UNIVERSITY OF SOUTHAMPTON

FACULTY OF LAW, ARTS AND SOCIAL SCIENCES

School of Management

Knowledge Management in Innovation Teams

A Case Study of an IT Development Institute in Taiwan

by

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ABSTRACT

FACULTY OF LAW, ARTS AND SOCIAL SCIENCES
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Doctor of Philosophy

Knowledge Management in Innovation Teams
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This thesis focuses on how knowledge management activities are undertaken in innovation processes. The research adopts Snowden's perspective of context management to refer to knowledge management in technological innovation. In particular, the research investigates knowledge management activities within a team context, rather than focusing on organisational knowledge management systems. Hence, this research raises the overall research question 'how are knowledge management activities initiated and undertaken to enhance innovation activities,' which were then broken down into three sub-questions.

This research investigates four IT R&D teams in an IT institute in Taiwan to explore how knowledge management related activities take place within technological innovation contexts. It is evident from the literature that knowledge management and its associated activities tend to be discussed generically, but the discussion lacks a deeper understanding of the contextual influence on knowledge management within specific contexts. Thus this research aims to examine in more detail knowledge management activities within an innovation context.

The research adopts an interpretive framework that allows in depth exploration of the type of knowledge processes and activities involved in teams with an innovation focus. A case study approach was adopted and through semi-structured interviews, team observation and documentary review data was collected to identify key themes that aid in our understanding of knowledge management related processes within innovation teams. The literature review and the analysis of the data generated a conceptual model for team knowledge management which comprises eight elements, namely, project characteristics, R&D process, R&D context, team operation, information systems, individual and team learning, knowledge management in practice and innovation practice and performance.

The model evidences that on initiation of a project, specific project characteristics, a team's R&D process and context, and a team's operation are determinants of how information systems are used, how individual and team learning takes place, and how and what knowledge management activities are performed. By understanding these processes, teams are able to improve their innovation capabilities which may result in better innovation practice.

In addition, this research outlines what contextual influences are within this specific IT innovation context and further highlights the importance of team dynamics and learning processes in knowledge management and innovation activities.

Overall, this research presents a detailed and substantial model that is rooted within R&D processes to show how knowledge management related activities are initiated and undertaken within innovation teams.

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Chapter 1 Introduction

1.1 Research intention

Knowledge management has been recognised as important and is associated with the improvement of competitiveness and the development of core competencies (Teece, 2000). However, how such concept is realised in practice seems still not fully revealed. In the last decade, most knowledge management applied in organisations seems to be greatly influenced by the successful development of information technology (IT). Subsequently, IT drives the development of knowledge management focused on developing information system (IS) infrastructure and information technology-based techniques to manage knowledge (Scarbrough et al., 2001). This apparent predominance seems to assume that knowledge can be managed and used if there is a standardised rule or procedure that can be applied in practice.

However, the author's experience in an innovation project context in Taiwan led to the belief that such IS-based knowledge management systems are not completely satisfactory for organisational members. In fact, the author noticed from the workplace that knowledge management in the workplace not only involves the IS-based infrastructure but is also about a social aspect and interaction amongst colleagues. IS-based knowledge management systems are built upon standardised procedures of codification of documents and the concept of e-library, which allows codified documents and publications to be shared and used through access to such system within the organisations. However, the author noticed from experience that the quality of codification of documents seems difficult to evaluate. This causes a problem in producing qualified documents for use. Moreover, IS-based knowledge management acts as an e-library which lacks an interactive function to link knowledge sources to where they are needed.

The challenge outlined here seems not to be about the accessibility and the use of such systems. Indeed, it seems about noticing the needs from organisational members and units, and also it appears to be about the interaction between people and between units. More precisely, the questions revolve around the following: what does knowledge mean

to organisations, to teams and to individuals; what are the objectives of organisations, teams and individuals and what knowledge is required to achieve such objectives. The urgency to manage these needs at different organisational levels is not very clearly distinguished and well connected. Moreover, IS-based systems may provide the infrastructure to enable knowledge to be stored and maintained for use; however, it seems not to be able to deal with the social nature of interaction when knowledge needs to be processed through interpersonal interaction and group dynamics. As the author noticed from previous experience, when people encounter a problem, accessibility to a human being to obtain essential help is more important than access to documents. This seems to suggest that interpersonal interaction and team dynamics are very important when considering knowledge management.

Furthermore, knowledge is a complex notion which contains different elements and exists in different forms (Ahmed et al., 2002; Davenport and Prusak, 1998). This difference may require different approaches to enable knowledge to be shared and used. Therefore, how knowledge can be appropriately managed and used is a challenge to organisations and individuals. The author asked himself where knowledge management should be positioned in organisational practice. For example, in R&D teams, every event or activity has a clear objective which is related to the outcomes at which a project is aimed. However, knowledge management seems not to have a clear objective in regards to its function. Davies (2001) and Hoegl and Schulze (2005) support this and suggest that successful knowledge management is likely to be connected to a clear purpose for managing knowledge. Thus, the author infers that knowledge management is viewed as a supporting function or process which contributes to an end, for example project outcomes, through embedding it in the processes and in a product or service. The advantage for an organisation from such knowledge management is through undertaking the process to enable knowledge to be widely shared and used. Hence it may lead an organisation to be able to develop an ability to deal with specific situations through a creation of knowledge. This suggests that there may not be a best practice to undertake knowledge management. Perhaps, successful knowledge management is based on the better understanding of an organisation itself to develop a tailor-made knowledge

management practice which reflects an organisation's aims and responds to what the organisation is doing and what its teams and members need (Cardinal, 2001; Snowden, 2002; von Krogh et al., 2000). In other words, knowledge management should not be seen as an independent event. Indeed, it is interdependent with organisational practice and embedded in organisational routines, rooted in organisational values, contexts and needs.

However, organisations are complex bodies with a diversity of features and functions. This may lead to a more centralised or standardised procedure and infrastructure as a preferable option in organisations in order to avoid management complexity. However, the author questions such thought. In order to gain a better understanding of knowledge management, the author considers that teams are a significant unit to investigate because the different features and specific needs within organisations are actually derived from its functional units and what the units are engaging in. Thus, if functional units and individual teams make up the complexity associated with organisations' knowledge management requirements, than this seems to imply that units and project teams are a valuable level to address and look at their differences in features and needs in order to assess knowledge management within organisations. Moreover, a project team may provide a focus of how a process of managing knowledge works if it is related to clear goals and is situated within patterns of interaction with organisational hierarchy in order to achieve project goals.

1.2 Research focus

The above experiences and reflections on practice motivated the author to initiate this research and carry out this PhD project. The author believes that there are some gaps that may need to be filled or clarified to enable knowledge management to be successfully undertaken. This research thus is aimed at gaining a better understanding of knowledge management within organisations. The author considers that issues such as the motivation, the purpose, the processes, and the factors influencing knowledge management may need to be further explored within an innovation context. Therefore, this thesis raises the following research question:

'How are knowledge management activities initiated and undertaken to enhance innovation activities?'

This thesis adopts Snowden (2002) and von Krogh et al.'s (2000) perspective considering that contexts are important when knowledge management is undertaken in organisations. By taking this perspective, the outcome of this research subsequently is expected to develop a process model to identify the factors which construct a team's contexts and influence the processes of undertaking knowledge management. The outcomes are also expected to distinguish project teams' specific features and needs and how knowledge management is performed to respond to these specific features and needs.

1.3 The structure of the thesis

In order to present this research, the thesis is divided into eleven chapters. Following this introductory chapter, chapter 2 is a literature review. This chapter firstly explores the knowledge management literature. By doing this, the thesis tries to arrive at a working definition of what constitutes 'knowledge' and 'knowledge management'. This working definition will be based on a discussion of different development paths that lead to knowledge management. In general, this thesis agrees with Snowden (2002) that knowledge management is not only about managerial techniques but also about managing contexts. Following the definitions the chapter then discusses knowledge management processes and knowledge management practices by examining different knowledge management models. A concept that has also gained some relevance within the knowledge management literature is learning. Thus the literature review will explore learning and how it is situated within knowledge management.

As this thesis aims to explore possible contextual factors influencing knowledge management within an innovation context, this thesis proceeds to look at the innovation literature to examine innovation contexts. It emerges from the literature that both the knowledge management and the innovation discuss the relevance of team dynamics, namely how organisations operate to enable both practices to be performed. Therefore, a

third aspect of the literature examines team operation which relates to both innovation and knowledge management. Based on the literature review, some gaps are identified which lead to a refinement of the initial research question. This development of the research question is discussed in chapter 3. Moreover, based on the literature the author was able to identify four major themes and use these themes to form an initial conceptual framework which preliminarily outlines knowledge management at team level within an innovation context. This framework was then used to guide the development of the research and aid in the design of the fieldwork.

In more detail, chapter 3 starts with refining the research question and breakdowns the research question into three sub-questions. The chapter then discusses the research design to answer the research questions. This research adopts a case study approach and uses triangulation of data collection (including interview, team observation and documentary review) to collect data based on four IT R&D teams from an IT research institute in Taiwan. The data analysis in this research is implemented based on a set of techniques of analysing free-flowing text.

Chapter 4 is the case description which provides information about the organisation's mission, organisational structure and policy, innovation strategy, specific organisational working contexts, and individual team's contexts. This was deemed important to provide the context in which this research was undertaken.

Chapters 5 to 9 each discuss a different theme that is part of the model. Each theme will be discussed individually to emphasise the findings and how these themes influence the overall model. Chapter 5 examines project characteristics. The author outlines three important project characteristics, funding sources, types of innovation, and types of products. This theme can be seen as the first contextual factor (related to research question 3) which influences teams to design its R&D process and arrange required resources for R&D.

Chapter 6 is concerned with R&D processes and contexts. The author firstly discusses R&D processes and R&D contexts in the four teams, and further outlines how the teams' R&D processes and contexts influence their interaction and knowledge management activities. These two themes may be described as the second and third contextual factors that influence a team's knowledge related interaction with regards to when and how knowledge related interaction take place.

Chapter 7 discusses team operation in which the author discusses the roles of the team leader and how different roles influence team interaction and knowledge management activities. This chapter also discusses how teams form their specific team atmosphere to support knowledge-related activities. Chapter 7 and chapter 8 address sub-question 2 and 3.

Chapter 8 is concerned with team knowledge management practice. The author explores how team knowledge management activities are undertaken to meet its purposes and respond to needs. The chapter also discusses how information systems and team learning influence the four teams' knowledge management activities. This theme provides evidence in response to all three sub-questions.

Chapter 9 focuses on the relationship between innovation and knowledge management activities. The author illustrates how knowledge management related activities are undertaken combined with innovation processes, and how the evaluation of innovation performance influences the teams' project selection and knowledge management activities. This is the last theme and shows the integration of knowledge management and innovation practices within the teams. Thus, this chapter is pivotal to answering the overall research question.

Based on the discussion in chapters 5 to 9, chapter 10 presents a process model of team knowledge management based on this particular organisational context. In order to provide the reader with a clear idea of what constitutes such a process model, this chapter firstly summarises the themes that comprise the model. Then, the chapter shows how the

model is constructed and describes the flow of the model to show how it may be employed. This process model is pivotal to answering the initial research question in chapter 1 and research question 3 outlined in chapter 3.

In the conclusion, chapter 11, the author summarises the model and the major findings. He then outlines the theoretical and empirical contributions that have been made by this research and what implications these may have for practice. He also points out the limitation of the research and where the potential for further research lies.

Chapter 2 Knowledge management and innovation

2.0 Introduction

In order to answer the research question raised in chapter one, this chapter reviews the literature containing three areas: knowledge management, innovation and team operation. Firstly, this chapter will identify what is meant by knowledge management, as different perspectives on what constitutes knowledge lead to different ways of managing knowledge (Carlsson et al., 1996). The first section of this chapter starts with defining the term *knowledge* and draws up a working definition of knowledge management for this thesis. With the definition of knowledge and knowledge management, the following section focuses on the implementation of knowledge management introducing and discussing different knowledge management frameworks. This section aims for answering why and how knowledge management is undertaken and if there is a relationship described within the literature that identifies how knowledge management may influence innovation activities.

Considering the research question, the second aspect that needs attention is innovation. This concept will be explored by focusing on R&D. Therefore, the second section aims to outline how R&D takes place and what elements of R&D may influence knowledge management. This section of the literature review will predominantly focus on R&D contexts and R&D processes.

It was outlined briefly in the previous chapter that both innovation and knowledge management have a common denominator, namely the need to manage the human component. Considering the need within with knowledge management and within innovation to look at group or team dynamics, it seems necessary to review and assess some relevant literature on team operations that relates to either or both concepts. Therefore, the final section of this critical review discusses team organisation with regards to team dynamics. This section aims to identify a linkage between knowledge management and innovation by reviewing the issues such as leadership, team

cohesiveness, team atmosphere and team interaction. These may provide answers for integrating both innovation and knowledge management activities.

