifacts increased shared understanding in a virtual innovation team and allowed team members to focus their discussion on specific design issues.

In project development, the input of contextual information may come from external evaluators' feedback or comments, or major technical challenges that the team is facing as a whole. These kinds of contextual information present common interests for team members to concentrate on and instill a mutual understanding that would facilitate the team's decision making process (Fiol 1994; Gersick 1988). For example, explicitly stated superordinate visions are found to consolidate diverse opinions in cross-functional collaborations and keep members orient towards a common task outcome (Pinto et al. 1993). In the context of group discussion, research suggests that team members would reframe their arguments in order to match received feedback; this reframing attempt promotes the process of integration by increasing the linkages between different issues for a boarder frame of interpretation (Fiol 1994). Overall, considering the effects of communication contexts on team communication as shown in Figure 3-6, we offer the following proposition.

P4: Communication context factors affect the development of the differentiation and integration processes in team communication.

(a) The size of discussion affects the process of differentiation by limiting the numbers of issue streams and attention switches.

(b) Shared artifacts improve the process of integration by tightening the conceptual linkages of discussed issues.

(c) The input of contextual information, including external evaluators' feedback and major technical challenges that the team is facing as a whole, promotes the process of integration by increasing the linkages between different issues.

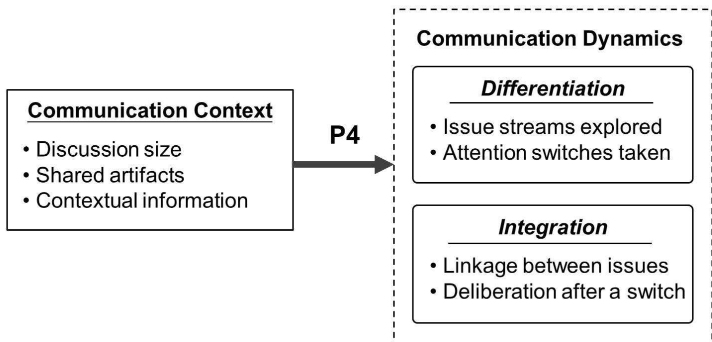

Figure 3-6. Effects of Communication Context Factors on Team Communication

3.6 Information Systems Perspective – Communication Environments

Due to the prevalence of tools available for initiating computer mediated communication, group discussion is no longer restricted to face-to-face meetings. Rather, a project team often mixes several communication media and platforms, such as emails, conference calls, Wiki, discussion forums, and group collaboration systems, to allow team members to communicate with one another continuously without the disruptions of temporal and geographical boundaries. To understand and explain the effect of communication media on collaboration, a number of media theories have been developed, including media richness theory, social influence model, and media synchronicity theory (Daft and Lengel

1986; Dennis et al. 2008; Fulk et al. 1990; Straus and McGrath 1994). While these media theories offer valuable insights, they fall short in two aspects when applied to a team context. First, instead of considering communication media as part of an overall communication environment where they complement one another in different capacities, these media theories categorize them *individually* along a single dimension according to certain characteristics (or capabilities)(Massey and Montoya-Weiss 2006). For example, media richness theory characterizes communication media individually by their richness according to their capacity for immediate feedback, the number of cues utilized, personalization, and language variety. While these characteristics are insightful and allow us to understand how each communication medium affects interactions, they cannot be used to assess the overall communication environment composed of various information systems and communication media.

Second, even though these media theories recognize the fact that effective communication is built upon individuals' ability to regulate and manage interactions, or "structural mechanisms [that] have to enable debate, clarification, and enactment" (Daft and Lengel 1986, p.559), what exactly these structural mechanisms are for the communication process per se has not been clearly stated. These media theories often employ the idea of "fit" to suggest if the characteristics of a communication medium would meet the need of a certain process or task to imply the required structural mechanisms. For example, media synchronicity theory matches communication media based on their synchronicity with two fundamental communication processes – conveyance and convergence (Dennis et al. 2008). However, what kinds of structural mechanisms are needed to facilitate effective conveyance and convergence are not clearly explained by the theory.

Indeed, the required structural mechanisms of a communication process are fulfilled, extended, or sometimes limited by the characteristics of communication media. But we argue that delineating these structural mechanisms separately from the characteristics of communication media is important because these structural mechanisms can represent a standard to evaluate the sufficiency of a communication environment comprised of different communication media and platforms. To illuminate the structural mechanisms demanded by the task of radical innovation, particularly when team members are collaborating across geographical boundaries in a virtual team setting, we take an inductive approach. We identify common communication issues experienced by pure virtual teams – those that collaborated entirely by email, discussion forums, and electronic chat rooms – and map the issues along our four structural properties of communication as shown in Table 3-1 to reveal the required types of control. For the identification of issues, we analyze available excerpts of message exchange in four virtual team studies (Jarvenpaa et al. 1998; Jarvenpaa and Leidner 1999; Massey et al. 2003; Piccoli and Ives 2003).

Table 3-1. Communication Issues in Pure Virtual Teams

Structural Property	Collaboration Difficulty	Description
The number of issue streams explored	(CI1) Failure to address relevant issues simultaneously	Team members try to communicate multiple relevant issues in one message but only salient ones get picked up in discussion (Piccoli and Ives 2003).
	(CI2) Struggle to establish sensible order for exploring issues	Team members are first occupied with issues of "how to proceed" in the asynchronous communication environment, such as how to label and organize messages (Jarvenpaa et al. 1998; Massey et al. 2003).
The number of attention switches initiated	(CI3) Failure to draw the team's attention to new issues	Team members fail to shift the team's focus to new issues as the team is being occupied with the ongoing conversation (Piccoli and Ives 2003).
The conceptual linkage between issue streams	(CI4) Lack of coherent in message threads when developing issue streams	Team members send out messages concerning different new issues without acknowledging or responding to preceding messages (Jarvenpaa et al. 1998; Piccoli and Ives 2003).
	(CI5) Difficulty managing a high volume of discussion for effective decision making	A project team fails into chaos when trying to coordinate multiple jobs in a short period of time (Massey et al. 2003).
The level of deliberation after each attention switch	(CI6) Inability to clearly express one's thought	Team members send out short messages that are unclear in their meaning and purpose. This creates confusion and misunderstanding (Jarvenpaa et al. 1998; Jarvenpaa and Leidner 1999).
	(CI7) Lack of substantive response	Team members who posed a question or suggested an idea do not receive responses that would enrich the discussion. For example, their teammates do not reply at all, or endorse or reject the idea without further contribution (Jarvenpaa et al. 1998; Jarvenpaa and Leidner 1999; Piccoli and Ives 2003).
	(CI8) Lack of explanation	Team members send out task-related materials without proper explanation on how to incorporate these materials (Jarvenpaa and Leidner 1999).

While the issues in Table 3-1 are generally perceived as behavioral ones, we believe that a better constructed communication environment can alleviate these issues to some degree. Specifically, we contend that these issues are partially caused by an insufficient communication environment that does not provide adequate support for meeting two important principles of communication – (1) grounding and (2) least collaborative effort. The principle of grounding suggests that a mutual understanding between individuals is reached through *moment-by-moment* accumulation of shared information or “common ground,” and stresses the importance of a proper sequence in a conversation (Clark and Brennan 1991). According to the principle of grounding, communication as a collective process involves two basic mechanisms: (1) checking for continued attention and (2) expecting a relevant next turn.

Checking for continued attention involves various grounding techniques for individuals to determine if they can start or continue a conversation. For example, to start a conversation, Individual A needs to get Individual B’s attention by available techniques, such as gestures or making an utterance. Individual B may use a nod or reply to acknowledge that he/she notices A. As the conversation develops, A and B constantly monitor available cues, such as the timing of an acknowledgement or eye gaze, to see if the other is paying attention and still engaged in the conversation. These subtle grounding techniques allow individuals to actively manage the flow of interaction and decide how to proceed with the conversation.

Expecting a relevant next turn – a reply that shows relevancy in context and timing – allows individuals to verify if they are correctly understood when they take turns to make conversation contributions. If they realize that they made mistakes in producing an utterance or were misunderstood by the other, they would try to repair the problem either by themselves or by inviting the other’s help (e.g., using a long pause or not finishing a sentence). As a result, by meeting the principle of grounding, “conversation generally divides into coherent sections that have identifiable entries, bodies, and exits" (Clark and Brennan 1991, p.132). This is consistent with our portrait of communication dynamics in Figure 3-1.

The principle of least collaborative effort concerns the cost of grounding in communication media, suggesting that participants in a conversation would try to minimize their collective effort from the initiation of each contribution to its mutual acceptance (Clark and Brennan 1991). As the discussion of the grounding principle above shows, various techniques (e.g., gestures, eye gaze, making correct utterances, turn taking, checking the relevance and timing of a reply, repair techniques etc.) are required and employed for ensuring proper grounding. The availability of grounding techniques varies across communication media, and when a technique is available, it generally costs more effort to perform in one communication medium than in the other (Clark and Brennan 1991). As a result, individuals formulate different communication strategies in different media in order to minimize the collective effort for grounding. For example, turn taking is perceived as more costly in the email exchange than in face-to-face conversations because the timing of email responses is irregular. When communicating with emails, individuals would try to reduce the amount of turn taking by being concise or communicating more in one turn (Clark and Brennan 1991).

According to the principles of grounding and least collaborative effort and the communication issues listed in Table 3-1, we delineate four structural mechanisms required for promoting the processes of differentiation and integration. For the process of differentiation, a sufficient communication environment needs to provide: (1) sensible structures for regulating the exploration of multiple issues and (2) the ability to promptly gain audience’s attention.

The first structural mechanism – sensible structures for regulating the exploration of multiple issues – has to deal with the communication needs for exploring multiple issues. According to the principle of grounding, task-related discussion requires orderly, moment-by-moment accumulation of common ground to ensure mutual understanding (Clark and Brennan 1991). In addition, issues may be conceptually associated with one another in some order that decisions for one issue cannot be made without addressing some other issues first or together (Langley et al. 1995). Although many communication media provide the capacity of parallelism that allows concurrent transmissions of messages and thus enables simultaneous exploration of multiple issues (Dennis et al. 2008), the lack of sensible structures to sustain the delicate conceptual relations of messages and issues often makes their use for extensive discussion awkward and ineffective. For example, team members may try to communicate multiple issues in a message in order to meet the needs for grounding (CI1 in Table 3-1), or team members would spend a large amount of time to establish rules or protocols first to maintain the conceptual orders of message exchange (CI2). Therefore, a sufficient communication environment should provide not only the capacity for parallelism but also sensible structures for regulating the exploration of multiple issues.

The ability to promptly gain audience’s attention is to deal with a communication difficulty that pure virtual teams often experience – team members’ inability to promptly gain attention to raise concerns or issues when these concerns or issues are relevant in the context (CI3). As attention switches play an important role in bringing in different perspectives, the inability to promptly initiate one jeopardizes not only the pace of team work but also the breadth of issues that a team would consider (Okhuysen 2001; Poole 1983). Specifically, gaining attention to speak in a discussion is more than just transmitting one's thoughts through a communication medium; it requires a series of acts of mutual acknowledgment to ensure grounding, usually facilitated by the use of multiple cues or symbol sets. The symbol sets may include raising a hand, eye gaze, a gentle touch on the shoulder, or a different vocal tone (Dennis et al. 2008). For example, in a face-to-face meeting, an individual may first *raise a hand or change the vocal tone* to signal the intention to change the focus of conversation (Step 1). The audience may *pause and use eye gaze* to show their notice and attention (Step 2). The individual would then speak and *expect a relevant next turn* to see if she/he is properly understood or a repair is needed (Step 3). Although these steps may be carried out with different grounding techniques, any missing link in the sequence hinders team members' ability to contribute to a discussion in a timely and productive manner. Therefore, a sufficient communication environment needs to provide structural mechanisms for individuals to promptly gain audience's attention to raise concerns or issues.

For the process of integration, a sufficient communication environment needs to provide (1) support for managing the relevance and transitions of discussion and (2) the initiation of an effortless interactive process of elaboration. The support for managing the relevance and transitions of discussion ensures that issue streams can be systematically and comprehensively developed. According to our model of discussion development in

Figure 3-1, a continuous flow of team communication is divided by attention switches into a number of distinct issue streams. Although these issue streams exhibit different focus and can be treated as separate conceptual units, together they represent a developmental process where each plays a particular role in transforming ideas into decisions and actions (Poole 1983). In this developmental process, relevant next turns are the building blocks. "Most turns are designed to carry that process forward and give evidence about the speaker's understanding of the previous step in the process" (Clark and Brennan 1991, p.132). Maintaining relevant next turns relies on (1) various grounding techniques to facilitate turn taking and repair and (2) communication aids to establish and inform the objectives of the discussion (e.g., meeting agendas and notes). Without the support of these grounding techniques and communication aids, an issue stream cannot be systematically developed (CI4) and different issues cannot be comprehensively explored (CI5). Therefore, a sufficient communication environment should provide the support for managing the relevance and transitions of discussion.

The initiation of an effortless interactive process of elaboration allows team members to be more spontaneous in sharing and explaining their ideas. As reflected in the notion of dialectical discussion in Section 2.2, elaboration is an interactive process that involves two different perspectives examining each other's premises. Such an interactive process, from a grounding point of view, is expensive and incurs several types of costs from participating parties. These costs include formulation costs (i.e., the time and effort to formulate proper utterances), production costs (i.e., the effort to produce utterances), delay costs (i.e., the cost of waiting or the cost of repairing confusions or misunderstandings after a long lapse), and speaker change costs (i.e., the cost for arranging multiple speakers to properly take turns) (Clark and Brennan 1991). These costs vary across communication media according to the principle of least collaborative effort. When the costs of taking on an interactive process are too high, individuals would reduce the length or number of message exchange or simply avoid being interactive (CI6-8). This would impair not only the process of integration but also the level of innovation. Thus, a sufficient communication environment should allow the initiation of an effortless elaboration process.

Overall, these four structural mechanisms or supports are suggested to promote both processes of differentiation and integration as shown in Figure 3-7. They can be used to assess if the overall communication environment of an innovation team is sufficient to support the innovation effort. Accordingly, we offer the following proposition.

P5: Communication environment mechanisms affect the development of the differentiation and integration processes in team communication.

(a) To promote the process of differentiation, a sufficient communication environment needs to provide sensible structures for regulating the exploration of multiple issues and the ability for individuals to promptly gain audience’s attention to raise concerns or issues.

(b) To promote the process of integration, a sufficient communication environment needs to provide the support for managing the relevance and transitions of discussion and the initiation of an effortless elaboration process.

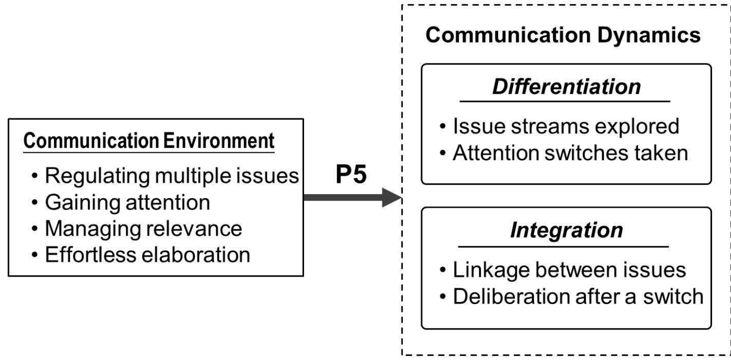

Figure 3-7. Effects of Communication Environments on Team Communication

3.7 Chapter Summary

By conceptualizing innovation project teams as interpretation systems and emphasizing the simultaneous processes of differentiation and integration, we developed a theoretical model for the dynamics of task-related discussion in innovation teams. We proposed four structural properties of team communication to capture the processes of differentiation and integration in team communication: (1) the number of issue streams explored and (2) the number of attention switches, (3) the conceptual linkage between issue streams, and (4) the level of deliberation after each attention switch. With these four structural properties and their relationship with differentiation and integration, we suggested that the processes of differentiation and integration affect the team's capability to manage team process and unexpected situations, as well as the level of consensus that the team reaches on its action plans. By taking three theoretical perspectives (i.e., interpretation system, communication, and information systems), we further identified four categories of factors – team composition, semi-structures, communication contexts, and communication environments, and theorized how these factors influence and shape the development of the differentiation and integration process in task-related discussion. The proposed theoretical model for the dynamics of task-related discussion in innovation teams is summarized in Figure 3-8. The six propositions in our theoretical model are summarized in Table 3-2.