2.1 Knowledge and knowledge management

Knowledge is '*a multi-trait complex phenomenon*' (Ahmed et al., 2002, pp. 11) which exists in different forms and comprises different components. Different perspectives of what constitutes knowledge lead to different aspects of managing knowledge (Carlsson et al. 1996). Therefore, understanding the notion of knowledge is vital to exploring how knowledge can be managed.

2.1.1 Knowledge

Knowledge is a complex concept. Defining knowledge has been an issue for philosophers over many decades and led to different epistemological debates (Alavi and Leidner, 2001). A precise definition of knowledge may be difficult to establish but a general notion of knowledge acceptable to Western philosophers is knowledge as '*justified true belief*' (Nonaka, and Takeuchi, 1995, pp. 21). Knowledge is based on an individual's understanding and justification of situations or objects that are experienced or encountered (Nonaka, and Takeuchi, 1995).

There are two polar models of knowledge creation and acquisition. According to the first, rationalism, in order to prove that something is true, there must be some knowledge existing prior to justifying what is true. Therefore, rationalism argues that true knowledge is not a result of sensory experience but a result of ideal mental process (Nonaka and Takeuchi, 1995), which enable one to judge truly. According to the second, in contrast, empiricism believes that knowledge is based on sensory experience rather than *a priori* knowledge. Therefore, rationalism argues that knowledge is deductively constructed through an individual's intellectual process (Cooper, 1999). In contrast, empiricism believes that knowledge is formed through an inductive method based on experience (Everitt et al. 1995). These two perspectives may provide one way of looking at a definition of knowledge.

A different perspective may be considered when looking at Edmund Husserl ideas of what constitutes knowledge. He argues that knowledge may be described as the interaction between pure consciousness and its objects, for example a concept or an idea for designing a new product (Nonaka and Takeuchi, 1995). This reflects that a concept or an idea of a design is based on one's interaction with the world or market, from where one obtains knowledge through interaction with customers and interpretation of information. This suggests that human mental processes and sensory experiences may not be two distinct processes. As William James argued '*ideas are worthless except as they pass into action*'(Dewey, cited by Nonaka and Takeuchi, 1995, pp. 27). This may further justify that knowledge is built upon the interaction between an individual and the world. This process of building up knowledge involves perspectives from both rationalism and empiricism. The individual cannot be independent of the world and is likely to use his/her mental capacity. The author believes that knowledge is obtained based on the interaction between mental process, sensory experience and action.

Considering the practical focus of this research and its aim to develop a workable process model for knowledge management by understanding its relationship to innovation, this philosophical discussion is sufficient, although by no means complete. However, it reflects different philosophical concepts of what constitutes knowledge. It is at times argued that such a discussion is not sufficiently incorporated in developing a sound theoretical base for knowledge management (Alavi and Leidner, 2001). However, this philosophical debate is necessary to be mentioned in knowledge management as it prevents researchers from understanding the nature of knowledge too simplistically (Walsham, 2001), as it makes one aware of the historical development process that lead to current definitions of knowledge.

The following sections will discuss and review what constitutes knowledge in more detail as it relates to knowledge management. This discussion will predominantly focus on how knowledge is perceived within the knowledge management community, and examine concepts surrounding knowledge that emerge from this community of researchers and practitioners, rather than from a philosophical point of view.

2.1.1.1 Views of knowledge in knowledge management

The term '*knowledge*' can be defined through taking different perspectives and considering its purposes. Therefore, it can be defined and categorised in different ways. However, before going further to build our understanding of knowledge, there is a distinction between data, information and knowledge that has been identified in the knowledge management literature. A hierarchy of data, information and knowledge can be formed. The argument is that knowledge is more contextual than information as knowledge is bound closer to an individual. Information on the other hand exhibits more context than data. Some scholars agree with a perspective that data is a set of numbers or facts, information is processed data which gives data meanings and knowledge is more meaningful, structural and contextual information with expertise insight (Vance, 1997; Davenport and Prusak, 1998). However, Tuomi (1999) argues that knowledge exists before information can be formulated and information precedes data. He argues, because knowledge exists, therefore articulation, verbalisation and structuring can take place to turn knowledge into information; when further given a set of representation or standard interpretation, information can become data (Tuomi, 1999). In his argument knowledge exists based on one's needs and initial stock of knowledge (Alavi and Leidner, 2001). This aspect seems to reflect a rationalist's claim. This research agrees with Alavi and Leidner (2001). They summarise the above argument and indicate that information is converted to knowledge when it is processed in an individual's mind and knowledge becomes information when it is articulated and structured in the form of text or other symbolic forms. The author agrees with this and considers the relationship between information and knowledge is a triangular process, one side is conversion and the other is structure and articulation, the process that lies between is an individual's thought. This explains why information is needed and how information can be used. On the other hand, how useful information becomes relies on people's knowledge to construct it in certain forms.

In addition to this hierarchical view, there are also several different perspectives of viewing knowledge, for examples: (1) *a state of mind*, (2) *an object*, (3) *a process*, (4) *a condition of having access to information* or (5) *a capability* (Alavi and Leidner, 2001).

In the first perspective, knowledge is viewed as a sort of understanding through experience and study. It is applied in knowledge management with a focus on enabling individuals to apply their knowledge to organisational needs (Alavi and Leidner, 2001). In the second perspective, knowledge is defined as an object which can be stored and manipulated (e.g. Carlsson et al., 1998; McQueen, 1998; Zack, 1998). In the third perspective, knowledge is viewed as a process of simultaneously knowing and acting in which application of expertise is the focus (e.g. Carlsson et al. 1996; McQueen, 1998; Zack, 1998). The fourth perspective views knowledge as a condition of access to information (McQueen, 1998). Lastly, knowledge could be seen as a capability of influencing future action (Carlsson et al, 1996) in which a capability of the use of information in decision making is considered (Watson, 1999). The five different perspectives may relate to different levels or requiring different types of knowledge inputs and have different emphases. For example, the first perspective may be suitable to be applied at individual and team level in which individual-based experience and expertise are an important input to complete tasks. The second perspective could be related to develop a knowledge management system as knowledge here is treated as an articulated object. Therefore, it can be stored and manipulated through an IT infrastructure. This perspective may be adopted at an organisational level. For this research, the author adopts the first and third perspectives viewing knowledge as a state, i.e. knowing or understanding, as well as a process, which is gained through experience, study and actions. This relates to what this research tries to achieve, namely gaining a better understanding of knowledge management as a process within a human context.

2.1.1.2 Taxonomies of knowledge

Some scholars (e.g. Polanyi 1969, Nonaka, 1994; Grant, 1996a) indicate that knowledge consists of two taxonomic dimensions which are tacit and explicit forms of knowledge. Tacit dimensions of knowledge cannot be expressed or presented in verbalised forms. Conversely, explicit dimensions of knowledge can be expressed by verbalisation or any other symbolic forms. Furthermore, Nonaka (1994) indicates that tacit knowledge comprises cognitive and technical components. Cognitive components involve an individual's mental models such as mental maps, briefs and aspects. Technical

components entail an individual's know-how, crafts and skills. This leads knowledge to become very personal and context-specific. Nonaka (1994) proposes the mode of externalisation to convert tacit into explicit for use in his work. However, Polanyi (1969) cautions that such distinction between tacit and explicit knowledge for use must understand that both are interdependent. Polanyi points out,

> *'these two are not sharply divided, while tacit knowledge can be possessed by itself, explicit knowledge must rely on being tacitly understood and applied. Hence, all knowledge is either tacit or rooted in tacit knowledge.'* (Polanyi, 1969, pp. 144)

This implies that knowledge has a sticky nature (Day and Wendler, 1998; Szulanski, 1996), knowledge is possessed by an individual and it cannot be easily used by others without understanding the context, which is the tacit component of knowledge. The author agrees with Polanyi's perspective. Although Nonaka and some scholars (e.g. Spender, 1996a; Spender, 1998; von Krogh et al., 2000) adopt the dualistic distinction of knowledge into two independent forms in their work by emphasising the importance of conversion between tacit and explicit forms of knowledge, no comprehensive explanation is given that covers different types of knowledge and how they are converted from tacit to explicit (Alavi and Leidner, 2001). Hence the author believes that not all types of tacit knowledge can be converted into explicit knowledge. This strengthens the importance of individuals as knowledge holders in organisations and the importance of group dynamics in order to make knowledge available for use.

Based on the above understanding of the nature of knowledge, this research describes that knowledge is obtained based on interaction among one's experience (object), mental process (subject) and action (or practice). Therefore, knowledge exists in an individual's mind which dominates the interpretation of truth. Based on this understanding of knowledge, the following section will define what knowledge is in this research.

2.1.1.3 Defining knowledge

Based on the above discussion, there are two definitions that may be closer to the author's perspective on knowledge. Firstly, Wiig (1998) defines knowledge as a form of belief. Based on this perspective, he defines knowledge as

> *'the body of understandings, generalisations and abstractions that we carry with us on a permanent or semi-permanent basis and apply to interpret and manage the world around us...we will consider knowledge to be the collection of mental units of all kinds that provides us with understanding and insights'* (Wiig, 1998, cited by Firestone and McElroy, 2003, pp. 5)

This definition emphasises that knowledge comprises various mental units with a strong tacit nature, which conducts people's thinking and action. This corresponds to the author's perspective that mental processes are an important part of knowledge. However, it may be too general to apply to knowledge management practice. Secondly, Davenport and Prusak (1998) define knowledge from a working point of view:

> *'Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organisations, it often becomes embedded not only in documents or repositories but also in organisational routines, processes, practices, and norms.'* (Davenport and Prusak, 1998, pp. 5)

Thus, knowledge can be seen as a synthesis of multi-elements of human actions which are apparent in human consciousness, individual specific skills, and worldview. This definition is more concrete in terms of applying it to knowledge management practice. From this perspective, knowledge can be further distinguished by knowledge-itself and skill. Senker (1998) presents a more cognitive definition:

> *'Knowledge implies understanding. The acquisition of knowledge is a purely perceptual and cognitive process. Skill implies knowing how to make something happen; it involves cognition, but also other aspects such as manual dexterity or sensory ability.'* (Senker, 1998, p.224)

For Senker, knowledge resides in the minds of knowers involving know how. Skills are sometimes based entirely on tacit knowledge but sometimes based on better understanding of scientific principles involved (Senker, 1998). Thus, skills are seen as a combination of tacit and articulated knowledge.

Knowledge involves an individual's perceptual and cognitive processes and the use of the results from the processes to evaluate and incorporate new information through action; thus, the author agrees with Davenport and Prusak in defining knowledge as a mixed phenomenon of experience, values, contextual information and expert insight, which provides a framework for understanding, evaluating and acting. This working definition reflects the author's understanding of knowledge.

2.1.1.4 Individual and group knowledge: individual, team and organisational knowledge

The above discussion has illustrated the nature of knowledge and defined what knowledge is for this particular research. However, this only takes account of knowledge as an individual aspect, neglecting its collective aspect. It is argued that knowledge not only exists at an individual level, but also resides within a collective (Nonaka and Takeuchi, 1995; Alavi and Leidner, 2001) which may influence behaviours within the group. This can be seen as embedded collective knowledge. Thus, the following content will further clarify individual, team and organisational knowledge.

Individual knowledge

As Nonaka and Takeuchi (1995) indicate, tacit knowledge comprises two elements which construct individual knowledge as they are individual-based and context-based. However, experience is an important element of knowledge which comprises what an individual has

done or encountered in the past, which tends to be tacit and physical (Nonaka and Takeuchi, 1995). Therefore, this research considers that individual knowledge includes mental models, experience, know-how, crafts, skills and expertise.

Mental models refer to an individual's knowledge structure and the processes of using this knowledge, which is associated with an individual's insights and view of the world (Merrill, 2000). Individual **experiences** not only represent experiences which people have had but also tell how people deal with their experiences and how people judge and think. This involves individual mental models, paradigms, and schemata expressed by people themselves; thus, knowledge may be hidden in a story when it is presented. **Know-how** represents how things are achieved in certain ways and with certain consequences. Often people cannot even explain exactly why (Koskinen et al., 2003). This is relevant to the procedures and applications of technological expertise. **Crafts** are dexterous abilities in specific events, which imply an inherent ability and practice which may not be expressed precisely. Context-specific **skills** are relevant to individual's sensory ability and cognitive process of long-term involvement in specific events and practices. Scientific and technological **expertise** is accumulated by engaging long-term in scientific and technological experiments and processes. Most of this knowledge can be learned and expressed through certain procedures but some of this knowledge is tacitly embedded in participants' mind and cannot be expressed.

Organisational knowledge

From the above perspective, knowledge is derived from an individual's experience, mental process and action (practice), which means that knowledge is possessed by an individual (Nonaka and Takeuchi, 1995; Alavi and Leidner, 2001). However, literature in knowledge management, organisational learning and organisational memory also proposes that knowledge can exist in a collective (Spender, 1996a, 196b).

Nonaka and Takeuchi (1995) believe that organisational knowledge is rooted in individual knowledge. However, they suggest organisational knowledge is formed through the interaction between tacit knowledge and explicit knowledge to mobilise

knowledge from individuals to a team or organisational level, which is a spiral process. However, they do not provide a comprehensive explanation to justify the interrelationship among the various types of knowledge they propose (Alavi and Leidner, 2001). Therefore, whether an individual's crafts and skills can become organisational knowledge through this spiral process is debatable. Literature in organisational learning tends to define organisational knowledge as an inherently collective action (Alavi and Leidner, 2001) which can be a collective perception or culture. Sackmann (1992) investigates culture and subculture in organisations and further identifies four types of cultural knowledge. He suggests that organisational knowledge is similar to individual cognitive knowledge, which is accumulated over time and exists in the different forms, dictionary knowledge, directory knowledge, recipe knowledge and axiomatic knowledge. These four types of cultural knowledge are embedded in an organisation and influence organisational members' commonly held descriptions, practices, judgments and reasons and explanation of causes (Sackmann, 1992). This implies that organisational knowledge can be seen as a process which may be embedded in an organisation's culture and routine (Grant, 1996a; Spender, 1996a).

Team knowledge

With the above distinction between individual knowledge and organisational knowledge, there is a missing level—team knowledge. Team knowledge in the literature is frequently referred to as shared knowledge which is explained through shared mental models, shared cognition and shared understanding (Cooke et al., 2000; Cannon-Bowers et al., 1995; Cannon-Bowers et al., 1993). Knowledge is possessed by individuals; team knowledge is created by and inherent in the collective actions of a group (Alavi and Leidner, 2001). These collective actions occur when team members have formed shared cognition to interpret and react to specific events or situations. Thus, team knowledge is not skills or know-how. In fact, it is a kind of collective reaction reflecting a team's members' shared mental models and common understanding.

The above discussion has distinguished the difference between individual, team and organisational knowledge. Managing knowledge at an individual level relates to

individual experience, know-how, skills, etc. At team level it relates to collective actions in a team and at organisational level it is relevant to organisational culture and routines. This is a useful distinction in this research to clarify team knowledge management and related activities and the relationship between team knowledge and organisational knowledge management.

Having identified different ways in which knowledge can be described, the following section will look at what is understood to be knowledge management.

2.1.2 Knowledge management

Based on this research's understanding of knowledge, this section aims at clarifying what knowledge management is and tries to achieve a working definition of knowledge management for this research. Different aspects of viewing knowledge lead to different approaches to managing knowledge. The way in which knowledge is 'being managed' (Hoegl and Schulze, 2005) also influence the selection of knowledge management methods. The concept of knowledge management has been widely discussed in the literature and the influences upon its development are plentiful (Kakabadse et al., 2003). Thus, it seems appropriate to introduce briefly some of the ideas regarding the developmental stages of knowledge management. This review is not discussing every aspect and influence of the development of knowledge management, but will focus on the ones the author deemed relevant.

2.1.2.1 The development of knowledge management

It appears that it is not only important what constitutes knowledge to identify what knowledge management is, but also it appears that the reasons for why knowledge should be managed and how this task is approached influences the understanding of knowledge management. The following discussion adopts two discrete development routes that seem to have influenced the development of knowledge management. The thesis therefore discusses how knowledge management developed by considering theories of the firm and secondly looks at the emergence of knowledge management from a more developmental

and theoretical perspective, namely the move from first to third generation knowledge management.

2.1.2.1.1 The theories of the firm

In earlier resource-based theories of the firm literature, knowledge is seen as an important asset which contributes to building a firm's core competencies and sustaining its competitiveness (Teece, 2000). Therefore, organisations should manage knowledge for re-use in the same way it manages its other asset, such as staff or raw materials. This draws the attention of knowledge management to the application of already existing knowledge rather than the creation of new knowledge (Grant, 1996a).

However, in recent research, a knowledge-based theory of the firm (Grant, 1996a) and a dynamic theory of the firm (Spender, 1996a) are proposed. These theories suggest that knowledge needs to be part of a more dynamic organisational process in that it needs to be available and usable every time an organisation adapts to new stimuli from the environment. Organisations are seen as dynamic entities that adapt to changing environmental conditions and respond to those through its resources, such as knowledge. Grant (1996a, 1996b) views organisations as institutions for integrating knowledge, rather than just managing it. Therefore, coordination is required to integrate specialist knowledge within organisations. This perspective has managerial implications for organisational capability, organisational design and the determinants of vertical and horizontal boundaries within organisations.

Nonaka (1994) and Spender (1996a) take this further and suggest that knowledge itself is dynamic, and not just firms, and involves social networks. Knowledge can be seen as a process (Spender, 1996a) rather than just a resource. This theory extend the previous notion by assuming that the organisational asset is not knowledge in itself, but the process through which it emerges and the organisational networks in which it travels. Organisational thinking has developed to assume organisations as a net of relationships and networks. This perspective lead knowledge management research to explore such notions as group dynamics (Brewer and Harasty, 1996; Smith and Henry, 1996; Holtz,

2004), social networks (e.g. Cross et al., 2001; Rulke and Galaskiewicz, 2000) and knowledge communities (e.g. Barrett et al., 2004; Boland and Tenkasi, 1995).

The discussion above outlines that knowledge as part of a firm can be seen in many different ways. However, this evolution of knowledge management and its theory is not abrupt or discontinuous. Indeed, it has been developed over time and is interdependent with changes in firms' economic environment. These perspectives reflect that organisations themselves are dynamic and multi-faceted in its use of knowledge as a resource. Therefore, from the author's perspective, knowledge management within organisations may need to include different perspectives; for example, knowledge may be seen in a different way according to the needs at different organisational levels. It could be that a management board of a large organisation is only interested in particular information on sales forecasts, using already existing knowledge to manage the process (original resource-based view of the firm). However, a new member to the sales force may encounter a problem that requires him/her to seek the knowledge and experience from colleagues who have worked in the organisation for a number of years (organisation as a knowledge network).

According to this research's focus, the author feels most sympathetic to the dynamic theory of the firm and considers aspect of the firms as knowledge networks important. In order for organisations to facilitate innovation, the organisation needs to react to changes in its environment and thus knowledge needs to be available. Furthermore, knowledge may not just be stored in some depositor, but may be held by other members or teams within an organisation.

2.1.2.1.2 The development of knowledge management: from first generation to third generation?

Knowledge management has been developed systematically since the 1980s. Some Scholars call this change as generation change (e.g. Koenig, 2002; Snowden, 2002; McElroy, 1999).

The first generation of knowledge management is seen as driven by information technology in which the Internet, best practice, lessons learned and knowledge sharing are the dominant ideas (Koenig, 2002). However, Snowden (2002) argues that this form of knowledge capture is about distributing information to decision makers, and he calls this objective to deliver knowledge first generation knowledge management. McElroy (2003) also indicates that first generation knowledge management is so-called supply-side knowledge management in which integration of created or existing knowledge through knowledge distribution or sharing is seen as a key issue. This aspect reflects ideas of the resource-based theory of the firm.

The second generation of knowledge management for Koenig (2002) is about human factors; organisational learning and knowledge creation in which conversion of tacit and explicit knowledge is emphasised. For Snowden (2002) too, the second generation is focused on conversion of tacit and explicit knowledge, whereby he adopts Nonaka's SECI model. McElroy (2003) argues that second generation knowledge management combines integration and production of knowledge. It not only focuses on the 'supply-side' knowledge sharing processes but also on the 'demand-side' knowledge processes to respond to 'problem-induced' demands. This distinction indicates that the thinking in knowledge management has evolved from seeing knowledge as an object to seeing it as related to the changing needs of the organisation and its need to be available to an organisation to respond to changes an organisation encounters. This view of knowledge management holds similar ideas to the dynamic theory of the firm view on knowledge.

Koenig (2002) sees third generation of knowledge management being about arrangements and management of content through taxonomy construction and use. Snowden (2002) argues that knowledge in the third age '*will be seen paradoxically as a thing and a flow; context, narrative, and content management will control our view of knowledge management*' (Firestone and McElroy, 2003, pp. 89). In this paradoxical situation, '*insights and learnings*' are important issues. As Nonaka and Takeuchi (1995) assume that '*human knowledge is created and expended through social interaction between tacit and explicit knowledge*' (pp. 61). McElroy (2003) disagrees and asks, 'is *a*

third age about beginning?' or *'are there already three?'* or *'are there two generation or age?'* He suggests that the above distinction of three generations of knowledge management does not reflect the development of knowledge management. He suggests that the evolution of knowledge management is still alongside supply-side and demand-side knowledge management. Only a fundamental change in the demand-side knowledge management will result in third generation knowledge management.

However, the author considers that Koenig and Snowden's perspectives of viewing knowledge management development provide useful guidance. Different focuses and perspectives allow research in this field to be more comprehensively developed, and this 'comprehensive development' is dependent upon a further understanding of organisational development, its needs and the application of new methods. Therefore, the development of generations of knowledge management is based on developed theories, frameworks and methods to extend rather than abandon old theories and frameworks. This explains why Koenig's perspective of information technology-driven first generation knowledge management is still continuously researched. The later elements such as social interaction and human factors are used to complement the insufficiency of first generation knowledge management. Similarly, the views of content and context management are also proposed to complement earlier theories and frameworks. Knowledge management is not just about managing knowledge, but managing people, culture and knowledge within a dynamic environment. From this viewpoint, the author agrees more with Snowden's perspectives as his perspective may help this research to answer the research questions and give some focus on how knowledge management is undertaken to improve innovation.

2.1.2.2 Defining knowledge management

On the basis of the above understanding of knowledge management development, knowledge management seems to move from a stock aspect of seeing it as an asset toward a dynamic concept of seeing it as a process in which interaction between people and between people and environment is gradually emphasised. This drives the management of knowledge from not only managing objects but also managing interaction

processes between people and environment to ensure knowledge is learned, transferred and used better. Being dependent on people, this raises the issue of knowledge being associated with contexts in which an individual experiences, acts and reacts. This makes knowledge context-specific at an individual level and involves an individual's experience and mental models, namely tacit forms of knowledge (Ahmed et al, 2002; Leonard and Sensiper, 1998; Senker, 1998). Therefore, it leads management of knowledge to draw more attention to managing tacit forms of knowledge (Alavi and Leidner, 2001) in which managing knowledge not only involves knowledge itself and methods of managing it, but also entails managing individuals and the contexts with which their knowledge is associated (Ahmed et al, 2002; Snowden, 2002).

The literature identifies various definitions of knowledge management. For example, Sveiby (1998) defines knowledge management as management of information and people. For him, knowledge is not a process. Learning, knowledge management and knowing are the processes. Knowledge itself is an outcome of these processes (Firestone and McElroy, 2003). Wiig (1998) defines knowledge management in three perspectives: business, management and hands-on operational perspective[1]. His definition contains resource collection, management activities, and knowledge processing and taking more managerial aspect (Firestone and McElroy, 2003).

Beckman (1997) defines knowledge management as

> '*Formalisation of, and access to, experience, knowledge and expertise that create new capabilities, enable superior performance, encourage innovation and enhance customer value.*' (pp.1-6)

[1] Business perspectives: 'focusing only why, where and to what extend the organisation must invest in or explicit knowledge...' Management perspective: 'focusing on determining, organising, directing, facilitating and monitoring knowledge-related practice and activities required to achieve the described business strategies and objective.' Hands-on operational perspective: 'focusing on applying the expertise to conduct explicit knowledge-related work and tasks.' (Firestone and McElroy, 2003, pp. 66)

For Beckman, managing knowledge is alongside the process of converting tacit components of knowledge to explicit forms of knowledge to enable knowledge to be managed and accessed. This perspective is closer to Nonaka's (1994) perspective and points to what knowledge management may lead to, namely innovation.

Wenig (1998) defines knowledge management as

> '*Consists of activities focus on the organisation gaining knowledge from its own experience and from the experience of others, and in the judicious application of that knowledge to fulfil the mission of the organisation...*' (cited by Firestone and McElroy, 2003, pp. 67)

From Wenig's perspective, knowledge management are activities which focus on obtaining and applying knowledge. However, he does not distinguish what these activities are and the differences between these activities and knowledge processing (Firestone and McElroy, 2003).

Ahmed et al. (2002) define knowledge management as

> '*the coming together of organisational processes, information processing technologies, organisation strategies and culture for the enhanced management and leverage of human knowledge and learning to the benefit of company.*' (pp. 12)

For Ahmed et al., knowledge is defined as a multi-trait complex phenomenon which contains features of sticky, extraordinary leverage and increasing return, fragmentation, constant change, uncertain value, context specific and subjective. Therefore, knowledge management involves all organisation contexts or environment factors and learning is an important element in knowledge management. This perspective refers to Snowden's (2002) perspective of third generation of knowledge management, and brings learning into knowledge management to respond to complexity and dynamism of knowledge

within organisation. However, this definition does not justify knowledge processes and does not seem to distinguish between individual and collective forms of knowledge.