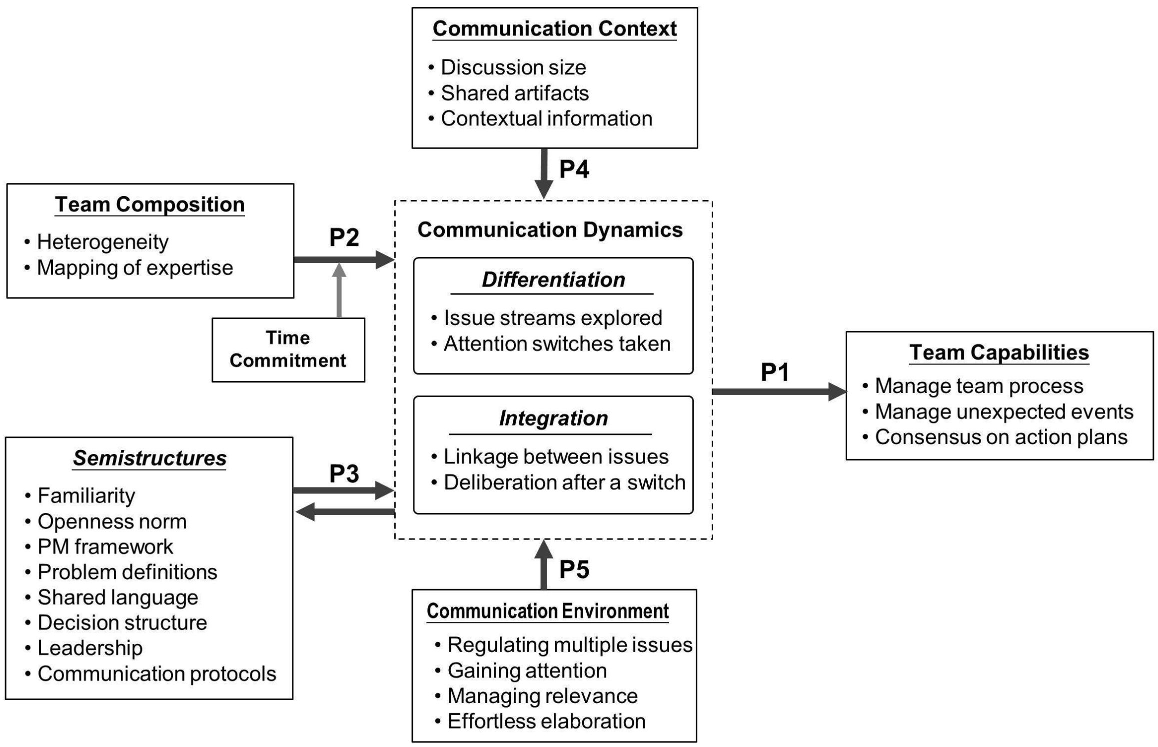

Figure 3-8. The Communication Dynamics of Innovation Project Teams

Table 3-2. Summary of Propositions in the Model of Team Communication Dynamics

Factor	Proposition
Team Capabilities	P1: The processes of differentiation and integration in team communication affect an innovation team's capabilities. (a) The process of differentiation affects an innovation team's capability to manage team process and unexpected problems. (b) The process of integration affects the degree to which an innovation team has consensus on its action plan. (c) The effect of the differentiation process on team capabilities has to be established on the condition that diverse perspectives have converged around a broader frame of communication by the process of integration.
Team Composition	P2: Team composition factors affect the development of the differentiation and integration processes in team communication. (a) The heterogeneity of membership promotes the process of differentiation. (b) A good mapping between task requirements and team members' expertise facilitates both processes of differentiation and integration. (c) The effects of team composition factors on team communication are contingent upon team members' time commitment and timely responses.
Semi-structures	P3: Semi-structures affect the development of the differentiation and integration processes in team communication. At the same time, the dynamics of team communication also affects the development of semi-structures. (a) Familiarity, openness norm, and project management framework promote the process of differentiation. (b) Problem definitions, shared language facilitates the process of integration. (c) Unanimous decision structure, effective leadership, and communication protocols improve both processes of differentiation and integration. (d) Semi-structures evolve and develop with team communication over time.
Communication Contexts	P4: Communication context factors affect the development of the differentiation and integration processes in team communication. (a) The size of discussion affects the process of differentiation. (b) Shared artifacts improve the process of integration. (c) The input of contextual information, including external evaluators' feedback and major technical challenges that the team is facing as a whole, promotes the process of integration.
Communication Environments	P5: Communication environment mechanisms affect the development of the differentiation and integration processes in team communication. (a) To promote the process of differentiation, a sufficient communication environment needs to provide sensible structures for regulating the exploration of multiple issues and the ability for individuals to promptly gain audience's attention to raise concerns or issues. (b) To promote the process of integration, a sufficient communication environment needs to provide the support for managing the relevance and transitions of discussion and the initiation of an effortless elaboration process.

CHAPTER 4: RESEARCH DESIGN

In this chapter, we present our research design for the case study, which is used as a preliminary test of our theoretical model. We first introduce our research site – the iPlant Collaborative – and discuss the way that we select our cases. Then we summarize our data collection process, including the development of an interview script as our data collection instrument. Last, we discuss how our research design addresses the reliability and validity issues.

4.1 Research Site and Case Selection

We chose case study as our research method for the field study[1]. Since our research focus is to investigate how team discussion of a radical innovation project evolves over time, a case study allows us to explore this phenomenon in depth within its real life context (Yin 2009). Furthermore, our interest at this point is to identify which factors in our model are important in influencing the development of team discussion as well as their potential interactions. The case study provides us a solution to cope with such a "technical distinctive situation in which there will be many more variables of interest than data points" (Yin 2009, p.18).

We conducted our study at the iPlant Collaborative (www.iplantcollaborative.org), a cyber-infrastructure initiative funded by the National Science Foundation beginning in 2008 for promoting collaboration in the plant science community. iPlant is well-suited for our case study for two reasons. First, its foremost mission is to develop a revolutionary cyber-infrastructure that is fully capable of analyzing large-scale datasets (or big data)

[1] The Institutional Review Board (IRB) Approval for the case study is provided in Appendix A.

and addressing grand challenges in the plant sciences. Achieving such a mission requires not only a great capacity for synthesizing various information and computational technologies, but also a clear vision of where the plant science field is heading, which is consistent with the spirit of radical innovation. Second, to delineate the computational requirements for the cyber-infrastructure, iPlant initiated two grand challenge projects – Genotype-to-Phenotype (iPG2P) and Tree-of-Life (iPTOL). Each project includes a number of multidisciplinary virtual teams to work on different analytical solutions for its corresponding challenge. In addition, iPlant also has on-site development teams to create and maintain its cyber-infrastructure and computational platforms. These grand challenge and development teams together represent a good spectrum of cases for us.

We adopted a multiple-case design for our study. According to Yin (2009), multiple cases resemble multiple experiments in such a way that a previously developed theory is used as a template to compare empirical results across cases. One important step in the multiple-case design is selecting cases that "are to be literal replications, such as a set of cases with exemplary outcomes in relation to some evaluation questions" (Yin 2009, p.59). According to our reasoning about the effect of communication dynamics on team capabilities (in Section 3.2), we select cases that illustrate one of the two exemplary outcomes: (1) being successful or (2) less successful at managing the team process for innovation.

To select suitable cases, we interviewed three informants at iPlant whose job responsibilities were related to project coordination. At the beginning of the interview, we asked each of them to describe their role at iPlant and, from their point of view, iPlant's organizational structure in regard to project teams. Then we provided them with a definition of an innovation task and asked them to name teams inside iPlant that were qualified as innovation teams according to the definition. The provided definition was derived from Perrow's framework for organization analysis (1967) and Henderson and Clark's innovation topology (1990) as follows:

- The problem to be solved or the content of the final deliverable is poorly defined or conceptualized.
- Distinct new ideas are embodied in the final deliverable, such as new ways to link components together.
- A high level of uncertainty is involved in the project, which is caused either by the novelty of technology or the complexity of procedure.

Following the informants' suggestions regarding teams, we further inquired which teams they considered to be more or less successful and the reasons. The interview was concluded with their recommendations for potential interviewees in each team. The interview script for the informants is provided in Appendix B. After analyzing their suggestions, we selected teams that were mentioned by at least two informants. A total of five teams was included in our case study as summarized in Table 4-1. The team names are masked with made-up IDs for confidentiality.

Table 4-1: Selected Project Teams for the Case Study

ID	Main Purpose	# of Core Members*	Period	Type	Level of Success
System	Developing a web-based user environment that integrates various computational resources and analytical tools	6-8	2009-Present	Local	Successful
Fusion	Integrating several major plant databases through a web data service	5	2011-2012	Virtual	Successful
Analysis	Providing an infrastructure for large-scale data analysis and modeling	4	2010-2013	Virtual	Less successful
Image	Providing a high throughput computational platform for analyzing plant-related images	6	2009-Present	Virtual	Successful
Channel	Developing a mechanism for automatically updating reference genomes with new species	5	2010-2011	Virtual	Less successful

*: Core members were the members who consistently participated in decision making

4.2 Data Collection

We collected data through interviews and via iPlant's Wiki site for team documentation. In order to comprehensively cover the four categories of factors in our model (i.e., team composition factors, semi-structures, communication contexts, and communication environments) and their effects on the team dynamics, the interview script as provided in Appendix C was designed with seven distinct sections with a total of 47 questions:

(1) Background information: This section is designed to elicit major events in the team development process and their timeline, including how and when the project was initiated, the final deliverable was defined, and the milestones were planned. We also asked interviewees to evaluate the innovativeness of their project with questions such as how well the final deliverable was defined when the project started.

(2) Team composition: We inquired about factors related to the team structure, such as team members' expertise and job responsibility and the ways that major decisions were made inside the team.

(3) Collaboration issues: To set a context for the following two sections, we asked interviewees to describe their teammates' collaboration style and team leaders' leadership. Major collaboration issues were also asked about.

(4) Discussion patterns at the early stage of the project: In this section, we asked interviewees to reflect on their team's discussion patterns in the first few months when the project was initiated. This includes how a group meeting was conducted, the communication media used, the meeting agenda, the discussion atmosphere, the effectiveness of group discussion in clarifying issues, and the level of consensus that the team reached on their action plans.

(5) Discussion patterns at the final stage of the project or at present: In this section, we set the time frame to be the final few months of the project or the present if the project was still on going, and asked interviewees to reflect on their team's discussion patterns as in the previous section.

(6) Changes in discussion patterns: If interviewees reported any significant changes in their team's discussion patterns, we further inquired about how those changes took place and their influence on the team process.

(7) Self-evaluation: In this section, we asked interviewees to evaluate the level of success that they achieved with the project, including factors that have promoted or impeded the success of the project.

For each selected team, we invited two key members as suggested by the informants or other members in the team for a one-hour interview. If the scheduled time was not enough to cover all the interview questions, the option of scheduling another interview was provided. The interview was audio recorded under the interviewee's consent and later transcribed for data analysis. In addition to interviews, we also collect each team's developmental documentation from iPlant's Wiki site, including its original proposal, project overview, member list, schedule and milestones, meeting minutes, and supplemental information about the final deliverable. The meeting minutes were traced back to as early as 2010, and follow a standard format that lists the time, participants, meeting agenda, conclusions, and action items.

4.3 Research Validation

Reliability and validity are two important components of research design to ensure that research results are credible, dependable, and trustworthy. According to Venkatesh et al. (2013), in qualitative research, reliability reflects the consistency and dependability of data and analysis; validity indicates the degree to which data are plausible and credible, and thus can be defended when challenged. To address reliability and validity, we take five approaches in our case study. First, based on our theoretical model, we established a case study protocol, including a data collection plan and an interview script, to increase the consistency of our data collection. The data collection plan specified how data would be collected from our five selected teams, including the interview schedule, interviewees' contact information and job responsibilities, and specific aspects of data that needed to be collected from the interviewees. As discussed in the previous section, we also developed an interview script from our theoretical model as our data collection instrument. According to Yin (2009), having a case study protocol with a data collection plan and an interview script can minimize the errors and biases in the data collection process, and thus increases the reliability of case study.

Second, we collected multiple sources of data from our research site and selected teams, including interview data, team development documentation (project overview, member list, project schedule and milestones), and meeting records. These data together provide a more comprehensive view of these teams, and allow us to cross-check the accuracy of each data source. As a result, the descriptive validity of our study (i.e., the accuracy of what is reported by researchers) can be increased (Venkatesh et al. 2013). Third, with our theoretical model, we employed a pattern matching logic to analyze our qualitative data. That is, we followed the definition of the factors in our theoretical model to code interview transcripts and team documentation. According to Yin (2009), this pattern matching logic helps establish a clear relationship between an empirically observed pattern and a predicted one. "If the patterns coincide, the results can help a case study to strengthen its internal validity" (Yin 2009, p.136). Furthermore, this pattern matching logic also helps address inferential validity (the quality of interpretation that reflects how well the findings can be confirmed) (Venkatesh et al. 2013).

Fourth, we followed a multiple-case design and included five project teams in our study. From a research design perspective, the multiple cases are similar to the multiple respondents in a survey. As a result, a replication logic (i.e., replicating a finding by several investigations) can be employed during data analysis, especially through cross-case analysis, to increase external validity or transferability (i.e., the degree to which the results of qualitative research can be generalized or transferred to other contexts or settings) (Venkatesh et al. 2013; Yin 2009). Fifth, after a draft of this dissertation is finalized, we will invite our key informants to review our analysis results. According to Yin (2009), this procedure is suggested as an important way of corroborating the essential facts and evidence presented in a case report. If key informants disagree on the actual facts reported, further investigation will be needed for collecting more evidence. As a result, the validity of a case study can be increased. Overall, we believe that with these five approaches, our analysis results, which will be presented next in Chapter 5, have sufficient reliability and validity.

4.4 Chapter Summary

To perform a preliminary test of our theoretical model, we conducted a case study using a multiple-case design. We chose the iPlant Collaborative as our research site and selected five project teams that met our research objectives. We developed an interview script, which included seven sections with 47 questions, and collected data through interviews and via iPlant's Wiki site for team documentation. We addressed the reliability and validity issues in our case study with five approaches: (1) establishing a case study protocol, (2) collecting multiple sources of data, (3) using a pattern matching logic for data analysis, (4) following a multiple-case design, and (5) having key informants review our analysis results. These approaches helped us increase the consistency and quality of our data collection and analysis.

CHAPTER 5: ANALYSIS RESULTS

In this chapter, we discuss our data analysis procedure. We present our analysis results for the five teams in our study, including within-case and cross-case analysis results.

5.1 Preliminary Data Analysis – Case Screening and Pattern Matching

Before proceeding to data analysis, we reviewed the interview transcripts and verified if the five selected teams were indeed qualified as innovation project teams. For Teams System, Fusion, and Analysis, their members consistently indicated that the project was initiated with a grand vision but the scope was poorly defined, and that the development process was highly uncertain and complex. But for Teams Image and Channel, their members suggested that, while the project was challenging from a technical aspect, the final deliverable was fairly well-defined from the beginning. As a result, we re-categorize Teams Image and Channel as general project teams and use them as contrasting cases in the study. The final matrix for case classification is shown in Figure 5-1. We have three types of cases, including one local innovation team, two virtual innovation teams, and two virtual project teams. It is noted that the focus of this dissertation – radical innovation – can only be defined in retrospect according to the *actual* impacts of the project's deliverables over time. Therefore, at this stage of research, we are not able to specify whether the innovation teams in our study are radical innovation teams. The term innovation team here is used to convey the condition that the team is aimed at achieving innovation goals and its project embodies the characteristics of non-routine tasks.

	Local	Virtual
Innovation	**System** (Successful)	**Fusion** (Successful) **Analysis** (Less successful)
Project		**Image** (Successful) **Channel** (Less successful)

Figure 5-1. Three Different Types of Cases in the Study

We analyze our qualitative data through within-case and cross-case analyses. For each selected team (or case), in addition to the compilation of two matrixes for members' backgrounds and project characteristics, we compiled a team chronology for analyzing its development process. We extracted from the interview transcripts particular events and their timeline that the interviewee mentioned when explaining the history of his/her team. These events typically linked to important team activities (e.g., the addition or departure of core members, group meetings, or product releases), project-related issues (e.g., the incidents of technical struggles or collaboration breakdowns), and decisions about the project (e.g., deciding project milestones, system specifications, or new technologies to adopt). We used these events to create a basic chronology and then review team documentation, such as the project schedule and meeting minutes, to further annotate the chronology. During the compilation of the team chronology, interviewees' narrative accounts for the same team were checked for consistency, and no contradictions were found.

To explore a team's discussion dynamics with our proposed model, we analyzed interview transcripts and meeting minutes using a pattern matching technique.

Specifically, a qualitative data analysis software (i.e., Nvivo 9) was used to code sentences on a transcript or meeting minute that indicate a pattern of discussion or match the concept of any influencing factor in our theoretical model. For example, when we asked an interviewee about how active his/her teammates were in bringing up issues or concerns in the discussion, the interviewee gave the following statement: *"In some cases, they didn't want to bring up. They thought if they brought it up, the discussion wouldn't amount to anything."* We coded the corresponding sentences on the transcript with the notation [DISCUSSION-ATTENTION SWITCH] as it suggests a certain level of hesitation in team members about initiating attention switches. When interviewees mentioned that they were participating in "SciPlant" meetings, we coded the corresponding sentences with the notation [SEMI-STRUCTURE-PM FRAMEWORK] because SciPlant was a particular group inside iPlant that helped establish project management concepts and measures for managing virtual collaborations, such as the use of project milestones and the introduction of a regular progress review structure.

During the within-case analysis, we also made notes on the relationship between coded factors and team events according to their context on the transcript. We used these notes to analyze how major events helped shape or strengthen the influencing factors and identify potential interactions between the factors. After the within-case analysis, a cross-case analysis was performed to verify the effects of team communication on team outcomes and to compare coded factors and their effects across case types as listed in Figure 4-2. For the cross-type comparisons, we focused on identifying factors that are common across two different case types and factors that are unique in each case type.

Specifically, we compared (1) the two virtual innovation teams with the local innovation team and (2) the two virtual innovation teams with the two virtual project teams. A table that lists our four categories of factors is used as a standard framework in which appeared factors in each case were marked for comparison.

In the following sections, we present our within-case analysis results for the five selected teams in our study and cross-case analysis results for the effects of team communication on team outcomes and the two cross-type comparisons – local versus virtual innovation teams and innovation versus project virtual teams.

5.2 Within-case Analysis Results

For the within-case analysis results, we briefly summarize each team's characteristics, provide a synopsis of its development history, and discuss important factors that shape and influence its discussion dynamics.

5.2.1 Team System (Local Innovation Team)

Team System was a local information systems (IS) team at iPlant, convened in the summer of 2009 for achieving one of iPlant's founding visions – creating a unified, web-based, user-friendly computational platform for supporting plant science investigations. The team included a team manager, a requirement analyst, and four to six system developers. A number of quality assurance (QA) engineers were initially included in the team, but later became independent and formed a central QA team supporting Team Systems and other iPlant development projects. Team System used a commercial issue tracking system to manage all of its development documentation, including user requirements, development status, and system issues, and met face-to-face for group discussions, often with the aid of standard conference facilities (i.e., white board, projector, computer, internet access etc.).

The user requirements for constructing the unified computational platform were driven by the two grand challenge projects –Genotype-to-Phenotype (iPG2P) and Tree-of-Life (iPTOL) – and then formalized by the team in consultation with iPlant leadership. Despite a number of the efforts to ascertain the needs of the plant community, the first two releases were heavily criticized by the plant communities, a situation that confused and frustrated Team System. "Imagine a castle up in the sky that solved all your problems, we were building that," a member said in the interview.

Team System underwent a major reorganization in the first half of 2011, including a change in leadership. Around October 2011, the computational platform that the team was developing started to receive positive feedback from the plant community, and its user base rapidly expanded. Team System delivered two acclaimed features regarded as significant novelties in the development of a computational platform. The first feature enables users to dynamically create their own analytical applications on the platform so that they can utilize various computational resources provided by iPlant to meet their specific needs. The second feature allows users to build an automatic workflow with which a number of analytical applications on the platform can be orchestrated to run in a series. These two novel features break the traditional image of pre-defined workflows in IS and give new meaning to system scalability.

Team Development: The major reorganization that took place in the first half of 2011 divided Team System's history of development into two distinct phases. During the first phase, which covered the team's first one and a half years to the end of 2010, Team System experienced intense internal conflicts and deep confusion about users' expectations. By following a hierarchical organization approach, the first team manager divided the team into two sub-teams – service and user-interface (UI) – according to the functional needs in the system development. The two core developers in the service team held a strong belief that a web service (i.e., a web-based program that implements certain business or data processing logics) should be simple and general in terms of functionality so that it can be reused by different applications. However, the members in the UI team felt that web services should be designed according to the user interface perspective (i.e., graphical icons and visual indicators that users actually interact with when using an information system) because user interfaces are laid out specifically to meet what users want. The disagreement between the service and UI teams over the way that web services should be designed gradually became intense in the summer of 2010, and spread from arguments in the group meeting to interpersonal conflicts in every possible arena in the workplace. "It would end up in our issue tracker, like I'm not going to do this … sometimes they (the service team) would just do passive-aggressive things like close it, they aren't going to fix it, close the issue so it won't get fixed."

Meanwhile, Team System was facing strong criticism from the plant community for under-delivering. The first release was aimed at addressing the computational needs delineated by the iPTOL project. A specific development plan was laid out during an iPlant organization-wide meeting in December, 2009. When the platform was released in March, 2010, which was close to the target stated in the development plan, it received “ceremonious disappointment” as one interviewee put it. The second release focused on the requirements of the iPG2P project and took place in August, 2010. This release received a slightly better response than the first one because an important feature that the iPG2P project had requested was delivered. But it was still widely criticized for its inevitable limitations (as the project was being young). In retrospect, one member suggested that the negative feedback on the first two releases was because “setting expectations or handling expectations” was not done properly. “The expectations of the community and people were out of control…People were unhappy because it didn’t look at all like their imaginary castles that solved all science bounds and everything.”

In the face of rising internal conflicts and the external criticisms for under-delivering, Team System’s morale was rapidly declining. During this difficult period of time, the team manager’s leadership style deepened to some degree, instead of alleviating, team members’ frustration and confusion. According to interviewees’ recollections, the team manager was very structured, keen to apply the ideas of a classical hierarchical organization to the management of the team, and organized group meetings in the style of open discussion. Under her leadership, each sub-team had the complete right to decide matters that fell within its functional responsibilities. When the service team repeatedly refused to accommodate the UI team’s needs in changing its web services’ design, the team manager did not intervene in the argument and resolve the conflict. Despite that the group meeting was conducted in open discussion, the manager often appeared to impose some conclusions that she already had on the discussion. “She did a lot of things to steer us to a particular direction but often we were off the mark…We were playing a charade at that time where she would tell us straight out like ‘this needs to happen.’” This mix of open discussion with pre-set conclusions caused team members to hesitate sometimes to bring up their own opinions or ideas. In addition, they also became increasingly disoriented about what they were developing for the project. “It’s founded to say if you can’t explain to your team what we’re building, and then they’re not going to build what you needed to build.” Even though Team System had several face-to-face meetings a week at the time, the group discussion was considered ineffective with low consensus reached.

The conflicts between the two sub-teams resolved when the two core developers in the service team left iPlant in late 2010, and a technical lead in the UI team took charge of the service team. The design of the web services then began to embrace a UI perspective, and the progress on the platform development was significantly improved. When the first team manager stepped down in May, 2011, the technical lead with the UI background was appointed as the new team manager. As an effort to increase internal stability, he hired a few new developers that he had previously known to be on the team, and structured the team based on individuals’ specialties instead of functional differences. So, a developer could do both UI and web service development if his/her skill set permitted. At the same time, major decisions on the platform design were being made solely among the team manager, the requirement analyst, and the two technical leads in the service and UI areas, and then specific programming tasks were dispatched to individual developers. If developers had concerns or issues with any team decisions, since they all knew the team manager well, they would talk to him directly. “They were the people that I knew were good, bright individuals from my previous interactions… They have the ability to call me out on any of the things they don't think were helpful." Because of the change in the decision structure, group meetings that involved all members were reduced from several a week to daily short stand-ups for progress reports and a few major meetings between releases.

In June, 2011, SciPlant (i.e., a particular group at iPlant that helped establish project management concepts and measures) invited a group of postdocs to come on-site and test use a new version of the computational platform. During the three-day visit, the platform was critically evaluated by the postdocs and a long list of system issues and requests was created as a result. Given the low team morale at the time, the postdocs' criticisms appeared extremely harsh to Team System, and little exchange of opinions took place between the team and the postdocs. "There was a certain level of 'I kill myself for this, and you guys hate it, so I'm not even going to listen to you,'" an interviewee recalled. Despite such resentment, the new team manager took the postdocs' issue list seriously. In consultation with a committee of prominent plant researchers, Team System prioritized listed items and systematically addressed them in four months with four releases to show the plant community that the platform was moving toward the direction they wanted. Around October, 2011, the computational platform started to receive positive feedback from the community, and the number of users started to increase significantly.

Based on this experience, Team System decided to engage users earlier in the development process and established the practice of user acceptance testing before each release, so major issues could be discovered and resolved before a new version of the platform was released to the community. Compared to the previous struggles for building a castle up in the sky, “now it’s relatively trivial…We all know what we’re building…We know whether or not what exists needs to be changed in order to accommodate new requests…and then we make a change and move on from that.” At the time when we conducted our interviews, the atmosphere of Team System’s group meetings was described as light and pleasant. System development issues were addressed effectively with high consensus reached.

Important Factors and Their Interactions: For the first one and a half years to the end of 2010 (Phase 1), Team System had good task-expertise mapping with skillful service and UI personnel on board, an important factor in our theoretical model that could promote both processes of differentiation and integration, but suffered high heterogeneity in beliefs that divided the team into two camps and that greatly intensified the process of differentiation, as revealed by the conflicts between the Service and UI teams. At the same time, the team lacked strong integration factors that could have consolidated different viewpoints. Specifically, they experienced: (1) vague problem definitions, (2) confusing contextual information, (3) ineffective leadership, and (4) unclear decision structure, four factors that could have enhanced the process of integration according to our model. First, the problem definitions for the project were initially vague and unclear. As a member reflected, “that was horribly vague… There was a lot of conflicting requirements from a development stand point like it’s a person led by someone else…It was very difficult to understand how we were able to build everything that people said we were building." Second, the received contextual information was confusing. Even though iPlant used grand challenge teams to clarify user requirements, the negative feedback from the plant community on the first two releases deepened the confusion, especially after Team System closely followed the specified development plan.

Third, the team leadership was ineffective. While the first team manager tried to use open discussion to gather consensus in the team, her purposely steering the discussion toward a certain direction actually hurt the consensus reaching process by not helping members to see how different issues were connected with one another. Fourth, the decision structure in the group discussion was unclear. The idea of having open discussion is to encourage team members to express their opinions and creates a more unanimous decision structure. But the team manager's act of announcing her pre-set conclusions in the discussion and the creation of two sub-teams that owned decision rights in their respective responsibilities indicated that the decisions in the team were in fact made by the person in charge. Such inconsistency in the decision structure caused members to sometimes hesitate to bring up their opinions in the open discussion if they sensed they had no say in the matter. Consequently, the group discussion during this period of time was described as ineffective with low consensus reached.

In this early phase of the project, interactions were found between the following factors from our research model:

- Heterogeneity and decision structure: The effect of heterogeneity on dividing the team into two different camps of thought was strengthened by the decision structure that the person in charge decides all, as reflected in the service team's arbitrary refusal to accommodate the UI team's needs that led to the intense internal conflicts.

- Decision structure and leadership: As Kerr et al. (1974) suggested that one important role of leadership is to initiate structure, the team's decision structure was shaped by the team manager's leadership style as she decided to structure the team into two sub-teams, and played the role of a ruler instead of a moderator in the group discussion.
- Problem definition and contextual information: The problem definitions became more vague and unclear when the plant community gave negative feedback on the platform that the team had created based on its previous understandings.

The level of heterogeneity in the team was largely reduced when the two core members in the service team left iPlant. Later the new team manager further brought in the factor of familiarity in our model to eliminate the team's heterogeneity by hiring developers that he had previously known to join the team. He also adjusted the team's decision structure by creating a central committee that decided major matters for the team. Inside the committee, decisions were made unanimously. This committee decision structure greatly simplified the communication process in the team. "So I try to keep more of a workman perspective of 'I want to tell you (developers) things that are going to happen in the next release or right after that,' but not anything beyond that. I worry about keeping the bigger picture and roadmap, if you're curious, I'll talk to you about it, but I'm not going to waste your time on that," the new team manager explained.

The visit of postdocs in June, 2011 organized by SciPlant helped the team establish the practice of user acceptance testing, which used a shared artifact (i.e., the computational platform that the team was developing) to elicit contextual information from the plant community to improve the quality of problem definitions. Inside the team, the computational platform that was re-designed from the UI perspective also became a form of a shared language that members could use to more effectively communicate why some changes were needed and how to do them. According to our model, these three factors (i.e., shared artifact, shared language, and contextual information) can promote the process of integration and cultivate group consensus. As reflected in one interviewee's comment, "now it's relatively trivial…We all know what we're building, we know kind of what we have, we know whether or not what exists needs to be changed in order to accommodate new requests…But when you have nothing, it's really…there were a lot of frustration we didn't really know what had been built." Overall, after the factor of heterogeneity was removed and other factors were added in (i.e., familiarity, effective leadership, committee decision structure, shared artifact, incoming contextual information, better problem definitions, and shared language), Team System created a constructive discussion atmosphere that promoted both processes of differentiation and integration. Subsequently, the discussion in this later phase of the project was described as light and effective with high consensus reached.

During this period of time (Phase 2), interactions are observed between the following factors from our theoretical model:

- Decision structure and leadership: The new team manager initiated a central committee for major decision making.
- Contextual information and PM framework: SciPlant helped organized the visit of postdocs to collect feedback from the plant communities.
- Contextual information and shared artifact: The team used the practice of user acceptance testing before releases to collect user feedback early in the development process.
- Problem definitions and contextual information: Team System felt clear and certain about what they were developing after starting receiving positive feedback from the plant communities. This interaction is implied in the notion of interpretation systems as discussed in Chapter 3 that an organization tries to interpret what outside environments are like by reading contextual information in order to decide appropriate actions or responses (Daft and Weick 1984).
- Shared language and shared artifact: The communication among members was improved by discussing and illustrating their opinions or ideas with the re-designed computational platform. The interaction is consistent with Carlile's finding (2002) that some boundary objects can be used as a shared language to facilitate knowledge sharing.

The important factors and their interactions identified from the case of Team System are summarized in Table 5-1.

Table 5-1: Important Factors in Team System

Time	Phase 1 (Summer 2009 – Dec. 2010)	Phase 2 (May 2011 – Mar. 2013*)
Discussion Patterns	Issue exploration: Ineffective Issue raising: Conflicts and hesitation Consensus: Low consensus	Issue exploration: Effective Issue raising: Good Consensus: High consensus
Important Factors	• Sufficient task-expertise mapping (+DI) • High heterogeneity in beliefs (+D) o *Ineffective leadership (~DI)* o *Inconsistent decision structure (~DI)* o *Unclear problem definitions (~I)* o *Confusing contextual information (~I)*	• Sufficient task-expertise mapping (+DI) • Familiarity (+D) • Effective leadership (+DI) • Committee decision structure (+DI) • Better problem definitions (+I) • Incoming contextual information (+I) • Shared artifact (+I) • Shared language (+I)
Interactions between Factors	- Heterogeneity and decision structure - Decision structure and leadership - Problem definitions and contextual information	- Decision structure and leadership - Contextual information and PM framework - Contextual information and shared artifact - Problem definitions and contextual information - Shared language and shared artifact

*: The time that interviews were conducted; DI: The factor is related to both processes of differentiation and integration; D: The factor is related to the process of differentiation; I: The factor is related to the process of integration; +: The factor was present and positive in its effect on discussion; ~: The factor was particularly mentioned but weak or absent in its effect on discussion

5.2.2 Team Fusion (Virtual Innovation Team)

In 2010, iPlant invited research proposals for Seed Projects, a new effort to address research areas and corresponding computational needs that were not covered in the scopes of the two grand challenge projects. One of the accepted proposals led to the creation of Team Fusion in mid-2011, a virtual team that was collaborating via emails and conference calls across three states in the U.S. The team included a project manager from iPlant in Arizona, a faculty lead and two developers in California, and an iPlant affiliated developer in New Mexico. Team Fusion aimed to develop a comprehensive solution for integrating data from different data sources, such as plant genomic data, plant trait data, and environmental data, so that full-scale scientific investigations could be carried out under one system architecture. When searching for potential new technologies to adopt, one of the developers in California spotted an iPlant-owned semantic web technology that iPlant had already invested two years to develop. The use of the semantic web technology to integrate various types of plant data was regarded as unique and novel, and a proof of concept implementation was released in August, 2012.