Firestone and McElroy (2003) define knowledge management as '*a management discipline that seeks to enhance organisational knowledge processing.*' (pp.70) They further define the knowledge management process as

> '*an ongoing, persistent, purposeful interaction among human-based agents through which the participating agents manage (handle, direct, govern, control, coordinate, plan, organise, facilitate, enable and empower) other agents, components and activities participating in basic knowledge processing (knowledge production and knowledge integration), with the purpose of contributing to the creation and maintenance of an organic, unified whole system, producing, maintaining, enabling, acquiring, and transmitting the enterprise's knowledge base.*' (pp. 71)

For Firestone and McElroy, knowledge management is more about management than knowledge, as knowledge is seen as embedded in the process of human action and interaction. Therefore, knowledge management itself is a management discipline which leads human-based agents to be managed to produce and integrate knowledge. This definition provides a clear notion of knowledge processing. However, it seems to deny the third generation view of knowledge management that emphasises context-influenced knowledge management and learning.

The above definitions indicate that there is no universal definition for knowledge management due to the variety of perspectives of seeing knowledge and adopting different methods to manage it (Ahmed et al. 2002). However, based on the above discussion of possible definitions of knowledge management, the author agrees with Ahmed et al. (2002) and Firestone and McElroy (2003) perspectives that knowledge management is context-influenced and involves learning factors. Also, knowledge management is a management discipline which enables organisations to manage human-based agents toward knowledge production and integration. By referring to these two

perspectives, this research suggests a working definition of knowledge management for this study:

> *Knowledge management is a management process which provides the guidelines for processing valuable information, managing contexts and people's actions and interactions to enable organisational members to produce and integrate knowledge improving an individual and collective ability of achieving task and enhancing innovation performance through encouraging interaction and learning.*

This working definition of knowledge management is in line with the author's assumptions about knowledge. This thesis assigned to a view on knowledge that suggested that individuals hold prior knowledge in form of mental models but are able to gain new knowledge through interacting with its environment (empiricism) and incorporate this knowledge in their individual mental models.

Having briefly outlined ideas about knowledge and knowledge management, and having provided a definition for this research, the following sections will further this discussion. The first issue to be explored is the process of managing knowledge, knowledge management in practice and learning. The second issue addresses the contexts in which knowledge management is undertaken. In this research it relates to innovation practice. The third issue is team dynamics which impacts on how knowledge management is performed.

2.2 Knowledge management processes and practice

The previous section has defined knowledge management as a process which not only involves ways of managing knowledge but also involves learning processes to enable knowledge to be transferred, embedded and used. Also, knowledge management in practice is associated with particular objectives which lead knowledge management to contribute to organisations. Therefore, this section discusses knowledge management processes in practice and ideas about learning.

2.2.1 Knowledge management processes

Knowledge management processes involve several different activities which can also be called knowledge manipulation activities (Handzic and Zhou, 2005). A number of classifications of knowledge management process have been suggested in the literature (e.g. Alavi and Leidner, 2001; Firestone and McElroy, 2003). Alavi and Leidner (2001) suggest four generic knowledge management processes which are knowledge creation, knowledge storage, knowledge sharing/transferring and knowledge application. These processes can be seen as the objective of knowledge management. Firestone and McElroy (2003) suggest that knowledge production includes formulation of knowledge, individual and group learning, information acquisition; knowledge integration includes searching/retrieving knowledge, teaching and sharing. This research combines Alavi and Leidner and Firestone and McElroy's classifications defining knowledge management processes to include five processes: acquisition of knowledge, sharing of knowledge, storing of knowledge, integration of knowledge and application of knowledge. However, these five processes for the author not only mean the procedures but also the action-based activities alongside daily practice. Therefore, this thesis defines these five processes as **knowledge management related activities.** In this research, the creation of knowledge is seen as a combining process underpinning the other processes to achieve certain purposes; therefore, it will be discussed separately. Furthermore, individual and group learning is also seen as an important element of any knowledge management process, which will also be discussed separately.

2.2.1.1 Knowledge acquisition

Knowledge sources may be located in different places and with different people. Access to those knowledge sources is associated with two channels: information system and social connections. Information system is one of significant R&D infrastructures for teams to undertake tasks and knowledge management activities (Nonaka and Takeuchi, 1995; Davenport and Prusak, 1998). It not only facilitates organisational members to access historical databases but also to access dynamic information and knowledge resources (Driskell et al., 2003; Mckenna and Green, 2002). Within this research this is

seen as relevant, as for an innovation team, a comprehensive IT service can be seen as a significant R&D infrastructure which not only enables the team members to access essential internal and external information and data sources but also enables them to exchange information with people outside the team. However, each team has its specific needs for the tasks. Considering the contextual and dynamic nature of organisations – as adopted with the dynamic view of the firm – IT systems may be used differently in different parts of an organisation.

The second channel is building social connections with knowledge sources. Research suggests that acquisition of knowledge and sharing of knowledge between people or between teams involves a high degree of socialisation and is influenced by social networks and relationships (Abrahamson and Rosenkopf, 1997; Dahl and Pedersen, 2005; Hansen, 2002; Rulke and Galaskiewicz, 2000). Hansen (1999) suggests that weak interunit ties facilitate searching for useful knowledge. In contrast, strong interunit ties facilitate sharing complex knowledge. This implies that social networks are an important element for the acquisition of knowledge. Furthermore, research (Chung, 2005; Chow and Ng, 2004; Wang et al., 2006) also suggests that personal connections especially in Chinese society have important influence on sharing information. Therefore, building connections and developing relationships are considered significant issues for the teams or individuals to acquire knowledge. The context of this research aims to provide further evidence to assess the role of social networks.

2.2.1.2 Knowledge sharing

Knowledge sharing can take place in many ways, such as face-to-face conversations, on-line chatting, e-mails, documents, and apprenticeship models (Davenport, De Long and Beers, 1997; Handzic and Zhou, 2005; Nonaka and Takeuchi, 1995). The methods adopted for knowledge sharing depend on the characteristics of knowledge (Davenport and Prusak, 1998; Handzic and Zhou, 2005). For example, explicit knowledge can be easily expressed and codified through talking and writing. Most of the knowledge we learn from books, classes, and Internet website is explicit knowledge. Sharing this kind of knowledge normally adopts the codification aspect through documents and database (Davenport and Prusak, 1998).

Tacit knowledge is normally embedded in an individual's mind, such as mental models and technical skills. Koskinen et al. (2003) indicate that tacit knowledge represents

knowledge that is based on the experience of the individual. It can be expressed by human actions such as attitudes, points of view, commitments, motivation, and so on. Thus, when observed tacit knowledge is accessed, one has to consider various factors and circumstances. In other words, tacit knowledge is highly context-specific and history dependent (Ahmed et al., 2002; Koskinen et al., 2003). That means, tacit knowledge includes 'how' (a certain method or concept) and 'where/when/what' (the background of an event). Thus, sharing of tacit knowledge not only involves a transformation of know-how but also entails the context and the thinking which are beyond that know-how residing in one's mind (Ahmed et al., 2002; Senker, 1998). Rosenberg (1982) defines tacit knowledge as *'the knowledge of techniques, methods, and designs that work in certain ways and with certain consequences, even when one cannot explain exactly why'* (pp. 143). Thus, tacit knowledge may be seen as a know-how or skill in practice, especially in innovation teams. Sharing this type of knowledge is more difficult as it is not codified easily.

Fernie et al. (2003) indicate that an effective knowledge sharing method is determined by two inter-related factors: '*an ability to generate debate and understanding through contextual disparities*' and the '*socialisation of individuals*' (pp. 182). Debate and dialogue within group interaction facilitate understanding between participants and their relevant paradigms. Dialogue can be used to expose individual's thinking in depth through conversation and discussion in a group's interaction (Senge, 1993; Nonaka and Takeuchi, 1995). Also, literature suggests (e.g. Handzic and Zhou, 2005; Nonaka and Takeuchi, 1995) that apprenticeship models facilitate tacit skills sharing through imitation and observation in which masters' individual skills, thinking, attitudes, language and behaviour can be further understood and learned by learners. Both dialogue and apprenticeship models enable a close relationship to be established with an atmosphere of mutual trust and better understanding of the context of the project or knowledge. The above methods may also lead to strong ties among participants, and further enhances knowledge sharing taking place within the group (Fernie et al., 2003). Moreover, scholars propose some conditions to facilitate knowledge sharing. They indicate that valid tacit knowledge sharing is often associated with mutual trust, a specific

space (Amin and Cohendet, 2004; Koskinen et al., 2003; Nonaka, 1994), proximity, and language (Koskinen et al., 2003).

Tacit knowledge sharing within a group/team faces two fundamental problems. a) How to know who knows? and b) How does knowledge become shared? The former tries to understand how members know who possesses useful knowledge within the team. In general, the formal organisational structure cannot point out definitely who holds useful knowledge (Cross et al., 2001). In other words, a leader is not necessarily holding essential knowledge or knowing the location of the knowledge. Members know the location of knowledge sometimes through personal social networks such as peer-groups. Some research (Gordon, 2000; Gray, 2000) indicates that knowledge maps facilitate members searching for knowledge within the organisation and also provide a visible framework for knowledge management. Some scholars (Cross et al., 2001; Liebeskind et al., 1996; Lopez et al., 2002) investigated this question by modelling social networks and comparing the formal organisational structure in order to expose the conflict between the two. Cross et al., (2001) reveal that there are few persons who act as nodes of information but those people are often not in a position of responsibility within the division.

The second question tries to reach an understanding of how knowledge is shared within a team. Explicit knowledge sharing can be achieved through documents, internet/intranet, email, face-to-face conversation, etc. This is highly associated with organisational knowledge management systems in which expert and decision-making systems are often adopted. Explicit knowledge sharing relies heavily upon systematic knowledge codification, storage, and diffusion. In IT-based knowledge sharing, developing efficient knowledge maps is likely to incorporate a diversity of knowledge and reduce cost of searching knowledge (Gray, 2000). Tacit knowledge sharing relies on much closer social interaction between members (Fernie et al., 2003; Koskinen et al., 2003). This means tacit knowledge sharing is access to a wide range of project's activities including ideas of other people, information and opportunities for participation (Koskinen et al., 2003). Thus, tacit knowledge sharing can be considered highly personal, socially dependent and activity dependent. Among the social interactions, face-to-face interaction may be

considered the most significant way. A lot of extra-messages can be transferred during personal interactions through body language, facial expression, and tone of voice. These often express knowledge beyond the spoken message (Meherabian, 1971 cited in Koskinen et al., 2003). However, a heterogeneous team may consist of team members from different departments or with different expertise. This may cause a problem of sharing knowledge between team members because they may each have their own language and interpretive framework originating from their previous work. Therefore, to establish a common language becomes a significant issue during personal interaction. Common languages facilitate a team to form shared mental models for understanding and interpreting knowledge and information (Davenport and Prusak, 1998; Koskinen et al., 2003). Moreover, early research suggests that social networks are an important issue in knowledge sharing. Recent research suggests that a strong tie benefits in receiving of useful knowledge (Wang et al., 2006; Hansen, 1999; Szulanski, 1996). A strong tie facilitates people to establish mutual trust and subsequently increase knowledge sharing (Coleman 1988; Tsai and Ghoshal, 1998; Wang, et al., forthcoming). In addition, corporeal proximity facilitates frequent interaction among team members and further produces interpersonal attraction which also facilitates sharing each other's tacit knowledge (Koskinen et al., 2003). Considering the nature of this research, understanding how different forms of knowledge can be shared is important to explore how knowledge management impacts on innovation.

2.2.1.3 Knowledge storage

The focus of knowledge storage in organisations is development and improvement of organisational memory through creating knowledge repository (Handzic and Zhou, 2005). However, as the previous discussion indicates, the nature of knowledge is multi-trait and complex (e.g. tacit/explicit, experience/know-how/skills, individual/ collective). Thus, knowledge can be stored in a number of different ways.

Some literature suggests that individuals' knowledge can be stored as written documentation or any other symbolised form (Alavi and Leidner, 2001; Nonaka, 1994; Spender, 1996a) through codification and conversion of tacit forms of knowledge into an

explicit form. Nonaka and Takeuchi (1994) suggest that tacit knowledge can be externalised into explicit knowledge. As it will be outlined later, this research disagrees with this understanding and argues that externalisation is an invisible process because it is influenced by message receivers' interpretation of the message. Therefore, the resulting externalisation may not be the same as its original meaning or concept. This may cause problems of accurate externalisation of one's tacit knowledge and incomplete tacit knowledge. If it is assumed that tacit knowledge can be externalised, this incompleteness may cause problems in the re-use of externalised tacit knowledge. Also, if this codification of knowledge cannot meet the needs of its users or is not in a form that can be understood by users, this codification may not be successful (Handzic and Zhou, 2005). This relates back to argument above that in knowledge sharing common understanding and common language are important factors influencing knowledge receivers to capture and understand the knowledge from a knowledge holder. Therefore, Markus (2001) suggests that codification of knowledge needs to consider who will be the user (e.g. self-used, similar background users, dissimilar background users) and then codify the knowledge in different ways to make sure users can understand.

At a collective level, collective knowledge can be stored in the form of collective memory which may be embedded in culture, routines, procedures, etc. (Alavi and Leidner, 2001; Handzic and Zhou, 2005; Spender, 1996b). This collective memory is defined as '*the means by which knowledge from the past, experience and events influences present organisational activities*' (Stein and Zwass, 1995, pp. 85). Such memory may have positive and negative influence on an organisation's behaviour and performance (Handzic and Zhou, 2005). The positive is that it can prevent reinvention and facilitate change management (Handzic and Zhou, 2005; Wilkins and Bristow, 1987). The negative is that it may cause decision-making bias at either individual level or organisational level (Handzic and Zhou, 2005) due to the embedded nature of such memory.

Furthermore, temporary project teams or people's rotation may disrupt existing routines or procedures. Thus, when a team or organisation faces re-structuring, such collective

memory may not remain and become fragmentary personal memory or experience. Therefore, this research argues that collective knowledge can be stored through routines or procedures, only if a team or an organisation continuously exist and is able to keep a certain amount of senior members to operate the team. Otherwise, collective knowledge may not be able to be sustained. This implies that collective knowledge cannot exist by itself. It exists when people get together and have experienced the same event or situation. This may imply that team experience and interaction are important factors of keeping collective knowledge.

2.2.1.4 Knowledge integration and application

Grant (1996b) argues that organisational competitiveness is derived from knowledge integration. Knowledge integration emphasises the economic value of specialisation and the effectiveness of integration (Huang and Newell, 2003). Demsetz (1991) also argues that the acquisition of knowledge requires individual's specialised knowledge in specific areas. The application of knowledge requires bringing many areas of specialised knowledge together. This means that knowledge is integrated when it is needed for use. Thus, the following paragraphs discuss knowledge integration and application.

Based on this thesis' definition of knowledge, knowledge is context-specific and constructed in specific circumstances. Therefore, knowledge integration takes place at an individual level through an individual's mind (Grant, 1996b). Knowledge integration at individual level can be described as a combination of different experiences and different bodies of knowledge through intellectual processes by which new knowledge can be fostered in the individual's mind to achieve certain purposes or react to situations. This responds to Nonaka's combination mode in which the experiencing and processing of a new event or action triggers the internalisation of knowledge. This integration process of knowledge seems to relate to the learning process in which practice is an important action that generates new insights and may change behaviour (Kim, 1993; Senge, 1993). This may also involve individual double-loop learning (Kim, 1993) (also see 2.1.5.1). In order to effectively use this knowledge integration process at an individual level, this research

suggests that environment, knowledge resources and achievements are playing an important role. They influence the situation that an individual is associated with and engaged in. This may influence the effect of learning at an individual level. The above discussion may justify the importance of context and content management in knowledge management (Snowden, 2002) favoured in this thesis. Considering these issues, the author likes to points out a weakness in Nonaka's SECI model where Nonaka does not justify how the combination process takes place and how it is managed. In fact, he uses the development of prototype as a platform to explain the phenomenon of knowledge integration without explaining how this can be effectively achieved.

Knowledge integration at group/team level differs from the individual level. Indeed, it may be more about integration of actions of a group of people (Senge, 1993). Therefore, knowledge integration in groups/teams can be divided into two dimensions: integration of multi-disciplinary knowledge (e.g. sources and types) (D'Adderio, 2001) and coordination of people. Integration of multi-disciplinary knowledge is associated with various organisational domains (different knowledge sources, e.g. internal research section, supply chain, research institute, university laboratory, distributors) and knowledge types (tacit/explicit, formal/informal, software-embedded/people-embedded). Coordination places an emphasis on group co-operation. Effective coordination relies on frequent social interaction and communication (Huang and Newell, 2003). Grant (1996b) indicates two mechanisms of integrating tacit knowledge: direction and organisational routines. Direction facilitates knowledge to be communicated at low cost between experts and non-experts or between people who are experts in different fields (Demsetz, 1991). Organisational routines provide mechanisms for coordination by which individuals develop continual patterns of interaction that permit the integration of their specialised knowledge without the need for communicating that knowledge (Grant, 1996b). Moreover, D'Adderio (2001) suggests that 'virtual prototyping' techniques, concepts, and models facilitate organisational knowledge integration and multi-functional process coordination.

Grant (1996b) assumes that knowledge integration is determined by three issues: the efficiency of integration, the scope of integration, and the flexibility of integration. Firstly, the efficiency depends on the extent of common language existing between participants, the level of coordination, and organisational structure. Secondly, scope refers to the level of complexity underlying the integration of differentiated knowledge. Finally, flexibility is determined by the organisation's ability for reconfiguring existing knowledge as a means of promoting continuous innovation. These assumptions shape significant issues of knowledge integration, and also provide the basis for further investigating knowledge integration issues.

As described, knowledge integration at group/team level can be carried out in various forms, but they depend on a number of factors, such as team members' characteristics (Demsetz, 1991) (e.g. expert/non-expert, domains of expertise, experience/non-experience, etc.), task characteristics (Senker, 1998) (e.g. incremental and discontinuous innovation, product and technique development), scope of knowledge (e.g. technology, marketing, distribution, etc.), and organisational culture (Firestone and McElroy, 2003; Hislop, 2005) (e.g. encouragement, centralisation/ decentralisation, formal/informal, etc.). These factors not only influence the performance of knowledge integration but also influence the ability of knowledge integration within a team. If knowledge is not integrated effectively, solving problems or driving innovation may be stifled, as the knowledge can not be applied when it is needed.

To sum up, knowledge integration can take place at two levels: at an individual level and a group level. Firstly, knowledge is, in the first instance, held by individuals (Davenport and Prusak, 1998; Grant, 1996b). If an individual is exposed to a new experience, this experience has to become part of an individual's mental models for successful integration and later application. On a group level, integration of people through a concrete goal, or 'virtual prototyping', and coordination is the primary issue (Grant, 1996b; Demsetz, 1991). This enables communication and information flow among team members. A concrete objective can unite members' concentration and motivation and further create a collective vision. Coordination can link all members together, and cultivate group

thoughts to be in tune with each other so that the group members' actions are instinctive-like in specific situations. This also facilitates growing mutual trust among team members. Hence, the activities of knowledge sharing and integration are able to take place gradually. Influencing this process are various factors that determine a team's composition and readiness to integrate knowledge. In regards to this thesis, these notions are important to keep in mind when exploring how knowledge management takes place within innovation contexts, especially in light of how individuals and teams use and gain their knowledge.

2.2.2 Application of knowledge management in the organisation: knowledge creation versus problem solving

With the above understanding of knowledge processes, one may discuss the purpose of knowledge management in organisations or teams and the initiators that trigger such processes. The following section focuses on answering this question through reviewing different frameworks.

In a previous section (2.1.2.1), the author has outlined that knowledge management is emphasised by organisations because it relates to an organisation's competitiveness. However, this seems to provide a big picture and generic, non-specific purpose of knowledge management for an organisation but lacks a sense of what it means to organisational units and members in practice and its influence on their operations, especially how it relates to their work. The previous section on knowledge storage discussed that knowledge repositories have to meet the users' needs, otherwise they are likely to be unsuccessful (Handzic and Zhou, 2005; Markus, 2001). Some research also indicates that successful knowledge management builds upon a clear objective and is relevant to an identified need (Davies and Mabin, 2001; Hoegl and Schulze, 2005). This implies that clarification of the purpose and initiation of knowledge management is important to enable knowledge management to be built close to practice and practitioner needs. The section below discusses a number of frameworks to see how knowledge management is employed and initiated to achieve specified objectives.

Wiig (1993) suggest a knowledge management framework with three knowledge management pillars. This framework identifies several components which illustrate the functions required for managing knowledge. The first pillar includes surveying and categorising knowledge, analysing knowledge and its related activities, and elicit, codify and organise knowledge. The second pillar is appraising and evaluating the value of knowledge and knowledge related activities. The third pillar is synthesising knowledge related activities, handle, use and control knowledge, and leverage, distribute and automate knowledge. The focus of this framework is on managerial issues. Thus, the framework identifies knowledge manipulation activities which are considered conducting knowledge management in organisation (Firestone and McElroy, 2003; Holsapple and Joshi, 1999). This framework provides a general idea of how knowledge can be managed but lacks a specific purpose linking it to why knowledge is produced or integrated (Firestone and McElroy, 2003) and for what reason.

Leonard-Barton (1995) suggests a framework of core capabilities and knowledge building activities. This framework provides four knowledge building activities (problem solving, implementing and integrating, experimenting, and importing knowledge) which are considered enabling an organisation to enhance its core technological capabilities (physical systems, managerial systems, employee skills and knowledge and values and norms). The difference of this framework is that it is not only concerned with knowledge processes themselves but also an organisation's development of core capabilities. However, this framework does not clarify different types of knowledge and then justify how knowledge manipulation activities are managed to contribute to the development of core capabilities.

Arthur Andersen and APQC (1996) suggest an organisational knowledge management model which presents that knowledge can be managed through a circular process of create, identify, collect, adapt, organise, apply and share. However, they neither indicate which starts the process nor define what organisational knowledge is (Holsapple and Joshi, 1999). Around this process, they identify four enabling factors – leadership, culture, technology and measurement – which facilitate this process. However, the author

is unable to identify a further discussion of these enablers. Thus, whilst these are probably useful concepts to consider when engaging in knowledge management, for this research, the lack of detail on how these enablers can enhance knowledge management makes this model inappropriate and incomplete.

Van der Spek and Spijkervet (1997) suggest a knowledge management framework as a problem-solving oriented cycle in which the cycle comprises four knowledge management stages: conceptualise, reflect, act and retrospect. In this framework, conceptualise is an initiation stage in which a concept is shaped, based on the use of existing knowledge. In the reflect stage, this conceptualised knowledge is evaluated, followed by a planning process to enhance its weakness. In the act stage, actions are to improve the knowledge, which involves developing, distributing, combining and holding knowledge. The fourth stage is about evaluating achieved results and comparing old and new situations. The stages in the cycle are influenced by internal and external development. Internal development is identified as culture, members' motivation, organisation, management and information technology. However, they do not identify what the external factors are (Holsapple and Joshi, 1999). Thus, this model is also incomplete and therefore not appropriate to for use in this research, as it is too vague on the possibilities of the external development processes. However, the model seems to be more detailed on how knowledge management can take place on a more specific level, as the model seems applicable to different types of problems.

The above frameworks provide broad concepts of how knowledge management takes place from different perspectives. However, they do not link the frameworks with practice and practitioners but they provide important concepts which may guide further research. In order to approach this research's concern with regards to innovation and explore how knowledge management is placed and initiated within innovation processes, the following section will be more specific and focus on Nonaka and Takeuchi's framework of knowledge creation as this framework is one of the best known frameworks and has been used in the context of technological innovation. This provides a

foundation for this research to look at how knowledge management takes place in innovation teams.

Nonaka and Takeuchi (1995) framework they attempts to combine both notions of tacit and explicit knowledge and the conversion of tacit knowledge into explicit form for use. This knowledge creation model, consisting of four modes of knowledge conversion, is used to illustrate how knowledge is converted and created in Japanese firms, which is the so-called '*spiral of organisational knowledge creation*' (Nonaka and Takeuchi, 1995, pp. 70-73). In this model, socialisation is the initially conceptual mode of knowledge conversion which emphasises the move from tacit-to-tacit knowledge through one-to-one sharing of experiences in order to create/share tacit knowledge. However, by definition, tacit knowledge is difficult to express. Thus, in order to share this type of knowledge, it needs to be shared through deep discussion and interpersonal communication.

The second mode of knowledge conversion is externalisation, i.e. tacit-to-explicit, which suggests that an individual's tacit knowledge can be explicated through metaphors, analogies, concepts, etc. This is proposed to facilitate the transfer of conceptual knowledge.

The third mode, combination, involves the combination of knowledge from different people or technological domains to develop a prototype. This stage argues for a sense-making process in which all the different types of knowledge are framed within known mental models or conceptual frameworks. In addition, it is proposed that externalised knowledge can also be codified and stored. Therefore, the explicit-to-explicit knowledge transferral is suggested.

The last mode is internalisation which involves individuals integrating knowledge into their behaviour and making it part of their mental models through practice. One possible result is the generation of new tacit knowledge. This move from explicit-to-tacit is assumed to also initiate a new cycle in which knowledge can be constantly created.