Team Development: Team Fusion exhibited distinct problem setting and solving stages, a developmental pattern that is often found in innovation teams as described in Chapter 2. The project objective stated in the original proposal was considered as general and vague, and the iPlant leadership was particularly worried about this project. The two developers in California started to work on the project in August, 2011. In the first two months, team communication took place sporadically between them and the project manager, mainly through emails, as they updated the project manager on the ideas that they had for approaching the project. In October, one of the developers wrote to the project manager and inquired about the potential of using a semantic web technology that he read about from iPlant related publications. In the meantime, however, iPlant leadership was having problems getting the affiliated developer in New Mexico to deliver this sophisticated technology. In order to understand his development progress and issues, iPlant had requested the semantic web developer to attend SciPlant meetings via conference calls for weekly updates.

Even though the project manager of Team Fusion realized the high risk of combining the project with such an uncertain technology, she thought that this might a good chance for the semantic web developer to show iPlant what he had. After sharing her thoughts with iPlant leadership, she contacted the semantic web developer and invited him to join the project. “So he (the semantic web developer) emailed them (the two developers in California) and said – okay, here is the safe bet, the middle ground, and the bleeding edge. They said – bleeding edge absolutely. I heard what they said and went – oh, Jesus, this is going to be a disaster,” the project manager reflected in the interview.

The addition of the semantic web developer was, in fact, a surprising blessing to the project. As an expert in the semantic web technology as well as anxious to prove his ideas to iPlant, he took a major lead in guiding the two developers in California to implement the technology. In addition, as a regular participant in the SciPlant meetings, he understood how project management practice worked and helped bring the practice into the team, including creating a project schedule and milestones, having weekly conference calls for internal discussion, participating in SciPlant meetings for progress reporting, and posting meeting minutes on the iPlant Wiki. The three developers became the center of the team and the project was successfully transitioned to a problem solving stage (Phase 2). In December, the project manager organized a kickoff meeting at iPlant for all the members to meet face-to-face for the first time. One item on the meeting agenda was for the three developers to work on and finish a test implementation of the semantic web technology on one of the data sources. This test implementation became a foundation for the team to build on as the project was expanding to more different data sources. The discussion dynamics among the three developers were described as positive and effective with high consensus reached.

Team Fusion crossed off its major milestones on schedule and had the first demonstration of its system to iPlant in March, 2012. In August, 2012 a production version of the system was released. Because of its success, iPlant decided to renew the project for another year. “Remember, this whole project, out of four Seed Projects, had the most vague proposal, used a technology that everyone was concerned about and hadn’t been demonstrated…and it was a beautiful collaboration,” the project manager concluded.

Important Factors and Their Interactions: Team Fusion’s development history provides a clear demonstration of how various influencing factors are gradually adopted by a new team and shape its communication patterns. The team started with (1) an insufficient task-expertise mapping and (2) vague problem definitions. When the project was founded, a new developer was specifically recruited into the California group, who would be a core member in the team and had no previous knowledge about the California group and the project. “It took him a while…He had to figure out what the [California] group was about, what they were doing, and what the seed proposal was.” The faculty lead, at the same time, had no clear ideas what to do with the project. “He (the faculty lead) said – Let [the new developer] see what he thinks we should do and I went … (shocked). They had this vague proposal and [the new developer] should figure out what exactly they should do,” the iPlant project manager recalled. In this initial phase that covered the first three months of the project (Phase 1), no strong factor was found from our model to promote the development of the processes of differentiation and integration. As a result, the group discussion took place sporadically via emails and involved merely sharing and reporting. "He (the new developer) was sending me papers, showing me what he was thinking about," the project manager said.

The process of researching iPlant technologies through iPlant publications, which constituted an important piece of contextual information for the project, became a turning point for Team Fusion as the new developer spotted the semantic web technology and created a more specific problem definition – using the semantic web technology to solve the data integration problem. The new problem definition led to the recruitment of the semantic web developer in New Mexico into the team, which significantly improved the original weak task-expertise mapping. The new composition of the team also sparked excitement and devotion (or time commitment) in the project. "[The new developer] was very keen to do this. And [the semantic web developer] was excited and had them try to do it. [A senior developer in the California group] would see what they would gain from doing this. It's just like a bunch of people who all want to do the project." In sum, referring back to our theoretical model, the factors of contextual information and problem definitions brought up the factors of task-expertise mapping and time commitment in the team composition.

From the semantic web developer, a shared artifact (i.e., semantic web services), the project management framework, and the practice of having weekly conference calls were brought into the team. Even though the two developers in California had no prior knowledge of the semantic web technology, by working together with the shared artifact, they communicated well with the semantic web developer, and had no problems understanding the technology. "A lot of people in iPlant had problems of understanding what [the semantic web developer] is talking about and got frustrated with him…What he's doing was complicated and it's hard to understand…But he sure works well with [the two developers in California]. They understand what he's talking about. It went well." While the semantic web developer was the expert of the technology, the two developers in California were the one who actually owned the project. This created a balanced decision structure similar to a consultant-advisee relationship in which they discussed and worked closely for each design decision.

These factors (i.e., clearer problem definitions, sufficient task-expertise mapping, time commitment, a shared artifact, the project management framework, communication protocols, a shared language, and the unanimous decision structure) together promoted both processes of differentiation and integration according to our model, and made Team Fusion swiftly transition from a problem setting phase to the actual platform implementation. The discussion pattern in this later phase (Phase 2) was described as effective with high consensus reached, as the team made steady progress according to their planned schedule and milestones.

In Team Fusion, we observed interactions between the following factors from our model:

- Problem definitions and contextual information: From researching iPlant technologies, the new problem definition – using the semantic web technology to solve the data integration problem – was created. This is similar to Team System's use of user acceptance testing to elicit contextual information to clarify problem definitions.

- Task-expertise mapping and problem definitions: The new problem definition led to the recruitment of the semantic web developer.
- Communication protocols and project management framework: The semantic web developer continued to participate in SciPlant weekly review meetings during this project period and established the practice of having weekly conference calls in the team. Since communication protocols and project management framework are both semi-structures in our model, this interaction is consistent with Okhuysen and Waller's finding (2002) that once a team adopts a semi-structure, it is more like to adopt other semi-structures as a spillover effect.
- Shared language and shared artifact: By working together with the shared artifact, the three developers formed a shared language and communicated well with one another.

The important factors and their interactions identified from the case of Team Fusion are summarized in Table 5-2.

Table 5-2: Important Factors in Team Fusion

Time	Phase 1 (Aug. 2011 – Oct.2010)	Phase 2 (Nov. 2011 – Aug. 2012)
Discussion Patterns	Sporadic conversations for idea sharing	Issue exploration: Effective Issue raising: Good Consensus: High consensus
Important Factors	o *Weak task-expertise mapping (~DI)* o *Vague problem definitions (~I)*	• Good task-expertise mapping (+DI) • Communication protocols (+DI) • Unanimous decision structure (+DI) • Time commitment (+M) • Project management framework (+D) • Clearer problem definitions (+I) • Shared artifact (+I) • Shared language (+I)
Interactions between Factors	- Problem definitions and contextual information	- Task-expertise mapping and problem definitions - Communication protocols and project management framework - Shared language and shared artifact

DI: The factor is related to both processes of differentiation and integration; D: The factor is related to the process of differentiation; I: The factor is related to the process of integration; M: The factors is a moderator; +: The factor was present and positive in its effect on discussion; ~: The factor was particularly mentioned but weak or absent in its effect on discussion

5.2.3 Team Analysis (Virtual Innovation Team)

Team Analysis was created in 2010 under one of the two grand challenge projects. Its project mission was to develop a comprehensive analytical architecture, including data storage formats, data processing mechanisms, and statistical algorithms, for modeling the relationships among plant genomes, environmental conditions, and resulted traits, a research area that was becoming prominent in plant science. The team included an informatics analyst and a computational biologist who were collocated in a research center in New York, and a statistician in North Carolina. The informatics analyst was assigned the team leader. Although they were in a team, these three core members mostly worked on their respective knowledgeable areas under the broad project mission, and barely communicated with one another for reaching common goals. “What happened was there were several people who had very different ideas about how things needed to happen … nobody was talking to each other about what they were doing and how they were tied together,” an informant said in the interview. As a result, the team did not deliver anything that could actually amount to the grand analytical architecture that had been expected. In early 2012, a project manager from SciPlant volunteered to join Team Analysis to help the coordination and moderating of the group discussion during the conference calls. During her involvement, the team began to make substantial progress and deliver. However, in early 2013, while a new vision for the team to move on was formed among the statistician, the project manager, and iPlant leadership, the subgroup in New York made their own plan and pushed for another direction. When we conducted our last interview in mid-2013, the team was trapped in severe disagreements again.

Team Development: The composition of Team Analysis suffered two major issues that led to the ineffective collaboration of the three core members initially. First, although these three members were knowledgeable in their respective areas in the project (i.e., informatics, ecological genomics studies, and statistical analysis), none of them had the expertise or experience in the analytical architecture that they were supposed to build. Without a person who was able to provide a vision and bridge the conversation, they had very different ideas on how and where to proceed. Second, while there were disputes over the project, there was no clear authority structure among them to resolve the differences and assign work. The team leader (the informatics analyst) and the computational biologist were peers in the research center in New York, reporting to the same manager who was marginally involved in the project. The statistician was a faculty member at a university in North Carolina and, due to her busy schedule, often expected the other members to carry out the work. As a result, they all behaved independently in the team and were unwilling to compromise their own positions to collaborate. “It’s challenging in this project because everybody is right – this is the best way to do it. Maybe they both are. It needs to be democratic about it,” a member said. Due to the very different opinions, these three members simply stopped communicating with one another and pick their respective preferred areas in the project to work on independently.

Team Analysis started to have monthly conference calls when the project manager from SciPlant came in to help with coordination in February, 2012. She spent three months communicating with individual members to figure out what they had been doing with the project, and came to the realization that reinitiating collaboration among these three members was difficult. “Everybody got to a point in their own projects where if it meant that ‘I have to work with you, I’m going to roll back some of what I’ve done and redo it.’ It seems everyone just wants to keep going down the path they’re going without really coming together,” the project manager summarized the situation. According to the meeting minutes at that time, there were around ten different work items that were simultaneously taking place in the team. So the project manager decided to let each member finish up their work items while finding a new direction for the team to come together and move on. In the summer of 2012, Team Analysis began to deliver some work items and have conversations on an overall roadmap that would tie these individual work items together and move the project forward. The statistician's vision on providing analytical capabilities for known truth datasets was gaining recognition among the project manager and iPlant leadership, and some work based on this vision was initiated.

However, the communication of the team was still ineffective and described as unfocused. Often the team could not reach consensus on its team matters. As a result, the project manager had to make decisions for the team, assign work to individual members, and do follow-ups. When the project manager asked to increase the frequency of conference calls from monthly to bi-weekly in order to improve coordination, the members in New York refused. In early 2013, the leadership was being transferred from the project manager back to the original team leader. Similar internal conflicts broke out again. The two members in New York began to ignore the overall roadmap and vision that the team had discussed, and made up their own plans. "This is time you just have to realize the project as it stands in its current form, just isn't going to move forward," a manager at iPlant concluded in our last interview with the team.

Important Factors and Their Interactions: Team Analysis started with a problematic task-expertise mapping such that there was no expert in the analytical platform that the team was supposed to build. With unclear problem definitions (i.e., the broad project scope), the three members had heterogeneous ideas about what needed to happen, as described in its team development history, while lacking effective leadership and time commitment for finding ways to collaborate. "He (the informatics analyst/team leader) would get things to a point, and if he gets blocked, he just stops and complains about someone else for not being able to complete." In the meantime, iPlant leadership had been trying to bring in experts from the plant community to clarify the problem definitions. But the community members' participation was fluid and to some degree complicated the already broad project scope. "We lost a lot of people, the emphases and focuses have changed over time …It's just that people involved have gone in and out." While the factor of heterogeneity persisted and fostered the process of differentiation, without strong forces to consolidate and integrate different opinions (i.e., problematic task-expertise mapping, poor problem definitions, ineffective leadership, lack of time commitment, and inconsistent contextual information), the three members simply chose to go their own ways and not communicate with one another.

The project manager from SciPlant helped established several semi-structures as suggested in our model in Team Analysis that brought the estranged members together again – leadership (i.e., the project manager's involvement in the team coordination and decisions), communication protocols (i.e., having monthly conference calls and posting meeting agendas and minutes on the iPlant Wiki), and the project management framework (i.e., the discussion on the overall project roadmap, and doing follow-ups). However, without having expertise and authority in the project related knowledge domains, the project manager was not able to truly help the three members to see how their individual ideas could be integrated, one important structural property (i.e., the conceptual linkage between issue stream) related to the process of integration in our model. "Basically we were re-hashing everything. There was no resolution," the project manager said. One explanation for this continued stalemate is that the team still suffered insufficient integration factors. According to our theoretical model in Chapter 3, the effective leadership and communication protocols improve both processes of differentiation and integration, and the project management framework promotes only the process of differentiation. As a result, while the team was making progress on understanding each other's ideas better, the force of differentiation was still stronger than the one of integration. This also explains why the team broke down again right after the leadership position was transferred back to the original team leader – the factor of leadership that would strengthen the process of integration was removed from the team.

In the case of Team Analysis, interactions were found between the following factors in our model:

- Problem definitions and contextual information: The fluid participation of the plant community members complicated the already broad and unclear project scope by instilling more diverse ideas into the team.
- Communication protocols and project management framework: The project manager from SciPlant helped to initiate monthly conference calls and the practice of posting meeting agendas and minutes on the iPlant Wiki. This is consistent with Okhuysen and Waller (2002) observation on the spillover effect of semi-structures.

The important factors and their interactions identified from the case of Team Analysis are summarized in Table 5-3.

Table 5-3: Important Factors in Team Analysis

Time	Phase 1 (2010 – Jan. 2012)	Phase 2 (Feb. 2012 – Jan. 2013)
Discussion Patterns	Almost no communication	Issue exploration: Ineffective Issue raising: Intense Consensus: Low
Important Factors	• High heterogeneity in beliefs (+D) o *Weak task-expertise mapping (~DI)* o *Ineffective leadership (~DI)* o *Unclear problem definitions (~I)* o *Inconsistent contextual information (~I)* o *Lack of time commitment (~M)*	• Leadership (+DI) • Communication protocols (+DI) • High heterogeneity in beliefs (+D) • PM Framework (+D) o *Weak task-expertise mapping (~DI)* o *Unclear problem definitions (~I)*
Interactions between Factors	- Problem definitions and contextual information	- Communication protocols and PM Framework

*: The time that interviews were conducted; DI: The factor is related to both processes of differentiation and integration; D: The factor is related to the process of differentiation; I: The factor is related to the process of integration; M: The factor is a moderator; +: The factor was present and positive in its effect on discussion; ~: The factor was particularly mentioned but weak or absent in its effect on discussion

5.2.4 Team Image (Virtual Project Team)

Team Image was part of iPlant's effort to make advanced image analysis technologies available to the plant community. It was a collaboration among iPlant, a California lab that owned an image analysis platform, and a Wisconsin group that developed algorithms for plant image analysis. "It was the first time iPlant took a proactive approach … They (the plant community) are focused on genomics now … As soon as they got some of that figured out, the next problem they're going to have is image analysis," an informant explained when talking about this collaboration. When Team Image was formed in 2009, iPlant was just starting to develop its own cyber-infrastructure. So the team focused on developing an overall project roadmap with iPlant and connecting the two different backend systems that the California lab and the Wisconsin group used in preparation for these two parties' collaboration. As soon as the iPlant cyber-infrastructure was taking shape in mid-2010, the team's focus was shifted to the integration of the image analysis platform with the iPlant cyber-infrastructure. At the same time, the Wisconsin group also turned its attention to the creation of its own computational environment by using the iPlant cyber-infrastructure for its algorithm development. The collaboration between the California lab and the Wisconsin group became less apparent in Team Image since then. In October, 2011, Team Image had a major release on the image analysis platform that was fully integrated with the iPlant cyber-infrastructure. The team was considered as one of the most successful projects at iPlant.

Team Development: The collaboration between iPlant and the California lab for developing the image analysis platform was well defined in terms of its project scope and work relationship. The California lab had already been developing the platform when the project was initiated. It continued to have full control over the development process. iPlant, as a customer, would request certain new features or functions according to its needs. "They (the California lab) had their own roadmap. We had things that we wanted to add…And we were paying them to do that. It wasn't unfunded. That's how it worked," the project lead at iPlant explained. Team Image did not have regular group meetings. The iPlant project lead would initiate email conversations or conference calls with the team when there was a need. It was typically about technical questions, new feature requests, or progress inquiries. In the beginning, the California lab and the Wisconsin group were both included in the communication. But when the project began to mainly focus on the integration of the image analysis platform with the iPlant cyber-infrastructure, the Wisconsin group became less involved in the group meeting. "It was a conflict in the software development life cycle…As the time went by, it was more iPlant and [the California lab] because we were discussing technical stuff that had nothing to do with [the Wisconsin group]…Once we got the iPlant [cyber-infrastructure] available for public use, they (the Wisconsin group) figured out how they could build things with that. Their interest was not as high…So we have two clear solutions, to me, it's double benefit…they were both solving problems in two completely different ways," the iPlant project lead commented on the situation.

The California lab would periodically use video conferencing to demonstrate some new features of the image analysis platform to iPlant. The communication between iPlant and the California lab was described as effective and pleasant. The only major issue they had in these years of collaboration was the negotiation of the integration schedule. "This group was really responsible and pleasant to work with. They care about what they're building and they have been building it for years. I think the passion was there," the project lead said.

Important Factors and Their Interactions: Compared to the innovation teams in our study, Team Image enjoyed several advantages that greatly helped to gather ideas and consensus early when the project was just initiated. First, the team had a good task-expertise mapping with two strong groups in the related areas – the developments of an image analysis platform and plant image analysis algorithms. Both groups were committed to the project and responsive, as reflected in the project lead's comment.

Second, the California lab had been developing an image analysis platform before the project was funded, and had its own development schedule. The already existing platform became a shared artifact that helped the three parties involved (i.e., iPlant, the California lab, and the Wisconsin group) to envision how their collaboration could be organized. In addition, the California lab's own development schedule provided a basic project management framework that regulated the team's work pace.

Third, the project scope and the problem definitions were largely certain. "It was some certainty of what we wanted to do, 75% of clarity, other 25% to be developed and watched as things went along." Fourth, the decision structure followed a simple buyer-vendor model – iPlant as the trusting buyer and the California lab and the Wisconsin group as the trustworthy vendor. "They had the expertise that we didn't have, so we couldn't second guess them…but what we saw after looking around, they were developing the most prominent technology for doing this." iPlant simply requested the system features that it needed and negotiated the implementation schedule. The decisions among the three parties regarding the implementation schedule were made unanimously – "it's just discussed, negotiated." Overall, according to our theoretical model in Chapter 3, with a good task-expertise mapping, the time commitment, the shared artifact, a basic project management framework, largely certain problem definitions, and unanimous decision structure among the three parties, Team Image successfully initiated both processes of differentiation and integration in its group discussion, as reflected in the mixed topics of the abstract project roadmap planning and the specific backend systems integration. Although Team Image did not have regular conference calls, and on many occasions communicated via emails, the team communication was described as effective with high consensus reached.

The only problematic factor in the early phase of the project was that iPlant just started developing its cyber-infrastructure with which the image analysis platform was to be integrated. This made a critical piece of contextual information in the project unclear at that time. But once the iPlant cyber-infrastructure was taking shape, the group discussion was mostly driven by the process of integration and focused on the system integration issues (because the factor of clear contextual information in our model also promotes the process of integration). This was evident in the situation that the issues discussed in the conference call were so tightened in their linkages (one of our structural properties) that the Wisconsin group had no role in such a discussion. ("As the time went by, it was more iPlant and [the California lab] because we were discussing technical stuff that had nothing to do with [the Wisconsin group]"). There is an interaction observed between problem definitions and a shared artifact in the case of Team Image, as the image analysis platform helped the three parties involved to see what they could achieve with the project. The important factors and their interactions identified from Team Image are summarized in Table 5-4.

Table 5-4: Important Factors in Team Image

Time	Phase 1 (2009 – mid-2010)	Phase 2 (Mid-2011 – Mar. 2013*)
Discussion Patterns	Issue exploration: Effective Issue raising: Good Consensus: High	Issue exploration: Effective Issue raising: Good Consensus: High
Important Factors	• Strong task-expertise mapping (+DI) • Unanimous decision structure (+DI) • Some PM framework (+D) • Clear problem definitions with some uncertainty (+I) • Shared artifact (+I) • Time commitment (+M) o *Uncertain contextual information (~I)*	• Strong task-expertise mapping (+DI) • Unanimous decision structure (+DI) • Some PM framework (+D) • Clear problem definitions with some uncertainty (+I) • Shared artifact (+I) • Clearer contextual information (+I) • Time commitment (+M)
Interactions between Factors	- Problem definitions and a shared artifact	

*: The time that interviews were conducted; DI: The factor is related to both processes of differentiation and integration; D: The factor is related to the process of differentiation; I: The factor is related to the process of integration; M: The factor is a moderator; +:The factor was present and positive in its effect on discussion; ~: The factor was particularly mentioned but weak or absent in its effect on discussion

5.2.5 Team Channel (Virtual Project Team)

Team Channel was roughly formed in December, 2011 as an improvement project. Its goal was to develop a sustainable mechanism that would automatically synchronize the ever-growing plant reference genomes between two analytical platforms at iPlant - Platform Investigation and Platform Comparison. It was also positioned as a pilot project for demonstrating the concept that iPlant users could flexibly move their data around different platforms inside the iPlant cyber-infrastructure for performing different types of analysis. Team Channel had five core members, including the owner of Platform Comparison, an expert in Platform Investigation, a manager from the iPlant training program, a developer from a research center in New York, and a project coordinator from

SciPlant. The training program manager and the developer in New York were responsible for the genome data verification. They all were voluntary participants who helped with the project on the side.

For the first four months, the team had two or three intermittent conference calls about how to approach the project and design the mechanism. In April, 2012, the Comparison owner finished the modification of his platform and released a sample of exported genome data from the platform for the team to verify. However, the exported data did not meet the standard of quality that the developer in New York and the training program manager were expecting. While discussing how to solve this technical issue on the Platform Comparison side, the team was also talking about a short-term backup plan in case the mechanism could not be ready in time for a workshop in June. On May 1st, Team Channel decided to communicate mainly through emails and stopped having conference calls. Intense arguments over the technical issue broke out in emails among the Comparison owner and the two members responsible for the verification. At the end of May, the expert in Platform Investigation and the training program manager released a function based on the backup plan without informing others in the team. Team Channel was dissolved right after this incident.

Team Development: Although Team Channel included experts in the two analytical platforms involved and in the genome data verification, it did not benefit from this all-star cast. The Platform Investigation expert, the Platform Comparison owner, and the training program manager were known as the three strongest personalities at iPlant and had some history of conflicts in their previous collaborations. In early 2012 when the team was about to make specific action plans (Phase 1), a major collaboration issue already emerged - the Comparison owner could not get responses from the Investigation expert. “As we moved forward, I said – I need you to help on this other thing. Nothing would happen. Just not write back…A couple of months later, I went – we really need to do this. It’s like I did everything that I could. But this guy never got back.” The Comparison owner decided to move the project along by himself and started to modify Platform Comparison for his part of the work.

When the Comparison owner released a sample of exported genome data in April, several emails with direct criticism on the data quality were sent out by the members doing data verification. As a result, a project coordinator from SciPlant volunteered to help organize weekly conference calls for discussing the solution and backup plan for the data quality issue (Phase 2). The discussion during the conference call was described as tense but managed in a professional manner. “Clearly it wasn’t effective as it could be. But the conversation wasn’t destructive. Everyone was trying to come out with a solution. Everybody had different opinions on how to do it,” a member recalled. The conference call at the end would reach a certain level of consensus on an action plan. However, only after two weekly conference calls, some of the members suggested communicating mainly with emails and to stop having weekly conference calls. The team communication returned back to the point where there were only criticisms over the data quality issue during the email exchange (Phase 3). “I felt in this project that they wanted not to help so much in terms of finding solutions, but they wanted to find as many problems as possible, and that got a little bit frustrating. That's like I need more help creating solutions, not just finding problems," the Comparison owner reflected on the situation.

In mid-May, 2012, the training program manager and the Investigation expert stopped responding to emails regarding this project. By the end of May, these two members released a short-term solution based on a backup plan discussed during the conference calls. The collaboration in Team Channel was dissolved right after the incident. "There were a lot of egos in play. There were some hurt feelings," the project coordinator commented at the end.

Important Factors and Their Interactions: Team Channel started with a strong task-expertise mapping by having experts in all required areas (i.e., Platform Comparison, Platform Investigation, and genome data verification) and had clear project scope and problem definitions. "Once we realized there was a problem, it was more of a support project or how-we-fix-it kind of project." Its dismal fate was somewhat dictated by the factor of devotion or time commitment, as all members were volunteers. Due to the constant absence of the Investigation expert, the discussion pattern in the first four months was intermittent and lacked of cohesion. As a result, the team was not able to drill down to specific designs and discover potential technical issues early, which is consistent with our proposition 2 in our theoretical model that time commitment moderates the effect of team composition on team communication. When the Comparison owner delivered a sample of exported data, as a shared artifact, for a data verification member to check, the technical issues started to emerge. These technical issues were part of the contextual information in the project and complicated the originally clear project scope and problem definitions. Because of the lack of devotion, the data verification member was not willing to participate in meaningful discussion for finding solutions. “He just found problems so I couldn’t get him to help me, propose any solutions at that front.”

The involvement of the project coordinator from SciPlant helped to establish communication protocols in the team by organizing weekly conference calls. However, the more effective communication environment via conference calls, which promoted the exploration of multiple issues and the initiation of attention switches, triggered the emergence of a hidden factor in the team – the heterogeneity in ideas, (“Everyone was trying to come out with a solution. Everybody had different opinions on how to do it”). As a result, the discussion pattern was described as tense but somewhat ineffective. But through the facilitation of the project coordinator, who played the role of maintaining the relevance of discussion and facilitating the elaboration in the communication environment as discussed in our model in Section 3.6, the team could still reach certain concrete conclusions. “I was there mostly to try to facilitate, more of a mediator, let’s come to a happy medium on this, how about we do this and try this, try to make it so everybody can be happy with the solution that we came out with.” While the team was making progress, because of the lengthy discussion, some members suggested canceling the weekly conference calls and communicating with emails only. “And he went like, we can probably handle this offline, and they went like we can probably just sort of, let’s just have email updates.” The leaner communication medium like emails, which lacked the capacity for promoting integration (Dennis et al. 2008), put the team back to the situation that no one was willing to participate in constructive discussion that could resolve their differences and find common solutions. Thus the communication in the team gradually died out and a short-term solution suddenly popped out. “If the collaboration isn’t working and is not fun, there are a lot of things we have to do that can be a lot more fun. So we let this one sort of dropped.”

In the case of Team Channel, interactions were observed between the following factors from our model:

- Problem definitions and contextual information: The technical issues discovered during data verification complicated the originally clear problem definitions.
- Communication protocols and project management framework: The SciPlant project coordinator helped to established conference calls in the team.
- Heterogeneity and communication environment: The communication environment via conference calls made the heterogeneous ideas apparent in the group discussion.

The important factors and their interactions identified from Team Channel are summarized in Table 5-5.

Table 5-5: Important Factors in Team Channel

Time	Phase 1 (Dec. 2011 – April 2012)	Phase 2 (Late April – mid-May 2012)	Phase 3 (Mid-May – June 2012)
Discussion Patterns	Issue explore: Ineffective Issue raising: Moderate Consensus: Low	Issue exploration: To some degree ineffective Issue raising: Intense Consensus: Moderate	Almost no communication
Important Factors	• Strong task-expertise mapping (+DI) • Clear problem definitions (+I) • Shared artifact (+I) o *Lack of time commitment (~M)*	• Strong task-expertise mapping (+DI) • Communication environments (+DI) • Communication protocols (+DI) • High heterogeneity in beliefs (+D) • PM framework (+D) o *Unclear problem definitions (~I)*	• Strong task-expertise mapping (+DI) • High heterogeneity in beliefs (+D) o *Communication environments* (~DI) o *Unclear problem definitions (~I)* o *Lack of time commitment (~M)*
Interactions between Factors	- Problem definitions and contextual information	- Communication protocols and PM Framework - Heterogeneity and communication environments	

*: The time that interviews were conducted; DI: The factor is related to both processes of differentiation and integration; D: The factor is related to the process of differentiation; I: The factor is related to the process of integration; M: The factor is a moderator; +:The factor was present and positive in its effect on discussion; ~: The factor was particularly mentioned but weak or absent in its effect on discussion

5.3 Cross-case Analysis Results

In this section, we present our cross-case analysis results. We first analyze the relationship between an innovation team's capabilities and its communication dynamics. Then we present the common and unique factors that shape teams' behaviors within and across case types. Specifically, we compare (1) the innovation teams between the local and virtual settings and (2) the virtual teams between the innovation and general project orientations.

5.3.1 Team Capabilities and Communication Dynamics

In our model, we suggest that the dynamics of team communication affect the team's capabilities. Specifically, the process of differentiation affects the team's ability to manage team process and unexpected situations. The process of integration affects the level of consensus that the team reaches on its action plans. To explore this relationship between team communication and team capabilities, we summarize the informants' subjective evaluations on our case teams' performance and their team members' reported discussion patterns as shown in Table 5-6. During the interviews, we also asked the participants to evaluate their own team's performance. Their self-evaluations are consistent with the informants' evaluations. From Table 5-6, we can see that there is a clear relationship between the level of success that a team achieved and its discussion patterns, no matter whether it is an innovation or a project team. For those teams that were considered successful, even though some of them had suboptimal beginnings, they all demonstrated constructive discussion patterns in the later phase. That is, well-developed and balanced differentiation and integration processes. The constructive discussion patterns and team success are often associated with a good level of confidence in the team's capabilities to execute the project during the interviewees' reflections. For example, in the case of Team Image, "very effective (the team discussion), they are very responsible groups to work with." "It's successful…They know what they're doing." In the case of Team System, "[n]ow we're at a point of knowing what we're building…

everyone is kind of understanding what the system is and what the system could be…I think it's definitely been a success. I think we definitely have built something that is notable in the science software world. So I think that's really cool."

Table 5-6: Discussion Patterns and Level of Team Success

Success	Team	Type	Discussion Patterns		
			Phase 1	Phase 2	Phase 3
Successful	System	Innovation Local	IE: Ineffective IR: Conflicts Consensus: Low	IE: Effective IR: Good Consensus: High	
	Fusion	Innovation Virtual	Sporadic conversations for idea sharing	IE: Effective IS: Good Consensus: High	
	Image	Project Virtual	IE: Effective IR: Good Consensus: High	IE: Effective IR: Good Consensus: High	
Less successful	Analysis	Innovation Virtual	Almost no communication	IE: Ineffective IR: Intense Consensus: Low	
	Channel	Project Virtual	IE: Ineffective IR: Moderate Consensus: Low	IE: Somewhat Ineffective IR: Intense Consensus: Moderate	Almost no communication

IE: Issue exploration; IR: Issue raising; Consensus: Consensus reached

On the other hand, for those teams that were considered less successful, as shown in Table 5-6, their discussion patterns were consistently ineffective, often demonstrated through an aggressive differentiation process (i.e., intensive arguments) and a low integration process (i.e., unwilling to compromise their positions). Their team members' reflections were full of frustrations and doubts about the collaboration. For example, in the case of Team Analysis, "the meeting wasn't very effective…I don't think they would be able to give completely usable products." In the case of Team Channel, "it was hard to communicate effectively with them in terms of affecting desired outcomes for different stages of the project…I would say I would get pretty frustrated with them, I would sense they would probably get frustrated with me." Overall, as shown in our cases, a team's discussion patterns clearly have effects on its team capacities and level of success. This pattern is consistent with our proposition P1.

In the following sections, we will present the results for our two cross-type comparisons – local versus virtual innovation teams and innovation versus project virtual teams. In these two comparisons, a table that lists all the four categories of factors in our theoretical model is used as a standard comparison framework as shown in Table 5-7. It is noted that since we did not collect specific data regarding the proposed four structural mechanisms in the communication environment (in Section 3.6), we listed these four mechanisms as one factor – communication environments. With this standard framework, we marked appeared important factors in each case for comparison. The two cross-type analysis results are presented as follows.