Nonaka and Takeuchi suggested that this conversion process between tacit and explicit knowledge involves social interaction which requires the space to enable the processes to take place. Thus, Nonaka and his colleagues, Nonaka and Konno (1998) and Nonaka, Toyama and Konno (2000), subsequently suggest 'ba' as an essential spaces to succeed in the knowledge creation processes. There are four types of 'ba' that correspond to four modes of knowledge conversion: originating ba, interacting ba, cyber ba and exercising ba. Originating ba is associated with socialisation in which tacit knowledge is shared through face-to-face interaction and discussion. This begins the process of knowledge creation. Interacting ba is associated with externalisation in which tacit knowledge is converted into explicit knowledge through dialogue and collaboration among individuals. Cyber ba refers to the combination mode in which explicated knowledge can be codified stored and integrated for use. Exercising ba refers to the internalisation mode in which codified knowledge is used and practised which enables knowledge to be internalised and facilitates generating new insights. These newly generated insights also further trigger the next run of the socialisation mode between individuals. It appears obvious to the author that Nonaka and his colleagues assume that knowledge can be created through social interaction between tacit and explicit forms of knowledge by which the spaces are the important element to make social interaction work. Furthermore, this social interaction for Nonaka and his colleagues not only entails internal agents but also involves external agents, especially customers. For them, customers are considered an important knowledge source for input of knowledge and driving the knowledge creation process. This greatly integrates R&D and customers within a value chain to ensure that knowledge creation meets customer needs. However, how this theory can be turned into practice seems subject to various conditions. Nonaka and colleagues suggest in their later research (von Krogh et al., 2000) that it is associated with the right context:

'But each company has an interaction style of its own and will use different kinds of experiences to form its networks of mutual obligation and trust. So how do companies create a coherent enabling context, one that fits both their knowledge vision and business strategy? Our short answer: the right context must be

accompanied by the right organisational structure.' (von Krogh et al., 2000, pp. 182)

This seems to respond to recent development in the knowledge management field in which context and content management are considered important issues (Snowden, 2002). However, in Nonaka and his colleagues' work, the issue of context is discussed in terms of organisational strategy and structure rather than identifying other situational and contextual factors and how organisational members work within the context. This lack of detail on context seems difficult, especially for this thesis, as this research looks at how knowledge management is applicable to people in specific contexts. Therefore, this research suggests a gap in the knowledge spiral model, namely what is context and how does it influence knowledge management being undertaken at specific organisational levels, something Nonaka's model is less clear about. This will be further explored in this research and some further discussion of the model follows below.

Nonaka's model seems to provide a clear purpose and its origins are connecting it to an innovation context by applying the model to new product development and demonstrating how their processes take place. This model also further implies that problem solving is an originating force to trigger socialisation. This may imply that problem solving in practice is an important initiator to create needs for knowledge sharing in order to solve problems; something other models suggest also (Van der Spek and Spijkervet 1997). Because of this need to solve a specified problem, individual knowledge is shared between individuals and among team members. However, this thesis is in doubts whether problem solving initiated knowledge related activities essentially lead to improved innovation performance and future capability. Problem solving may be one way of coordinating knowledge related activities for current needs (Holsapple and Joshi, 1999), but it may not lead to future development (Ahmed et al., 2002). In response, Nonaka would suggest that his model is a spiral process from one circle to another circle. For him, knowledge related activities need to be continuously performed in order to achieve the creation of knowledge and support of future needs. However, there may be a

gap in the practice of knowledge management in organisations, as this appears to be predominantly a theoretical argument.

With regards to Nonaka's model in practice, this research considers that it provides a model of a general process of knowledge creation, and demonstrates how knowledge could be converted through each mode, and how knowledge may be employed in R&D. However, this process seems to build upon a simplistic assumption that all knowledge can be classified into tacit and explicit knowledge by ignoring knowledge's complex nature (Alavi and Leidner, 2001; Meyer, 2004). In the model, it seems, knowledge can be converted from tacit to explicit and vice versa by following the model's process; and subsequently different types of knowledge can be treated separately. Meyer (2004) and Alavi and Leidner (2001) question this simplistic classification of knowledge, and argue that Nonaka's assumption only entails some of the important considerations. As the previous discussion shown, the author defined knowledge as production based on the interaction between mental models, sensory experience and action. This thesis agreed with Polanyi (1969) that '*all knowledge is either tacit or rooted in tacit knowledge*' (p. 144). Therefore, it is seen as implausible that all knowledge can simply be treated in its tacit or explicit forms. Indeed, the author considers that the interaction between tacit and explicit is an important part of knowledge processes but it is insufficient to solve the conversion of all types of knowledge. Furthermore, the author agrees with Snowden (2002) and Firestone and McElroy (2003) that to solve such complex body of knowledge involves learning processes and the management of content and context. In other words, some knowledge may not be able to be explicated but can be managed through managing learning processes and the environment to enable knowledge to be learned by individuals through experiencing situations and practising. In summary, this thesis joins the criticism of Nonaka's model as being simplistic in its assumption about the nature of knowledge.

Furthermore, sharing knowledge not only involves sharing expressible components, but also involves sharing tacit components, such as meanings and a sense of contexts. This raises a significant point in regards to the mechanism behind the process of sharing in order to make knowledge meaningful from one person to another. This may involve

individual learning[2] (Ahmed et al., 2002) as learning makes knowledge to become meaningful when it is shared from one to another. If such processes were part of Nonaka's model, it would make Nonaka's socialisation mode to become more meaningful and useful in sharing different types of knowledge. Kim (1993) suggests an individual double-loop learning process which denotes that to learn something new actually involves constant observation and practice to modify or develop a new scheme to view things and is followed by changing behaviours. Therefore, to make the sharing of knowledge become meaningful, it is important to note that it is not simply about receiving a piece of information or any other form of message. Meaningfulness ought to be developed through practising and developing new mental models. Similarly, internalisation of knowledge is also involved in this individual learning process. However, Nonaka's model does not clearly show how individual learning processes work in this model to enable socialisation and internalisation to take place. This results from their simplistic assumption of knowledge and the way knowledge is exchanged between people. Thus, this research assumes that knowledge cannot be exactly divided into tacit and explicit knowledge, but needs to be understood as constituting tacit and explicit components. Also, in order to make knowledge sharing and internalisation become more effective, this research adopts Kim's viewpoint, i.e. seeing learning processes as a significant component of knowledge management activities.

In addition, in Nonaka's model, externalisation and combination take place at project team or even higher organisational levels in which knowledge is converted from tacit to explicit forms of knowledge through interacting ba and cyber ba. Therefore, knowledge can be used and stored. This research suggests that this makes sense of how knowledge is converted at an individual level. However, what Nonaka's model lacks is a clear explanation of how individual knowledge is converted into team knowledge and what is meant by knowledge in teams. The argument here is that skills, know-how, operational knowledge, conceptual knowledge are possessed by individuals. If on assumes knowledge of that type can be explicated, such conversion to explicit knowledge may be

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[2] 'learning and knowledge therefore mutually reinforce each other in a cycle. The act of learning provides knowledge and understanding, which in turn feed further learning.' (Ahmed et al., 2002, pp. 17)

aided through metaphor, analogy, or drawing (Nonaka, 1995). However, some knowledge cannot be treated in the way Nonaka suggests. This indicates that externalisation of knowledge cannot be applied to all types of knowledge. There is ambiguity in the distinction of the types of knowledge. For example, one example provided by Nonaka and Takeuchi (1995) is the externalisation of the conceptual idea about a new car '*Tall boy*' (pp.64-67) from a manager's perspective. This example may show how conceptual knowledge may be externalised. However, one may not be able to apply this externalisation process to other types of knowledge, such as specific skills and/or mental models. For example, in Nonaka and Takeuchi's book (1995) a Japanese company that planned to produce a leading-edge bread baking machine was not able to capture all the knowledge through simple processes of externalising the knowledge held within experts. Understanding how the dough is kneaded was captured through observation and imitation of a recognised master. The engineers finally found a specific skill that a master baker possesses. In this case, it actually involved the engineers' individual learning process through constant observation and practice to understand the details and nuances of that knowledge, combining their engineering expertise to transform that skill in the design of how they think it may work. In this process, the master baker's tacit knowledge was not really externalised into explicit knowledge. The form in which the knowledge transfer took place is difficult to describe and capture.

The argument here is that the means whereby these skills are externalised is not the same as externalising conceptual knowledge. Based on this reflection, this research agrees with authors who argue that the simplistic view of knowledge sharing adopted by Nonaka and Takeuchi is limiting a full understanding of the complexity of knowledge, and ignoring different types of knowledge requiring different ways to deal with (Alavi and Leidner, 2001).

In addition, returning to the issue of where knowledge is located, Nonaka and Takeuchi's model seems to imply that once knowledge is shared across the whole team, the knowledge will become team knowledge. However, they do not define what team knowledge is and justify how it occurs. This makes the externalisation mode somewhat ambiguous. Individually possessed knowledge may be diffused across the whole team;

however, it is based on one-to-one interaction. Due to individuals' capability and experiences, the same skill, know-how, operational knowledge, or conceptual ideas may be differently interpreted and practised. This may result in different individual insights. Thus, the author argues that there is a weak linkage between individual and team knowledge in Nonaka and Takeuchi's model. This relates to their ambiguity of distinguishing the type of knowledge and lack of defining team knowledge. Indeed, from earlier discussions, this research sees team knowledge as a shared team mental model which refers to collective recognition of team members in specific situations and events (Johnson-Laird, 1983; Langan-Fox, 2001). It enables a team to create shared meaning structures (Langan-Fox, 2001) which help in sharing of team knowledge and based on that to co-ordinate a team's action and reaction in some contexts or circumstances (Langan-Fox, 2001; Cannon-Browers et al., 1995; Senge, 1993). Therefore, this research suggests that to convert tacit knowledge into explicit forms of knowledge should be seen within the context of team learning processes underpinning a shared meaning structure to enable tacit forms of knowledge to be understood and interpreted in the same ways. To reach such team learning, the author adopts Kim's (1993) model of team double-loop learning processes which will be discussed later.

Considering the above argument, this research believes that the relationship between those four modes may be neither linear nor circular, nor individual or organisational. In fact, it is an interdependent relationship (Alavi and Leidner, 2001) with situational order subject to types of knowledge and objective. Considering the weaknesses identified in Noanka's model, this research suggests that knowledge creation and its associated processes rely on individual and team learning processes to make the process become comprehensive. The following section will further discuss this point.

2.2.3 Learning

The above discussion shows that knowledge sharing, integration and creation depend upon learning processes, to comprehend the processes and cope with knowledge's

complexity. Thus, the following discussion will focus on individual and team learning, and how they relate to Nonaka's model and knowledge management related activities.

2.2.3.1 Individual learning

Learning involves '*the actions of using existing insight or knowledge to produce new insights or knowledge*' (Ahmed et al., 2002, pp. 17). It enhances people's abilities to cope with complexity of living and working. Effective individual learning, according to Senge (1993), is a radical change of mental models by which people change their vision and behaviour. But how can people know when and what they should learn? Espejo (1996) indicates that people learn when they detect and correct 'errors'. 'Error' means that our experiences do not match our expectations. When errors occur we start to learn and try to correct this error. This kind of learning is called 'experiential learning'. This experience-based learning enables one to integrate and alternate thinking and doing through experiencing various events or situations (Davis, 1990) – thus this notion of learning is closely related to this research's understanding of how knowledge is acquired. Kolb (1985) suggests a 'learning cycle' which may explain how experienced-based learning process takes place. This learning cycle is comprised of four stages: 'concrete experiences stage', 'observational and reflective stage', 'abstract conceptualisation stage' and 'active experimentation stage'. The initial stage may be triggered by the perception of the world. Then the stage of internalisation begins, followed by stepping back from reality and drawing conclusions and generalisations. The last stage checks out theories and hunches by testing them in the new situations. This model provides a simple learning process and exhibits the cyclical and active nature of learning. However, an individual not only learns from experience but also learns from various knowledge sources, such as reading, listening, networks, etc. Thus, Kolb's model only explains one important part of learning.

Kofman (1992) suggests an OADI learning cycle (or so-called single-loop learning) which consists of four steps: observe, assess, design, and implement. These four steps are repeated in the process of learning. The process starts by observing where a learner takes

in a specific experience. Then he or she reflects on his/her observation; this action is called assess. In the third step, the learner, according to his or her reflection, builds an abstract concept of that reflection. In the last step, the learner tests that concept against reality.

This individual single loop learning is associated with problem solving as it is based upon a error-and-correction process (Argyris and Schön, 1978), without examining the appropriateness of current learning behaviours (Argyris, 1992). The author believes that individual single-loop learning may enable a learner to gain experience and take appropriate action, but it may not be beneficial to enable a learner to gain new insights and change learning behaviours. Therefore, this type of learning may not sufficiently support Nonaka's knowledge creation processes because these processes do not address tacit components of knowledge, hence emphasising the need for deep learning. This reinforces the essence of double-loop learning.