Table 5-7. Standard Comparison Framework for Cross-case Analysis

Category	**Factor**
Team composition	Task-expertise mapping (DI) Heterogeneity (D) Time commitment (M)
Semi-structures	Leadership (DI) Decision structure (DI) Communication protocols (DI) Familiarity (D) PM Framework (D) Open norm (D) Problem definitions (I)\ Shared language (I)
Communication context	Discussion size (D) Contextual information (I) Shared artifact (I)
Communication environments	Communication environments (DI)

DI: The factor is related to both processes of differentiation and integration; D: The factor is related to the process of differentiation; I: The factor is related to the process of integration; M: The factor is a moderator;

5.3.2 Comparison between Local and Virtual Innovation Teams

For the innovation teams, including the local and the virtual innovation teams, twelve factors are identified to play an important role in shaping the team's discussion patterns as shown in Table 5-8. In the team composition category, all three factors – task-expertise mapping, heterogeneity, time commitment – are found important in one or more cases. In the semi-structure category, seven out of eight semi-structures are mentioned – leadership, decision structure, communication protocols, familiarity, project management (PM) framework, problem definitions, shared language. The only exception is the openness norm; the interviewees did not mention that their expression of different opinions was encouraged or suppressed by a team norm. In the communication context category, contextual information and shared artifacts are found to have an effect. Since our teams were not that different in size, we did not observe any specific effect of discussion size on team communication. We also did not observe any particular role that the communication environments play in the cases of innovation teams. Although Team Fusion switched its major communication medium from emails to conference calls in the later phase, other factors are more prominent and significant in explaining its change in discussion patterns (e.g., problem definitions, PM framework, communication protocols, and shared artifact).

To identify (1) which factors are critical in differentiating successful innovation teams from less ones and (2) which factors are unique to virtual innovation teams, we put the innovation teams that show the same outcome or attribute (i.e., successful versus less successful, and local versus virtual) side by side for comparison as shown in Tables 5-8 and 5-9. The comparison results are summarized as follows.

Table 5-8: Successful versus Less Successful Innovation Teams

Success		Successful		Less Successful	
Team		System (P2)	Fusion	System (P1)	Analysis
Important factor	Task-expertise mapping (DI)	+	~ +	+	~ ~
	Heterogeneity (D)			+	+ +
	Time commitment (M)		+		~
	Leadership (DI)	+		~	~ +
	Decision structure (DI)	+	+	~	
	Communication Protocols (DI)		+		+
	Familiarity (D)	+			
	PM Framework (D)		+		+
	Problem Definitions (I)	+	~ +	~	~ ~
	Open norm (D)				
	Shared language (I)	+	+		
	Discussion size (D)				
	Contextual information (I)	+		~	~
	Shared artifact (I)	+	+		
	Communication environments(DI)				
Interaction between factors	Heterogeneity & Decision structure			√	
	Decision structure & Leadership	√		√	
	Problem definitions & Contextual information	√	√	√	√
	PM framework & Contextual information	√			
	Contextual information & Shared artifact	√			
	Shared language & Shared artifact	√	√		
	Task-expertise mapping & Problem definitions		√		
	Communication protocols & PM framework		√		√

+:The factor was present and positive in its effect on discussion; ~: The factor was particularly mentioned but weak or absent in its effect on discussion; √: The interaction appeared

Successful versus Less Successful Innovation Teams: When analyzing the success factors in the innovation teams, we decided to treat Team System's Phase 1 and Phase 2 as two teams instead of consecutive phases in the team development. This decision is justified based on four reasons. First, these two phases were separated by a significant reorganization that lasted five months in the first half of 2011 (January – May, 2011). During this reorganization period, many of the team's initial members left iPlant, including its first team manager. As a result, there was not much overlap in personnel between these two phases. Second, Team System rewrote most of its analytical platform during Phase 2. "We've coded and deleted all the code from the first two releases. The code is completely turned over from what it's right now to where it was in 2010." As a result, the platform did not constitute a shared artifact that could bridge ideas between these two phases. Third, from the informants' point of view, Team System was very different under the two team managers' leadership. "[Team System] has significant reformation and adjustments. Senior manager was fired, and new manager stepped in. Very different personality, very different ability to get the team to produce, very different management style." Last but not least, each phase covered at least one and a half years in the team's life span. The length of time in each phase was sufficient for the team to develop a stable behavior and discussion patterns. After considering these four issues, we felt that it would be more meaningful and insightful to treat Team System's two phases as two teams in terms of team success, Phase 1 as less successful and Phase 2 as successful.

From Table 5-8, five factors are identified to differentiate less successful innovation teams from successful ones in our case study:

(1) Heterogeneity: The less successful teams – Team System Phase 1 and Team Analysis – were constantly trapped in severe disagreements because of very different ideas on how the project should proceed, whereas in the successful

teams – Team System Phase 2 and Team Fusion, team members respected one another's opinions and were able to find common ground for their collaboration.

(2) Problem definitions: The less successful teams suffered unclear problem definitions. At the same time, they passively received contextual information that was inconsistent in perspective, which further deepened the teams' confusion as revealed by the interaction between problem definitions and the contextual information. The successful teams, on the other hand, were able to clarify their problem definitions by actively researching or collecting contextual information. For example, Team Fusion researched iPlant's innovation capacity by iPlant-related publications and identified the semantic web technology. Team System in Phase 2 adopted the practice of user acceptance testing to engage users early in the development process.

(3) Decision structure: The successful innovation teams had a clear decision structure that promoted unanimity. In Team System Phase 2, the new team manager created a committee-like structure that major decisions were made among him, the requirement analyst, and the two technical leads in the service and UI areas. If the developers had concerns about the decision, they would come directly to him for a discussion. In Team Fusion, the decision structure was like a perfect consultant-advisee relationship that the three developers respected one another's opinions and sought consensus. But in the less successful teams, the decision structure was either unclear or absent. In Team System Phase 1, the first team manager would gather everyone for open discussion but steered the meeting toward a certain

direction that she wanted. In Team Analysis, there was no decision structure at all; every member behaved as independent.

(4) Shared artifact: The less successful team did not have a shared artifact that every member could agree on to bridge their ideas and opinions. In Team Analysis, every core member developed their own work without sharing it with one another. In Team System Phase 1, the Service team refused to accommodate the UI team's needs, even though they were developing the same platform. As a result, the UI team had to constantly find its way through without the service team's involvement. But in the successful teams, members had a shared artifact to bridge conversations when making design decisions. In Team Fusion, the artifact was the semantic web services and the test implementation that the team was working on during the kickoff meeting. In Team System Phase 2, the artifact was the analytical platform that had been re-designed from the UI perspective.

(5) Shared language: From the shared artifact, the successful teams were able to develop a shared language that helped teammates to communicate their understanding and ideas about the system they were working on, as indicated by the interaction between the shared artifact and the shared language. For the less successful teams, they did not have a shared artifact. As a result, they did not develop a shared language to facilitate team communication.

In sum, the successful and less successful innovation teams in our study were differentiated by five factors – (1) heterogeneity, (2) problem definitions, (3) decision structure, (4) shared artifact, and (5) shared language. Although we did not notice any interaction between heterogeneity and problem definitions during the data analysis, their co-appearance may imply that when problem definitions are unclear, heterogeneous ideas about the project are more likely to happen and persist.

Local versus Virtual Innovation Teams: From Table 5-9, three factors unique to the virtual innovation teams in our theoretical model are identified – (1) time commitment, (2) communication protocols, and (3) PM framework. Since members in a virtual team are not tied together in one physical facility, when the project or collaboration gets difficult, they can easily avoid communication with one another as revealed in the situation of Team Analysis in Phase 1. Time commitment in our model is a moderator that changes the magnitude of effect of team composition on team communication. That is, when team members show high time commitment, they are more likely to participate in the group discussion and contribute to both processes of differentiation and integration. This moderating effect of time commitment is an important factor for virtual innovation collaborations because it creates a positive team atmosphere that members are willing to overcome their physical bounds to work together and help each other solve problems.

Table 5-9: Local versus Virtual Innovation Teams

Local/Virtual		Local		Virtual			
Team		System		Fusion		Analysis	
Important factor	Task-expertise mapping (DI)	+	+	~	+	~	~
	Heterogeneity (D)	+				+	+
	Time commitment (M)				+	~	
	Leadership (DI)	~	+			~	+
	Decision structure (DI)	~	+		+		
	Communication Protocols (DI)				+		+
	Familiarity (D)		+				
	PM Framework (D)				+		+
	Open norm (D)						
	Problem Definitions (I)	~	+	~	+	~	~
	Shared language (I)		+		+		
	Discussion size (D)						
	Contextual information (I)	~	+			~	
	Shared artifact (I)		+		+		
	Communication environments (DI)						
Interaction between factors	Heterogeneity & Decision structure	√					
	Decision structure & Leadership	√	√				
	Problem definitions & Contextual information	√	√	√		√	
	PM framework & Contextual information		√				
	Contextual information & Shared artifact		√				
	Shared language & Shared artifact		√		√		
	Task-expertise mapping & Problem definitions				√		
	Communication protocols & PM framework				√		√

+:The factor was present and positive in its effect on discussion; ~: The factor was particularly mentioned but weak or absent in its effect on discussion; √: The interaction appeared

The communication protocols and project management framework together, as indicated by their interaction, help create basic collaboration rhythms with which team members meet on a regular basis to discuss their ideas, progress, and problems. This is, in some way, consistent with the proposition of Maznevski and Chudoba (2000) that effective virtual teams develop a rhythmic communication pattern defined by regular group meetings. For example, Team Fusion consistently met their milestones by having weekly conference calls and progress reports. In the case of Team Analysis, when the project manager from SciPlant got involved in Phase 2, the team started to deliver and have conversations about their project roadmap. Overall, these three factors (i.e., time commitment, communication protocols, and PM framework) can foster trust and confidence in virtual innovation teams as members are dealing with highly uncertain and complex tasks. More importantly, these three factors make project-related issues more likely to be discussed and addressed in a timely manner, enhancing the team's capabilities to manage unexpected problems or situations.

5.3.3 Comparison between Innovation and Project Virtual Teams

For the virtual teams, twelve factors are found to play an important role in shaping the team's discussion patterns, as shown in Table 5-10. In the team composition category, all three factors – task-expertise mapping, heterogeneity, time commitment – are found important in two or more cases. In the semi-structure category, six out of eight semi-structures are mentioned – leadership, decision structure, communication protocols, project management (PM) framework, problem definitions, shared language. Consistent with the comparison of the innovation teams, we did not observe the effect of open norm. In addition, the virtual teams do not have the factor of familiarity, which appeared only in the case of Team System. In the communication context category, contextual information and shared artifacts are found to have an effect. As in the comparison of the innovation teams, we did not observe any specific effect of discussion size on team communication in the virtual teams. We found the factor of communication environments in the virtual teams, as the case of Team Channel shows how a change in the main communication medium could lead to different discussion patterns. For the interactions, three out of four virtual teams have interactions between problem definitions and contextual information and between communication protocols and the project management framework. These two interactions are also commonly found in the innovation teams, indicating their profound effects on general team interactions.

Innovation versus Project Virtual Teams: As shown in Table 5-10, there are two factors that differentiate the innovation virtual teams from the project virtual teams – problem definitions and task-expertise mapping. The innovation virtual teams had a general, vague project scope in the beginning, which to some degree hindered the team's ability to decide what kinds of expertise would be required for the project. For example, in the case of Team Fusion, the semantic web developer would not have been recruited if the team did not discover the use of the semantic web technology for solving its data integration problem. According to our theoretical model, the task-expertise mapping is an important factor that promotes both differentiation and integration processes. When the innovation virtual teams did not have a good task-expertise mapping to start with, they also could not have meaningful discussion in their early phase as seen in Teams Fusion and Analysis. The communication was almost dead in these two teams in their Phase 1. Compared with the innovation virtual teams, the project virtual teams started with clear problem definitions and, consequently, could effectively evaluate if the team had experts in all required areas. This led to a better task-expertise mapping in their initial composition as well as better initial discussion patterns. For example, in Team Channel, even though its members lacked time commitment and group discussion was sporadic, when the two key members (i.e., the Comparison owner and the Investigation expert) could finally get together for two or three short discussions, they would describe the discussion as good and productive.

Table 5-10: Innovation versus Project Virtual Teams

Innovation/Project		Innovation		Project	
Team		Fusion	Analysis	Image	Channel
Important factors	Task-expertise mapping (DI)	~ +	~ ~	+ +	+ + +
	Heterogeneity (D)		+ +		+ +
	Time commitment (M)	+	~	+ +	~ ~
	Leadership (DI)		~ +		
	Decision structure (DI)	+		+ +	
	Communication Protocols (DI)	+	+		+
	Familiarity (D)				
	PM Framework (D)	+	+	+ +	+
	Open norm (D)				
	Problem Definitions (I)	~ +	~ ~	+ +	+ ~ ~
	Shared language (I)	+			
	Discussion size (D)				
	Contextual information (I)		~	~ +	
	Shared artifact (I)	+		+ +	+
	Communication Environments (DI)				+ ~
Interaction between factors	Heterogeneity & Communication Environments				√
	Problem definitions & Contextual information	√	√		√
	Problem definitions & Shared artifact			√	
	Shared language & Shared artifact	√			
	Task-expertise mapping & Problem definitions	√			
	Communication protocols & PM framework	√	√		√

+:The factor was present and positive in its effect on discussion; ~: The factor was particularly mentioned but weak or absent in its effect on discussion; √: The interaction appeared

Table 5-11: Successful versus Less Successful Virtual Teams

Success		Successful		Less Successful	
Team		Fusion	Image	Analysis	Channel
Important factor	Task-expertise mapping (DI)	~ +	+ +	~ ~	+ + +
	Heterogeneity (D)			+ +	+ +
	Time commitment (M)	+	+ +	~	~ ~
	Leadership (DI)			~ +	
	Decision structure (DI)	+	+ +		
	Communication Protocols (DI)	+		+	+
	Familiarity (D)				
	PM Framework (D)	+	+ +	+	+
	Open norm (D)				
	Problem Definitions (I)	~ +	+ +	~ ~	+ ~ ~
	Shared language (I)	+			
	Discussion size (D)				
	Contextual information (I)		~ +	~	
	Shared artifact (I)	+	+ +		+
	Communication Environments (DI)				+ ~
Interaction between factors	Heterogeneity & Communication Environments				√
	Problem definitions & Contextual information	√		√	√
	Problem definitions & Shared artifact		√		
	Shared language & Shared artifact	√			
	Task-expertise mapping & Problem definitions	√			
	Communication protocols & PM framework	√		√	√

+:The factor was present and positive in its effect on discussion; ~: The factor was particularly mentioned but weak or absent in its effect on discussion; √: The interaction appeared

Successful versus Less Successful Virtual Teams: From Table 5-11, four factors are identified to differentiate the successful from the less successful virtual teams in our study:

(1) Heterogeneity: The cases of Teams Analysis and Channel reveal that when a virtual team has strong different opinions about the way the project should be approached (i.e., the factor of heterogeneity in beliefs), team members have the

tendency to decrease, rather than increase, their internal discussion because the process of differentiation was highly intensified, and the communication cost for reaching agreements via emails or conference calls became too high. This behavior pattern exacerbates the already problematic team situation. For example, Team Channel voted to switch back to email exchanges after two lengthy conference calls when strong different opinions still persisted within the team. Intense disagreements via emails took place again afterward, and eventually team members just stopped responding to each other.

(2) Time Commitment: The successful virtual teams demonstrated high level of interest and devotion in their collaboration (i.e., time commitment), whereas the less successful teams did not. In addition, the successful virtual teams all had good task-expertise mapping in their later phase and no heterogeneity factor. According to our theoretical model, the time commitment, as a moderator, would increase the magnitude of the effect of team composition on team communication. In the case of the successful virtual teams, the factor of good task-expertise mapping was magnified, significantly promoting both processes of differentiation and integration. As a result, their team communication was effective. In Team Image, a successful virtual project team, the project manager at iPlant could initiate effective conversations with any of the core members at any time, even though the team never had regular group meetings. ("Very effective, they are very responsible groups to work with"). On the other hand, in Team Analysis, a less successful virtual innovation team, team members would expect others to carry

out the job instead of taking responsibilities. As reflected in a member's comment, "[a teammate] likes to tell people what to do and say this is what we need, but doesn't really contribute to solving the problem." This lack of time commitment created a negative discussion atmosphere and reinforced the low interest in the virtual collaboration.

(3) Decision structure: The successful virtual teams had a clear decision structure that promoted unanimity. For example, Team Image followed a simple buyer-vendor model and the decisions regarding the implementation schedule were all made unanimously among the three parties. ("It's just discussed, negotiated"). According to our theoretical model, a unanimous decision structure helps promote both processes of differentiation and integration, leading to more effective discussion patterns. But in the less successful virtual teams, there was no clear decision structure that could effectively resolve differences and gather consensus. For example, in Team Channel, the project coordinator had to bridge the team's different opinions and help team members find the acceptable middle ground for their action plans.