Argyris and Schön (1978) suggest double-loop learning which emphasises the effect of learning being able to modify governing variables rather than just correct errors. In other words, double-loop learning leads to the change of behaviours in which change is motivated by new insights. This corresponds to what Nonaka called internalisation. Moreover, Kim (1993) suggests that learning can be divided into operational learning and conceptual learning. Operational learning is to learn about the 'know-how' or procedural knowledge; conceptual learning is to learn about the 'know-why', which refers to an understanding of the underlying experience and insight of a procedure. Kim (1993) combines Kofman's OADI model with individual mental models, conceptual learning and operational learning to be the OADI model of individual learning (so called individual double loop learning). In this model, conceptual learning relates to the steps of assessing and design; operational learning relates to the steps of implementing and observing. The process of individual learning will finally change or build individual mental models. In Kim's model, conceptual learning can be seen as a process by which an individual can understand the insights of the events and build up intellect; and operational learning can be seen as a practice by which an individual can modify his/her

mental models or schemata by self experiencing or practicing. This responds to Argyris's viewpoint (1992) that double loop learning emphasises continuous experimentation and feedback in an ongoing examination to modify self defining. This model seems particularly useful for this research as it responds to the criticism levelled against Nonaka's model and incorporates earlier assumptions of this research about knowledge. This model of learning looks at the complex process involved in learning, which may be conceptualised as knowledge acquisition and integration.

This aids in understanding of Nonaka and Takeuchi's knowledge creation processes in which operational and conceptual leaning may aid in socialisation to justify how knowledge can be acquired through sharing of know-how and study. The OADI learning cycle aids in justification of how knowledge is integrated and internalised based on implementation. This emphasis of individual learning strengthens the arguments that have been raised in 2.1.4 that Nonaka's socialisation and internalisation modes need to be underpinned by individual double-loop learning.

2.2.3.2 Team learning

Teams are task units and also social units (Altman and Iles, 1998). Therefore, team learning is rather different from individual learning and is more complex and dynamic. Individual learning involves the issues of individual attitude, implementation, experiences and mental models. The focus is to enhance individual mental models (Espejo, 1996). Conversely, team/organisational learning involves the issues that include individual learning, interpersonal interaction, shared mental models and environmental factors. In early research, March and Olson (1975) suggested a simple model of organisational learning in which organisational learning constitutes four elements: individual beliefs, individual action, organisational action and environmental response. In this model, individual beliefs lead to individual action. When an individual wants to solve problems, his or her action will trigger an organisational response (or action). Organisational action then leads to environmental responses and reactions. Any environmental response may lead to a change in an individual's beliefs. In this model,

environmental responses are significant extra-factors that impact on individuals' beliefs and further change individuals' actions. However, March and Olson's model seems a little too simplistic. The author believes that this model offers little insight into the actual processes that facilitate the change of people's mental models and/or behaviour.

The author is more convinced by Kim's (1993) integrated organisational learning model: the OADI-SMM model of organisational learning. This model combines OADI model (individual learning), shared mental model (SMM) (organisational learning), and March and Olson's (1975) organisational learning model. The model constitutes four learning modules: individual double-loop learning, organisational double-loop learning, individual single-loop learning, and organisational single-loop learning. The characteristic of this model is that it can explain a complete process of organisational learning. Moreover, it not only explains the formation of collective learning by adapting organisational double loop learning but also presents the relationship between learning and the environment. This thesis adopts this learning perspective as a comprehensive foundation that explains how knowledge management related activities are necessarily built upon team learning processes and why interaction with the environment is so important. Moreover, this perspective also strengthens this thesis's assumptions that knowledge management activities are context-specific and team learning is part of knowledge management activities. In order to match this research's setting, the following discussions are focused on a project team's learning.

Edmondson (1999) indicates that team learning behaviours include the sharing of knowledge and organising knowledge. Operationally, team learning behaviours involve either internal or external interaction (Edmondson, 1996). Internal interaction is associated with internal communication of knowledge. In contrast, external interaction is about acquiring knowledge and sharing knowledge situated outside the team. Sole and Edmondson (2002) further suggest that team structure is an important factor which influences team members' communication and knowledge sharing and subsequently influences team learning. By taking Edmondson's perspective, the author believes that

effective team learning and knowledge management activities are greatly dependent upon how team members interact and communicate.

Bresnen et al. (2003) indicate that social practice is an important part that influences knowledge sharing and learning in a project-based context. For example, they outline that social patterns, practices and a community-based approach of managing knowledge greatly influence a project team's knowledge sharing and learning. This implies that a team's social contexts and interactions (see section 2.3, team operation) and the way the team processes a project (see section 2.2, innovation context) may influence a team's learning and knowledge related interaction. Moreover, Scarbrough et al. (2001) investigate project-based learning. They suggest that learning boundaries emerge when a project is divided into different task groups. These divisions influence knowledge sharing between groups and a team's learning. To some extent, this result shows that learning has a nested nature which means that learning within a project team is associated with what team members are engaged in. This implies that effective team learning may inherently be influenced by how a team designs work and processes a project. In order to cope with learning boundaries, the author considers that a team's consensus may be an important element to bring team members together.

Senge (1993) states if team members' learning cannot achieve 'alignment' and 'complement', the intelligence of a team may be lower than that of the individuals. This means that the effects of team learning are lost. Moreover, Espejo (1996) suggests that successful organisational learning is based on 'co-ordinated action' in which vision and commitment are agreed by members and also guide them toward the same direction. Both scholars agree that team learning is about alignment of team members to enable them to move forward in the same direction. In the process, leadership and coordination are the significant factors. This seems to imply that team learning not only involves the development of processes but also involves the integration of team members to see the team as a whole. This raises a question of how a team operates to reach a consensus. This is further explored in this research.

Effective team learning facilitates a team to build its core capability in terms of knowledge and innovation capability. Helleloid and Simonin (1994) indicate the relationship between organisational learning, core capability, and competitiveness. They suggest that each organisation is likely to have their own unique style and ability to learn. In order to sustain their competitive advantages, they not only search for specific information but also learn how to learn and unlearn, which enables them to enhance their core competences. Over time, effective organisational learning enables them to develop the ability to select the information or knowledge they need, which enables them to upgrade their core competence and, further, to sustain long-term competitive advantages. Their suggestion points out a critical factor: the ability to determine what information an organisation needs. It is significant for an organisation to distinguish and select valuable information from a complex and a large amount of information. However, effective learning not only relies on the four processes of organisational learning (acquisition, processing, storage, retrieve) but also involves the improvement of the learning environment and team members' mental models.

The notion of team learning is adopted for this research because it is able to justify how Nonaka's (1994) externalisation and combination modes take place within a project team, as it is about building common understanding and aligning team members' action. This supports the argument at the previous section (2.1.4) that Nonaka's model insufficiently justifies how the four different modes are combined and work as a process to lead knowledge to be created. Through the above discussion, this section shows the importance of team learning in knowledge management activities.

2.2.4 Knowledge management context: The case for this thesis

This research agrees with Davies and Mabin. (2001) and Hoegl and Schulze (2005) that successful knowledge management underpins an appreciation of how knowledge is created and used. Therefore, initiation of knowledge management activities ought to be related to its objectives and needs (Meyer, 2004) and organisational/team contexts (Barrett et al, 2004; Ciborra et al., 2001; Fernie et al., 2003; Teece, 2000).

Moreover, Tidd et al. (2001) indicate that the management of innovation in organisations is related to seeking valuable organisational routines and articulate them into procedures which therefore cannot be imitated by other organisations; thus enabling an organisation to sustain its advantages. With this perspective, knowledge management within organisations should be turned into a valuable organisational routine. As Nonaka and Takeuchi (1995) suggest, their model in itself can be seen as an organisational routine in successful Japanese companies as they emphasised in '*The knowledge creating company*' (p. 3). Furthermore, different organisations have different contexts which lead to different ways to seek valuable routines and face different needs (Davenport and Prusak, 1998; von Krogh et al., 2000). For this research, it is one of the objectives to identify different contexts and understand how they influence knowledge management to be undertaken.

Although most knowledge management frameworks are focused on identified knowledge processes and how to manage these processes, the author argues that technological innovation usually takes place in R&D departments. Furthermore, R&D departments may cooperate with other departments to generate new ideas for products. This indicates that building connections or incorporating ideas from outside the team is very important to innovation activities. However, R&D project teams are still responsible for transforming ideas into products. This means that project teams are a valuable focus to further explore how knowledge management actually takes place. The emphasis lies on considering specific team contexts in which knowledge management related activities are undertaken. Thus the notion is to not only to concentrate on knowledge management processes modelled by literature (e.g. Nonaka and Takeuchi, 1995; Anderson and APQC, 1996; Leonard-Barton, 1995; Wiig, 1993; van der Spek and Spijkervet, 1997) but also to consider how team contexts and collective learning processes impact on knowledge management. This is based on Senge's (1993) suggestion that teams are the best unit for undertaking collective learning. Therefore, the research adopts a viewpoint focusing on project teams' knowledge management and knowledge-related activities to understand knowledge management within specific contexts.

On the above basis, this research believes that ultimately, knowledge management-related activities converge towards knowledge creation and the use of knowledge to complete innovation activities. However, this process involves a variety of elements which are associated not only with technical issues about how to manage this process, what is going to be managed and where a case is situated. In other words, what are the local contexts within a team such as project characteristics, local R&D processes and contexts, and team dynamics? In general, this research adopts Nonaka and Takeuchi's process model as a good starting point. However, it needs to be further extended by focusing on local contexts, and assessing in more detail the processes that underline the different stages in the model. Particularly, the process model needs to identify more detailed aspects of knowledge management related activities to allow for the application of such a model to a variety of contexts; knowledge management and innovation are too dependent on situational factors to rely on a "one-size-fits-all" type model. With this understanding, this research emphasises that knowledge management is associated with managing local contexts rather than only managing methods and techniques in general. Therefore, the following sections will further review the literature to outline innovation contexts and team operation to provide a more compete picture of the current state of research within these areas.

2.3 Innovation contexts

The above discussion has pointed out that knowledge management is influenced by organisational context where different organisations have different ways to implement innovation and knowledge management. Thus, this section tries to outline the knowledge management contexts for teams in technological innovation context.

2.3.1 Innovation

Innovation is about '*change*' (Tidd et al, 2001, pp. 6) – to change organisational procedure, to change strategy, to change designs, to change the way of producing products, etc. With considering this research's focuses on technological change;

therefore, this thesis defines innovation as '*to change design or to develop new*'. Change involves two dimensions; the first is what is going to be changed and the second is the degree of the change. The first dimension entails the things that could be products or services and the ways to do things which could be the processes such as manufacturing processes and the use of equipment. The degree of change can be from '*minor*', '*incremental*', '*radical*' to '*complete change*' (Tidd et al, 2001, pp. 8). Within those two dimensions, this research focuses on technology and product incremental and radical innovation.

Incremental innovation can be defined as an innovation which adds new features to an existing product or improves existing technologies (Garcia and Calantone, 2002). For example, since the personal computer (PC) was launched in the 1980s, it has been incrementally improved based on the development of Central Processing Units (CPU). In the information technology (IT) industry, every launch of a new CPU not only means enhancing the speed but also enhancing a PC's efficiency and effectiveness. This enlarges the PC's functions and pushes related application software to be developed and upgraded.

In contrast, radical innovation can be defined as an innovation which is embedded in a new technology and may result in a new market infrastructure (Garcia and Calantone, 2002). For example, the success of Internet technology has not only extended a PC's functions but has also changed the way that people live such as consumer behaviour, interaction models, and access to information. This is a recent example of radical innovation.

Although these two types of innovation have different degrees of change, their efforts can be complementary and influence an organisation's capabilities of undertaking innovations continuously. Tidd et al. (2001) summarises an approach to managing innovation. Firstly, innovation is the search for effective routines and through the learning process embeds the patterns of the behaviours of the routines into organisational structures and procedures to deal with change and the change process (Tidd et al., 2001).

Furthermore, effective routines and learning processes are the important elements toward innovation. Tidd et al. further outline the important routines as strategy, internal and external linkages, enabling mechanisms to initiate change and a supportive organisational context. Thus, this emphasis on learning links to this research's definition of knowledge management.

For Tidd et al. (2001) strategy refers to goals and how to reach the goals. An appropriate strategy cannot be made without considering an organisation's current position, the path of technological development, and current organisational procedures (Tidd et al., 2001) as change is based on current situation toward future situation. In this process, finding new opportunities, departing from the current situation, and initiating change need to be considered and well planned. Building external linkages with customers, technology suppliers, equipment suppliers, and other organisations are considered important for obtaining information and knowledge. Moreover, an organisation needs an implementation mechanism to turn the ideas or opportunities into reality. This entails systematic problem solving and an effective decision-making framework, and also requires skills of project management and control, and integration of the market and technology stream (Tidd et al., 2001). In addition, an environment that allows creative ideas to come up and to be effectively deployed is necessary. This relies on a good arrangement of communication, work structure, award system, training system, etc. As Tidd et al. (2001) indicate, these requirements converge on forming a learning organisation by which the ability to accumulate knowledge and manage innovation processes can be fostered.