(4) Problem definitions: According to our theoretical model, when a team has clear problem definitions, team members are more likely to identify important and relevant issues in the project and discuss these issues systematically. This helps to make the team discussion more focused and promotes the process of integration. The successful virtual teams – Teams Fusion and Image – had clear problem definitions in their later phases. On the other hand, the less successful virtual

teams suffered unclear problem definitions that hampered the effectiveness of their discussions. For example, in Team Channel, the problem definitions became unclear when the data quality issue emerged during the validation process. As a result, team members started to have different ideas on how to solve the problem and could not reach agreement effectively. ("Everyone was trying to come out with a solution. Everybody had different opinions on how to do it").

In sum, the successful and less successful virtual teams in our study were differentiated by four factors – (1) heterogeneity, (2) time commitment, (3) problem definitions, and (4) decision structure. A summary for our within-case and cross-case analysis results is provided in the next section.

5.4 Chapter Summary

In this Chapter, we present our within-case and cross-case analysis results. For the five selected teams in our study, we summarized the history of their team development and discussed the important factors that influenced and shaped their discussion patterns. In our cross-case analysis, we analyzed the relationship between an innovation team's capabilities and its communication dynamics, and identified common and unique factors within and across case types. For the relationship between team capabilities and communication dynamics, we found a clear connection between the level of success that a team achieved and its discussion patterns, no matter whether it is an innovation or a project team. In addition, the constructive discussion patterns and team success are often associated with a good level of confidence in the team's capabilities in the interviewees' reflections, whereas for the teams that were considered less successful, their members often expressed frustration and doubts about the collaboration. These observations are consistent with our proposition P1.

Table 5-12: Summary of Cross-case Analysis Results

Success		**Successful**			**Less successful**		
Type		Local Innovation	***Virtual*** Innovation	***Virtual*** Project	Local Innovation	***Virtual*** Innovation	***Virtual*** Project
Team		System(P2)	Fusion	Image	System(P1)	Analysis	Channel
Team composition	Heterogeneity(D)				+	+ +	+ +
	Task-expertise mapping(DI)	+	~ +	+ +	+	~ ~	+ + +
	Time commitment(M)		+	+ +		~	~ ~
Semi-structures	Leadership(DI)	+			~	~ +	
	Decision structure(DI)	+	+	+ +	~		
	Communication protocols(DI)		+			+	+
	Familiarity(D)	+					
	PM Framework(D)		+	+ +		+	
	Problem definitions(I)	+	~ +	+ +	~	~ ~	+ ~ ~
	Open norm(I)						
	Shared language(I)	+	+				
Communication contexts	Discussion size(D)						
	Contextual information(I)	+		~ +	~	~	
	Shared artifact(I)	+	+	+ +			+
Communication environments	Communication environments(DI)						+ ~

+:The factor was present and positive in its effect on discussion; ~: The factor was particularly mentioned but weak or absent in its effect on discussion

For the common factors that consistently affected and shaped the development of the differentiation and integration processes across case types (i.e., local versus virtual innovation teams, and innovation versus project virtual teams), we had a number of findings as summarized in Table 5-12. First, in the category of team composition, we found that heterogeneity in beliefs played a critical role in determining a team's collaboration outcomes by intensifying the team's differentiation process. This is consistent with our proposition P2(a). In addition, the moderating effect of time commitment was significant in a virtual team setting, which is largely consistent with our proposition P2(c). However, regarding the factor of task-expertise mapping, we had mixed findings. We found that when the factor of heterogeneity did not appear in the team, the effect of task-expertise mapping was magnified, leading to constructive discussion patterns (i.e., a good balance between the differentiation and integration processes). But when heterogeneity appeared, the task-expertise mapping did not provide reliable predictions. Therefore, proposition P2(b) was conditionally supported by our observations.

Second, in the category of semi-structures, although we observed seven out of eight semi-structures in our cases, only two semi-structures had consistent effects across case types – decision structures and problems definitions. The successful teams in our study all had a clear decision structure that promoted unanimity. Team System Phase 2 had a committee decision structure, Team Fusion had a consultant-advisee relationship for decision making, and Team Image followed a simple buyer-vendor model. But for the less successful teams, we did not observe a clear decision structure that could effectively promote both differentiation and integration. The successful teams also had clear problem definitions in their later phase, whereas the less successful teams did not. For the innovation teams, we additionally found that the factor of shared language was important. Specifically, when a team has a system prototype with which all members can work together, the prototype can help create a shared language among members to facilitate discussion and finding solutions. Overall, our proposition P3 is partially supported by our observations.

Third, in the category of communication factors, we did not observe any effect from the factor of discussion size because all our teams were similar in size. As a result, we are not able to validate our proposition P4(a) at this point. For the contextual information, we found that if a team is able to enhance its discussion with extensive contextual information, it would have a higher level of consensus and better collaboration outcomes. However, this effect was not consistently observed across case types as shown in Table 5-12. Thus, our proposition P4(c) is only partially supported. As discussed in the factor of shared language, we found that a shared artifact played an important role in facilitating innovation teams' communication, especially by helping team members clarify project-related issues and create shared understandings. This observation is largely consistent with our proposition P4(b).

Regarding the four structural supports in an overall communication environment (i.e., sensible structures for regulating the exploration of multiple issues, the ability to promptly gain audience's attention, the support of managing the relevance and transitions of discussion, and the initiation of an effortless elaboration process), we observed some effect in the case of Team Channel when the team switched its major communication media between email and conference call. But we did not have enough data to validate the corresponding proposition P5. A summary of our propositions and case study observations is provided in Table 5-13. Overall, we identified five common factors that differentiate the successful from the less successful innovation teams – heterogeneity, problem definitions, decision structure, shared artifact, and shared language. We also found that the factors of heterogeneity, time commitment, decision structure, and problem definitions distinguish between the successful and the less successful virtual teams. The implications of our analysis results are discussed next in Chapter 6.

Table 5-13. Summary of Propositions and Case Study Observations

Factor	Proposition	Case Study
Team Capabilities	P1: The processes of differentiation and integration in team communication affect an innovation team's capabilities. (a) The process of differentiation affects an innovation team's capability to manage team process and unexpected problems. (b) The process of integration affects the degree to which an innovation team has consensus on its action plan. (c) The effect of the differentiation process on team capabilities has to be established on the condition that diverse perspectives have converged around a broader frame of communication by the process of integration.	P1:consistently observed across case types
Team Composition	P2: Team composition factors affect the development of the differentiation and integration processes in team communication. (a) The heterogeneity of membership promotes the process of differentiation. (b) A good mapping between task requirements and team members' expertise facilitates both processes of differentiation and integration. (c) The effects of team composition factors on team communication are contingent upon team members' time commitment and timely responses.	P2(a):consistently observed across case types; P2(b): conditionally observed; P3(c) consistently observed in virtual teams
Semi-structures	P3: Semi-structures affect the development of the differentiation and integration processes in team communication. At the same time, the dynamics of team communication also affects the development of semi-structures. (a) Familiarity, openness norm, and project management framework promote the process of differentiation. (b) Problem definitions, shared language facilitates the process of integration. (c) Unanimous decision structure, effective leadership, and communication protocols improve both processes of differentiation and integration. (d) Semi-structures evolve and develop with team communication over time.	P3: partially observed; (problem definitions and decision structure are consistently observed across case types; shared language is consistently observed in innovation teams)
Communication Contexts	P4: Communication context factors affect the development of the differentiation and integration processes in team communication. (a) The size of discussion affects the process of differentiation. (b) Shared artifacts improve the process of integration. (c) The input of contextual information, including external evaluators' feedback and major technical challenges that the team is facing as a whole, promotes the process of integration.	P4(a): not able to validate; P4(b): consistently observed in innovation teams; P4(c): partially observed
Communication Environments	P5: Communication environment mechanisms affect the development of the differentiation and integration processes in team communication. (a) To promote the process of differentiation, a sufficient communication environment needs to provide sensible structures for regulating the exploration of multiple issues and the ability for individuals to promptly gain audience's attention to raise concerns or issues. (b) To promote the process of integration, a sufficient communication environment needs to provide the support for managing the relevance and transitions of discussion and the initiation of an effortless elaboration process.	P5: not able to validate

CHAPTER 6: DISCUSSION AND IMPLICATIONS

Innovation has been a motto of corporations in high velocity industries to thrive in the ever-changing business environment. Even though researchers have devoted years to finding the secret recipe for successful innovation, research is full of conflicting principles and requirements, especially in the organizational aspect of innovation (e.g., the impacts of corporations' culture and structure and the management of an innovation project team). In this dissertation, we consider that these conflicting requirements are caused by the simultaneous needs for differentiation and integration, a phenomenon evident in the innovation literature. By taking a communication/interpretation perspective, we developed a comprehensive theoretical model to investigate how these two processes – differentiation and integration – are shaped by various factors during group discussions, and influence an innovation team's collaboration dynamics. We also conducted a case study that included one local innovation team, two virtual innovation teams, and two virtual project teams to explore the validity of our theoretical model and found that the model was able to comprehensively explain the discussion dynamics of the five case teams and their collaboration outcomes.

This dissertation makes five major contributions. First, from the literature on decision making, team process, and group consensus, we delineated four structural properties of team communication – the number of issue streams explored, the number of attention switches initiated, the conceptual linkage between issue streams, and the level of deliberation after each attention switch. These four structural properties together provide a systematic way to capture the development of the differentiation and integration processes over time. Second, we identified four categories of factors that influence and shape the development of team discussion – team composition, semi-structures, communication contexts, and communication environments. These four categories of factors can systematically explain how the processes of differentiation and integration evolve over time and create specific discussion patterns. Third, considering the role of information systems in facilitating team communication, we proposed four structural supports that a communication environment needs to fulfill – sensible structures for regulating the exploration of multiple issues, the ability to promptly gain audience's attention, the support for managing the relevance and transition of discussion, and the initiation of an effortless interactive process of elaboration. These four structural supports are important for promoting both processes of differentiation and integration and have significant implications for creating a sufficient communication environment for an innovation team.

Fourth, we clarified the relationship between the two processes (i.e., differentiation and integration) and the collaboration outcomes. Specifically, we suggest that well-developed, balanced differentiation and integration processes during group discussions can increase the team's capabilities to manage team process and unexpected situations and at the same time, lead to a high level of team consensus on action plans. This relationship further enabled us to explain why some teams in our case study were regarded as successful and others were not. Last but not least, from our case study, we identified five important factors that differentiated the successful innovation teams from the less successful ones – heterogeneity, decision structure, problem definitions, shared language, and shared artifact. In addition, we also found that the factors of time commitment, communication protocols, and the project management framework were important to the virtual innovation teams. These findings provide valuable insights into the way that an innovation team should be organized and managed. Overall, our theoretical model provides a comprehensive way to diagnose an innovation project team's organizational issues through analyzing its discussion patterns and the interplay with its team environments. In addition, our case study illustrated how different factors in our theoretical model came into play in an innovation team and gradually molded the group discussion into specific patterns, which subsequently affected the team's collaboration outcomes. We believe that our theoretical model and the case study together contribute to better understandings of the sophisticated nature of innovation as well as the management of an innovation project team.

6.1 Implications and Directions for Future Research

This dissertation has six implications for research in the areas of innovation project teams and virtual teams. First, consistent with prior research (Ericksen and Dyer 2004; Jehn et al. 1999; Lovelace et al. 2001), we found that the factors in the team composition (i.e., heterogeneity, task-expertise mapping, and time commitment) play a crucial role in creating the basic interaction patterns of teams. Specifically, the task-expertise mapping, which indicated the information diversity in our study, was important and beneficial to both processes of differentiation and integration. The heterogeneity, which represented the value diversity, intensified the process of differentiation, causing internal arguments or even conflicts. The time commitment, acting as a moderator, increased or reduced the effects of the heterogeneity and task-expertise mapping on the group discussion. However, unlike some of the studies that regarded the heterogeneity in value as a potential catalyst for new ideas or understandings (Lovelace et al. 2001), we observed a fatal effect of the heterogeneity on team collaboration; once the factor of heterogeneity appeared, team members simply stopped communicating with each other unless a strong organizational factor was involved, as seen in Team System Phase 1, Teams Analysis, and Channel. This avoidance behavior may be attributed to individuals' inclinations towards heterogeneous ideas in a work relationship and the overall organizational structures (i.e., power and decision structure, peer or management pressure, the clarity of job responsibilities etc.). We encourage organizational and behavioral scholars to take on this interesting issue and further investigate how organizations can initiate some interventions to turn the factor of heterogeneity in beliefs from a negative force into a positive one.

Second, in our case study, we found that when problem definitions were unclear or vague, the factor of heterogeneity was more likely to emerge and persist. At the same time, we also observed an interaction between problem definitions and the contextual information. That is, the successful innovation teams would take some active measures, such as information research, expert counseling, and user acceptance testing, to elicit contextual information and clarify problem definitions. Although we did not find direct evidence in our study showing the relationship between the heterogeneity and the contextual information, we speculate that by engaging in the activities of researching and understanding its outside environments, an innovation team is more likely to consolidate different opinions and gather consensus on its action plans. Brown and Eisenhardt (1997) discussed a similar finding that successful innovation managers would devise a variety of low-cost experiments or information probes to understand the market and customers, and use the collected information to organize their innovation efforts. Future research should explain the relationship among the heterogeneity, problem definitions, and the contextual information in order to clarify their effects on one another.

Third, to our surprise, we did not observe a strong role of leadership in our case study. Three out of the five teams, including a successful innovation virtual team and a successful project virtual team (i.e., Teams Fusion and Image), did not have a specific person playing the role of a leader. In addition, we found that the effective leaders in the innovation teams (i.e., the team manager in Team System Phase 2 and the project manager from SciPlant in Team Analysis) were exercising their leadership through weaving the team's communication and decision making processes together. That is, they helped construct a clear, unanimous decision structure by facilitating team communication, taking care of individuals' opinions and ideas in the decision making process. For example, the team manager in Team System Phase 2 created a committee-like decision structure to simplify the decision making and communication processes in the team. But when developers had concerns or issues about the committee's decisions, they would come talk to him directly and he would help them resolve the concerns or issues. Furthermore, an effective leader should possess the expertise and ability to explain to his/her team members how various project-related issues are connected together and help them to see a bigger picture of the project. In this case, the project manager from

SciPlant in Team Analysis, who did not possess the domain expertise in the project, was less capable of achieving this. As a result, the team broke down again right after she reduced her involvement in the project. These findings about the effective leadership in an innovation team are consistent with the conclusion of Kerr et al. (1974) on the two important dimensions of leadership – consideration and initiating structure. These findings also explain why the leadership became less important when the team (1) had a good task-expertise mapping, (2) formed a clear, unanimous decision structure, and (3) initiated a constructive discussion atmosphere, an observation similar to what Kerr and Jermier (1978) called the "substitutes for leadership." We feel that the relationship among the leadership, decision structure, task-expertise mapping, and discussion patterns can be further clarified and theorized. Specifically, future research can look into the way that leadership exercises its influence through decision making and discussion processes in order to understand the conditions that a good task-expertise mapping, a clear decision structure, and a constructive discussion atmosphere can replace leadership.

Fourth, the communication protocols and project management framework were found to be important for the innovation virtual teams. This finding is, in some way, consistent with the proposition of Maznevski and Chudoba (2000) that effective virtual teams develop a rhythmic communication pattern defined by regular face-to-face meetings (in our case the pattern was established via regular conference calls). Furthermore, we also observed an interaction between the communication protocols and the project management framework. That is, when a virtual team adopted the project management framework, it was more likely to establish specific communication protocols with regular conference calls. This observation is consistent with the finding of Okhuysen and Waller (2002) that when a team adopts a semi-structure, it is more likely to adopt a second one as a result of spillover effects. However, in our case study, we do find an exceptional case – Team Image, a virtual project team that did not have regular conference calls but coordinated well. Its success can be explained by its clear problem definitions, team members' high time commitment, and a shared artifact to facilitate coordination and communication. Whether these three factors (i.e., clear problem definitions, high time commitment, and a share artifact) can replace the needs for specific communication protocols and regular conference calls, and create a more flexible communication and coordination model in a virtual team more generally is a question that requires further research to answer.

Fifth, as Malhotra et al. (2001) reported in their study, we also found that the existence of a shared artifact (i.e., a system or prototype with which team members were working and mutually agreed) helped cultivate shared understandings in the innovation team. Specifically, in the cases of Team System Phase 2 and Team Fusion, the shared artifact was used to create an information loop with the team's outside environments for early feedback (i.e., user acceptance testing) and constituted a shared language among team members when they were discussing about design issues and options. However, despite the importance of the shared artifact in the innovation effort, we do not find much investigation and discussion about it in the literature, and believe that theorizing the role of the shared artifact in innovation would be fruitful to enhance our understanding of the innovation collaboration.

Last, regarding the communication environments of a virtual team, we had three interesting observations from the case of Team Channel. First, we found that a "richer" communication medium, such as a conference call, helps promote the process of differentiation by increasing the number of issues and attentions that can be explored and initiated in a given amount of time. However, the communication medium itself does not support the process of integration in the discussion unless a moderator or facilitator is involved in helping tighten the linkage of issues and organize the process of elaboration. Second, due to the promotion of differentiation by the richer communication medium, the factor of heterogeneity in beliefs is more likely to be apparent to the team and affect the team's collaboration dynamics, especially by decreasing team members' time commitment to the project. Third, when the factor of heterogeneity appears, the team communication in the richer communication medium becomes lengthy and burdensome because, as more different opinions are flowing into the team, members would have to spend more effort to reach common ground. In such a situation, team members would be inclined to switch to a leaner communication medium, such as email, to decrease the diversity of information and opinions, as seen in in the case of Team Channel. These three observations all point to the inherent lack of integration elements in the communication media. How the communication environment of a virtual team can be constructed to facilitate the process of integration, with support for managing the relevance and transitions of discussion and the initiation of an effortless interactive process of elaboration, is an important topic for design science researchers to investigate.

6.2 Implications for Innovation Teams' Dynamics

We have three implications for innovation teams' communication and collaboration dynamics. First, we found that the communication dynamics of our successful teams (i.e., Teams System, Fusion, and Image) evolved over time from the process of differentiation to that of integration. For example, Team System in Phase 1 experienced extensive conflicts between two different camps of thought (i.e., user interface and web service). But as the project was maturing, there was a certain level of organizational pressure to push the team to move toward the process of integration, which triggered the major reorganization and the replacement of its leadership in early 2011. The process of integration became increasingly apparent in Team System during Phase 2. "At that point, the (communication) atmosphere was pretty light, once we started building towards October, it's much better. September, October, November, we were making progress." In Team Image, we also observed a similar pattern that in Phase 1, the team would have certain emphasis on the process of differentiation and discussed its overall plan for the future collaboration. But as the project was progressing over time, the team discussion became so focused that it actually excluded the Wisconsin group from contributing its different ideas to the team. This pattern of moving toward the process of integration over time is to some degree consistent with Karau and Kelly's attention focus model (1992) that when the time resource is recognized as scarce, temporal constraints are likely to become salient and propel individuals to focus on activities directly related to the task completion. However, except for Team Fusion, Teams System and Image were long-term project teams with a life span of at least three years. What factors actually made these two teams feel the scarcity of the time resource (e.g., the time or monetary investment or the elapse of time) and pushed them to move toward the process of integration is a question that requires further investigation.

Second, we found that the innovation teams in our study extensively adopted new semi-structures over time. For example, Team Fusion had five new semi-structures in Phase 2 – communication protocols, unanimous decision structure, project management framework, clear problem definitions, and shared language. Team System also established five semi-structures in Phase 2 to help facilitate the processes of differentiation and integration – familiarity, effective leadership, committee decision structure, better problem definitions, and shared language. From the literature, there are two different theories that can explain why a team would acquire new semi-structures. The first theory is the spillover effect that Okhuysen and Waller (2002) suggested – once a team adopted a semi-structure, its members are more likely to adopt a second or third one. The second theory is Giddens' structuration theory (1984) that a knowledgeable agent helps initiate structures through social interactions. In our case study, these two theories are both plausible for explaining the adoption of new semi-structures in innovation teams. For example, in Team Analysis, the adoption of communication protocols can be seen as the spillover effect of the project management framework. In Team Fusion, the new semi-structures were brought in by the semantic web developer (i.e., a knowledgeable agent). Since semi-structures play an important role in regulating team process and interactions, how these two theories can be integrated to provide a more comprehensive explanation for the adoption of the semi-structures is an area that requires further research.

Third, we observed two types of organizational interventions initiated by SciPlant that would change the collaboration dynamics of a team. The first type of intervention was to create opportunities for the team to interact with its outside environments, such as its community users, peer projects, and iPlant leadership. For example, SciPlant invited a group of post-docs to come on-site and evaluate Team System's computational platform, which led to the establishment of user accepting testing and a positive feedback loop between the team and its community users. The second type of intervention initiated by SciPlant was the direct involvement of a project manager in helping a team's communication and coordination. For example, a project manager from SciPlant joined Team Analysis and helped organize the team with regular conference calls and follow-ups. From our case study, we found that these two types of organizational interventions had totally different effects on teams' collaboration outcomes. The first type of intervention (i.e., creating opportunities for the team to interact with its outside environments) helped transformed Teams System and Fusion into successful innovation teams. The second type of intervention (i.e., direct involvement in facilitating team coordination) provided temporary relief from the collaboration difficulties of Teams Analysis and Channel. But when the project manager lessened his/her involvement in the team's activities, the team simply fell apart again. Since organizational interventions constitute an important measure for organizations to resolve the issues of dysfunctional teams, the nature of organizational interventions and their effects on team collaboration require further investigation and clarification.

6.3 Implications for Practice

From our theoretical model and case study, we have four implications for practice. First, in this dissertation, we developed a comprehensive theoretical model for understanding the complicated nature of an innovation team. Specifically, we delineated four structural properties of team communication to investigate if an innovation team is engaging a constructive discussion for pushing its task forwards, and identified four categories of factors that influence and shape the team's discussion patterns. From our case study, we found that this theoretical model can provide a systematic way to analyze a team's collaboration dynamics and outcomes. As a result, we believe that our theoretical model has significant practical value in diagnosing an innovation team's issues and difficulties. According to the aspect of issues (i.e., differentiation or integration) and its influencing factors in the model, corresponding organizational interventions can also be devised, such as adjusting team composition, instilling certain semi-structures, or providing relevant communication supports via the team's communication environments.

Second, when analyzing the effect of communication environments on group discussion in Team Channel, we found that the commonly used communication media, such as conference calls and email, were inherently insufficient to support the process of integration, often causing collaboration issues in virtual teams (as discussed in the last implication for research). At the same time, we also found that a shared artifact and an active approach to elicit contextual information can help create a shared language and clarify problem definitions. These four factors (i.e., a shared artifact, increasing contextual information, a shared language, and clear problem definitions) together can significantly improve the process of integration. When project managers find their virtual teams having difficulties in reaching consensus via conference calls, they may consider bringing in a shared artifact or organizing research activities for gathering more contextual information to increase integration factors and resolve the situation.

Third, while many companies believe that an all-star team is the key to successful innovation, our case study provides a slightly different story. We found that a strong task-expertise mapping was important to bring in different ideas and expertise into an innovation team. But the heterogeneity and time commitment played a more crucial role in determining the success of the collaboration. Specifically, if the team members had heterogeneous ideas about how to approach the project or lacked time commitment, even though together they created a strong task-expertise mapping, they were less likely to spend time to understand each other's ideas and synthesize their different insights into an innovation. This observation echoes Ericksen and Dyer's finding (2004) on the importance of (1) task-competent and time-engaged team members and (2) consensual and complete performance strategies in initiating a virtuous path in team collaboration. Therefore, when a project team is created to take on an innovation task, its overall task-expertise mapping, members' time commitment, and heterogeneity in beliefs need to be evaluated at the same time to ensure the success of collaboration.

Last, in our case study, we observed a unique role that SciPlant played in helping various projects at iPlant establish project management (PM) measures, such as creating an overall project roadmap, schedule, and milestones and having weekly conference calls and progress reviews. From the informants and interviewees' reflections, SciPlant performed three important functions at iPlant. First, SciPlant helped strengthen the information flow between a project team and its outside environments, including other peer projects, iPlant leadership, and the plant community. Second, by hosting weekly progress reviews, SciPlant helped create a rhythmic communication pattern in a virtual team, regulating the team's internal communication and work pace. Third, SciPlant had a neutral position to intervene in a dysfunctional collaboration and facilitate team communication, especially when the team did not communicate well or was having severe internal conflicts. In addition to assigning a dedicated project manager to a project team, SciPlant – a central, independent project management group - can provide an alternative model for establishing a project management framework in virtual or innovation teams.

6.4 Conclusion

Because of the competing forces and conflicting requirements inherently found in the nature of innovation, innovation project teams often struggle to accomplish the mission that they were set up to do. In this dissertation, we aim to provide a comprehensive understanding of the collaboration challenges that an innovation team is facing. By considering the simultaneous needs for differentiation and integration in the innovation effort and taking a communication/interpretive perspective, we developed a theoretical model to investigate how the processes of differentiation and integration are shaped through team communication and influence an innovation team's collaboration outcomes.

Specifically, we delineated four structural properties of team communication to capture these two processes – the number of issue streams explored, the number of attention switches initiated, the conceptual linkage between issue streams, and the level of deliberation after each attention switch, and identified four categories of factors that influence the development of these two processes – team composition, semi-structures, communication contexts, and communication environments. We conducted a case study at the iPlant Collaborative with five case teams to explore the validity of our theoretical model, and found that the model can provide comprehensive explanations for the collaboration dynamics and issues of these teams. After all things considered, we provide extensive discussion on the implications of this dissertation for future research and practice.

APPENDIX A: INSTITUTIONAL REVIEW BOARD (IRB) APPROVAL

THE UNIVERSITY OF ARIZONA.

Human Subjects
Protection Program

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HSPP Correspondence Form

Date: 04/13/12
Investigator: Susan Brown, Ph.D. **Department:** MIS/Eller
Project No./Title: 08-0077-00 The iPlant Collaborative: A Cyberinfrastructure-Based Community for a New Plant Biology
Current Period of Approval: 01/18/08 – No Expiration

IRB Committee Information

Administrative Action **Administrative Review – Modification**
FWA Number: FWA00004218

Documents Reviewed Concurrently

F213: Modification of Approved Human Research (signed 03/30/12)
Consenting Instruments:
Subject's Consent Form (version 04/06/12)
Recruitment Materials: Invitation Letter (dated 03/28/12)
Other (define): Interview Script

Description of Submission

- **Protocol changes:** Including a case study that investigates the factors that led some project teams in the iPlant project to be more successful than others. Interviews will be conducted with key members of selected teams. This will provide a better understanding of how geographically distributed teams learn to coordinator their task work more effectively. Subjects for these interviews will be recruited via invitation letters and will be asked to re-consent
- **New Subject's Consent form:** To reflect the new protocol procedures
- **New study documents:** Recruitment/Invitation Letter and Interview Script

Determination

Approved as submitted effective 04/13/12

Comments

1. For file documentation and complete, please update your Project Review Form to reflect all IRB Approved modifications since initial IRB approval. Please submit this at either your next protocol modification, or within 3 months of the date of this letter, whichever occurs first.

Regulatory Determination(s)

☒ Not Applicable

Elaine Jones

04/13/12

Elaine G. Jones, PhD, RN
Chair, IRB 2 Committee
UA Institutional Review Board
EGJ/deg

Date

Reminders: **No changes to a project may be made prior to IRB approval except to eliminate apparent immediate hazard to subjects.**

APPENDIX B: INFORMANT INTERVIEW SCRIPT

Opening question: Please describe your role in iPlant. How long have you been in that role and/or associated with iPlant?

Q1: Can you describe the different types of project teams that have been formed in iPlant?

Q2: Can you provide the examples of the teams under each type?

Q3: I'm looking for innovative project teams. First, the problem to be solved or the content of the final deliverable is poorly defined or conceptualized. Second, distinct new ideas are embodied in the final deliverable, such as new ways to link components together or new ideas about the final deliverable. Third, a high level of uncertainty is involved in the project, which is caused either by the novelty of technology or the complexity of procedure. Is any project team in iPlant close to this definition?

Q4: Can you provide more detail about those project teams? Did the project team already complete their project? What kinds of task does (did) the project team work on? What is the size of the project team? Why was the project team initiated in the first place?

Q5: What kind of technological and managerial support did iPlant provide to those project teams?

Q6: In your opinion, which teams have performed better? Why do you think they have performed better? Do you think what the factors that made them perform better?

Q7: Did any of those more successful project teams go through substantial adjustment or reformation? Can you describe the adjustments that they went through?

Q8: In your opinion, which teams were not performing as expected? Why do you think they were not performing as expected? Do you think what the factors that made them perform not as expected?

Q9: Did any of those less successful project teams go through substantial adjustment or reformation? Can you describe the adjustments that they went through?

Q10: If I want to interview some members of those project teams, who would you recommend I talk to?

APPENDIX C: TEAM MEMBER INTERVIEW SCRIPT

Background of the project:

1. When did the project start? Is the project completed?
2. How was the project initiated in the first place? Who initiated the project?
3. What were the major deliverables of the project?
4. How specific was the description in relation to the deliverables expected given in the first place?
5. When did the team start to actually work on the deliverables?
6. Please describe how the team defined the final deliverable (clear specifications from the task delegator without much group discussion defining it, core members defined it and divided the task, team members actively sharing their interpretations and reaching a consensus)?
7. From your perspective, what are the most challenging parts of this project?
8. How did the team define its overall roadmap and milestones?
9. How did the team manage its project related documents?

Team composition:

1. How many team members did you have? Did the size of the team change during project?
2. How was team members recruited (invitation, recommendation, or assigned)? Who was taking charge of member recruitment and made the decision?
3. Can you verify the team member list?
4. What was the mapping between task requirements and members’ expertise when members were recruited (role structure)?
5. How many members worked together before the project (familiarity)?
6. Where were team members’ physical locations(boundaries)?
7. When the team was forming, how were major decisions related to the task supposed to make (core group, majority vote, unanimity, or hierarchical)?

Context setting question:

1. How would you describe the collaboration style of each key member?
2. How would you describe the overall collaboration style of the team?
3. What were the major project related issues that the team encountered (eg., difficulty in managing progress, difficulty in converging different interpretations, difficulty in real-time communication, difficulty in managing project documents)?

4. What kinds of communication media that the team used for communication (e.g., telephone, email, Skype, conferencing software, groupware, Wiki, forum)

Communication patterns - Before the date that the deliverables were defined (or the first few weeks):

1. How frequently did the team meet for discussion?
2. How was the discussion usually initiated? Who would initiate the discussion?
3. What was the communication media used mainly for discussion?
4. How would you describe the structure of group discussion (open discussion without pre-defined agenda, open discussion with pre-defined agenda or issues, core members leading the discussion with specific issues to solve)?
5. What was the main agenda of group discussion (e.g., defining final deliverable, project schedule, group collaboration policies, job division and assignment)? Can you give some examples of the topics that were discussed?
6. How would you describe the discussion atmosphere at that time (how active was the discussion)?
7. How progressive were project-related issues explored?
8. How much consensus about the deliverables was there?
9. How were those project issues managed and followed up?
10. Would team members discuss task issues with emails between group meetings? How responsive were team members in email discussion? How frequent? What kinds of issues that the team would choose to discuss with emails instead of in group meetings?

Communication patterns - The last few weeks of the project (or now):

1. How frequently did the team meet for discussion?
2. How was the discussion usually initiated? Who would initiate the discussion?
3. What was the communication media used mainly for discussion?
4. How would you describe the structure of group discussion (open discussion without pre-defined agenda, open discussion with pre-defined agenda or issues, core members leading the discussion with specific issues to solve)?
5. What was the main agenda of group discussion (e.g., defining final deliverable, project schedule, group collaboration policies, job division and assignment)? Can you give some examples of the topics that were discussed?
6. How would you describe the discussion atmosphere at that time (how active was the discussion)?
7. How progressive were project-related issues explored?
8. How much consensus about the deliverables was there?

9. How were those project issues managed and followed up?
10. Would team members discuss task issues with emails between group meetings? How responsive were team members in email discussion? Did the frequency of email exchange increase or decrease ? What kinds of issues that the team would choose to discuss with emails instead of in group meetings?

Changes of discussion patterns (if any):

1. What triggered those changes?
2. When did those changes happen? Why?
3. From your perspective, did those changes help the team progress in their task? Why?

Wrapping up Question:

1. Overall, how successful was this team?
2. What factors do you believe were important to the team's success?
3. What factors do you believe might have gotten in the way of the team's success?
4. Is there anyone else you suggest we talk to about this team's process and outcome?

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