The above perspectives of innovation management may be developed based on an organisational level, but they provide the general ideas for managing innovation. However, adopting these perspectives and applying them to teams, the first problem one may face is how an organisation's goals are formed, and the second is how these goals relate to each team or how a team's goals fit with organisational goals and become part of such goals.

In this study, a project-based organisation is investigated. In such organisations, organisational goals may not easily be converged at one focus. It is sometimes multi-focused according to project sources and technological trends. Therefore, this thesis assumes that there is flexibility for an organisation and its teams to communicate goals and how they can be achieved. However, organisational hierarchy and structure influence the distribution of power and resources. Therefore, the argument here is that organisational factors influence a team to form its goals as part of organisational goals, and influences ways to achieve the goals. This thesis sees knowledge management as an aspect of the processes to enhance an organisation or a team's innovation ability. Therefore, this thesis considers that innovation practice within an organisation or a team can be seen as a significant contextual variable that is likely to have an influence on knowledge management and how it is undertaken.

Indeed, innovation context is associated with many factors, such as organisational factors (e.g. decentralisation, top management characteristics, organisational culture and climate, size, formalisation, etc. (Blindenbach-Driessen and van den Ende, 2006; Kim, 1980; Kimberly and Evanisko, 1981; Damanpour, 1991)) and team factors (e.g. expertise, experience, operation, etc.). Furthermore, innovation is mostly undertaken at team level and based on a team's contexts. These team contexts can be identified including team leader, creative climate, extensive communication, training and development, participation, learning, etc (Tidd et al., 2001). Moreover, Tidd et al. (2001) indicate that innovation is established alongside the learning organisation. Therefore, to develop a team as a learning mechanism is an important issue and part of innovation practice.

To combine the above discussion, this thesis considers that a project team is a significant implementation unit for innovation. Therefore, any related discussion should be centred on a project team to further explore how innovation is practised within teams. In order to build up a central perspective, this thesis adopts Tidd et al. (2001) suggestion of focusing on an aspect of a team's effective implementation mechanisms.

Implementation of R&D involves the process of systematic problem-solving and a clear decision-making framework to carry projects through. This requires the skills of project management. However, each organisation has its specific context and ways to undertake and manage projects (Shenhar, 2001; Cardinal, 2001). In this research context, project management is set in the context of a public research organisation. In this type of organisation, project management involves three elements. The first one is the features of the project which are associated with funding sources, types of innovation, and products. The second one is R&D contexts, which includes R&D mechanisms, resources, decision-making framework, and R&D facilities. The third one is the ways of processing the projects. This is associated with how a R&D team schedules the project, copes with uncertainties, and solves problems. The following sections will discuss respectively these three elements.

2.3.2 Project characteristics

A project can include a number of different characteristics that can be dependent upon a project's achievements, products, organisational capability, and sponsors. For example, the characteristics of the project can be identified along several dimensions, such as funding (public, self support, and contracted funding) (Link and Scott, 2001; Gans and Stern, 2003), innovativeness (incremental and radical innovation) (Damanpour, 1991 and 1996; Subramanian and Nilakanta, 1996), product (specific technical know-how, designs, and prototypes), nature (science and technology), user (industrial product and consumer product), and complexity of the project (Shendar, 2001). These characteristics influence how a project is generated, performed (e.g. functions, processes, structure, people), and allocated the resources. In this research, context, funding, innovativeness, and product are adopted as important project characteristics. This understanding is based on the researcher's knowledge of the organisation under study.

With regards to the funding dimension, publicly funded, self-funded, and privately funded projects may aim at different purposes. Lee and Om (1996) investigated project selection at public and private R&D institutes. The result suggests that public R&D

institutes are more concerned with the 'diffusion effect factor'. Conversely, private R&D institutes take market characteristic factors as a consideration. Deriving from this suggestion, this research assumes that a publicly funded project, especially one funded by the government, may aim towards scientific knowledge development or industrial core technology development because the outcomes can be used to support a specific industry. In this type of project, in order to lead industry and support industry, the team may need to interact with industrial firms to capture new information about market and technological trends and interact with specific research organisations to acquire scientific knowledge.

Conversely, a privately funded project may aim at a new functional module's development, and it tends to use existing technology in order to reduce risk and cost. Pavitt (1984) investigated traditional industry's innovation with results that suggest most innovations in those industries (such as food manufacture and construction) are driven by suppliers when they are providing new equipment or material. Most innovations of firms are focused on improving product or process technology in order to adapt new equipment or materials. These are called supplier-dominated firms (Pavitt, 1984). A similar situation emerges in the information industry and its technology-follower (Forbes and Wield, 2000) firms. In the information industry, leading companies, such as Microsoft, Apple, Intel, and IBM, usually dominate industrial standards, technical platforms, and core technology. The technology-follower firms' innovations are mostly based on existing specification and its technical platform to develop extended functions or technical solutions for solving specific problems. Thus, in-house R&D is more required for this type of firm (Forbes and Wield, 2000). This also means that this type of privately funded project relies more on internal experts' and engineers' knowledge and expertise (Senker, 1998).

Regarding the dimension of innovativeness, radical innovation and incremental innovation are associated respectively with different organisational conditions. Damanpour (1996) indicates that managerial attitude and technical knowledge resources facilitate radical innovations; structure complexity and decentralisation lead to

incremental innovation. Radical innovation is often associated with higher uncertainty stemming from higher degree of technological change. Therefore, to perform this kind of innovation depends upon top (higher) management's attitude and support to sort out the inputs of resources and make decisions. Thus, this kind of project is usually conducted by a higher position leader, which facilitates the project team to coordinate with other teams and divisions by using the leader's status within the organisation. Conversely, incremental innovation may involve a lower technological change. Thus, it is easier to be initiated by teams. This may explain why incremental innovation is associated with decentralisation of R&D structure because its change can be conducted by the teams or divisions. This illustrates that different project characteristics are associated with different supporting conditions. If the support conditions match with the characteristics of the project, the project can be undertaken more effectively and efficiently than projects without matching conditions.

At the dimension of product, different products are also associated with different resource inputs. For instance, developing technological know-how may involve seeking better understanding of specific scientific knowledge, and transforming it into an implemented procedure for use or so-called technological know-how. This may require a team to interact with scientists in order to obtain their knowledge and skills. Conversely, in a prototype development project, team members may have a diversity of expertise in different technical subjects to support different functional requirements. In this situation the team may need to develop an integrative capability to cope with expertise integration problems. This means the interaction and communication between different expertises should be addressed. Those examples imply that different products are associated with different knowledge inputs and the ways of operating the teams (Cardinal, 2001). Considering previous discussion, it is important to be aware of those differing requirements, as different project characteristics seems to require different inputs and processes. This links to this thesis' understanding of knowledge management and the need to be locally grounded in order to undertake successful knowledge management.

2.3.3 R&D contexts

Having identified project characteristics, this section will focus on the R&D environment. A team undertaking R&D is subject to organisational contexts as the organisation provides the resources and empowers the team to carry out the project. However, each team has its specific situation and experiences which lead the teams to undertake the project in different ways. This may force teams to develop their specific R&D contexts which complement organisational R&D context. The following section will discuss respectively organisational R&D contexts and team R&D contexts.

2.3.3.1 Organisational R&D contexts

R&D is a series of activities to transform an innovative idea into a reality. It not only involves a team's R&D practice but also involves a number of organisational factors as its inputs. For example, a degree of uncertainty and financial risk may lead top/senior managers to choose different R&D structure (e.g. centralisation and decentralisation) (Hill et al., 2000). This influences how a team is empowered and obtains support from the organisation in terms of finance, expertise and related resources (e.g. training system and knowledge sources). Moreover, some R&D projects require long-term investment, and may not produce an immediate return (Nobelius, 2004). This requires top/senior managers' involvement and support. Damanpour (1991) suggests that top management involvement facilitates innovation, especially during the implementation stage (Damanpour, 1991; Grant, 1996b). Mohamed and Rickards (1996) also indicate that top management involvement facilitates to foster a creative climate and form a new culture. However, the degree of involvement of top management that is required may be determined by the particular situation. For example, incremental innovation requires lower involvement of top management and radical innovation requires higher involvement of top management (Damanpour, 1991). Radical innovation requires more resource support from the organisation and requires more coordination. Therefore, top and senior management's involvement can provide essential support. However, deep involvement of top management may decrease a team's creativity and dominate a team's

actions. Thus, how a team interacts with top and senior management to gain support is an important issue to a team to undertake innovation and knowledge management activities.

The organisation itself can be seen as a knowledge base (Grant, 1996b) which provides significant knowledge inputs to R&D processes. This knowledge base is usually developed by organisational members over time and stored in many forms such as documents and organisational memory. Organisational memory is partially embedded in organisational routines and procedures (Davenport and Prusak, 1998) which influence organisational members' behaviours and the ways of doing things. Moreover, a variety of knowledge resources reside in an organisation's subunits, which rely on the organisation to link those knowledge sources for further application (Grant, 1996b). This is an important notion in the context of organisational R&D when investigating team R&D activities, as this relates to the acquisition of knowledge.

Training is an abstracted way of allowing people to learn new skills. However, it needs to be set within specific contexts from practice to application of the skills. This is known as internalisation of knowledge (Nonaka and Takeuchi, 1995). Effective training needs to be combined with practice to articulate training efforts into individual tacit knowledge which is considered the way of inputting knowledge into innovation processes (Bresnen et al., 2003; Leonard and Sensiper, 1998 Senker, 1998;). Therefore, training systems are an important part in the context of organisational R&D. Furthermore, considering the previous discussion of the need to base knowledge management on individual and organisational learning, this aspect of training seems especially relevant.

Talent exchange is a way of diffusing knowledge. There are some strategies that have been discussed in the literature, such as rotation of expertise (Nonaka and Takeuchi, 1995) and matrix structures (Burns, 1989; Chi and Nystrom, 1998). However, it may not be necessary in all organisations because divisional boundaries limit the transfer of talents between divisions. Also, each team has its own specific situations to support teamwork. Such specific situations may not be transplanted and imitated from one team to another team through rotation of expertise. Therefore, temporary teams based on the

use of matrix structures seem to be an alternative solution to be adopted in R&D context. However, this matrix structure may raise the problems of how a temporary team develops an appropriate atmosphere to support knowledge related activities.

So far, the view of the R&D contexts adopted here emphasises the mechanisms that are needed for supporting organisational R&D. However, for a division or a project team, it seems too broad, and involves too many organisational mechanisms which may not exist at a project level, but they can be seen as the supporting or constraining conditions for the project teams. Therefore, at project team level, it may be more sensible to focus on how R&D teams undertake a project under organisational limitations and how much resources are put into R&D activities within the project teams and how project teams employ or manage those resources.

2.3.3.2 Team R&D contexts

R&D contexts at a team level can be defined as a set of mechanisms which are founded by the organisation or created by teams/divisions themselves to support their R&D activities. These mechanisms are directly associated with performing the projects, such as generation of ideas, communication with internal/external experts and sponsors, connection with knowledge sources, transfer of talents and training. However, each team has its own specific situations and needs. Therefore, team R&D contexts are difficult to be generalised. In fact, it can be very situational according to each team's situations and project needs[3] (Cardinal, 2001).

Team R&D contexts are associated with the issues of what the R&D objective is (i.e. product or technological know-how) and how problems are solved. Firstly, product development can be seen as a platform for creating and applying knowledge in which different supportive mechanisms are required.

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3 'an organisation itself is historically the product of its own politics, economics and social factors that contribute to the use of processes, practice and philosophies.....we can also deduce from this systemised view of knowledge and context that analysis of an organisation's process and practice must be executed in full awareness of the context within which the practice is embedded (Fernie et al., 2003)

For example, Matsushita creates the new knowledge from the development of home bakery (Nonaka and Takeuchi, 1995). In this case, the new knowledge is not only technology itself such as dough-kneading, heating control, and fermentation, but also the know-how of new product development. Required R&D contexts in this project include software mechanisms (learning- acquisition of bread-making skills, criteria setting- taste evaluation) and technological mechanisms (product design, engineering, and electronic control system) (Nonaka and Takeuchi, 1995). Software mechanisms provide the know-how of baking bread to the technological groups through learning from the master of bakery at the Osaka International Hotel. Moreover, it also enables the team to develop a set of taste criteria to evaluate the quality of bread made by the home bakery machine. In these mechanisms, the activities are focused on learning, observing, making and analysing the process of baking bread. The efforts are applied on design, test, and modifying the new product.

This case demonstrates that the R&D contexts in the product development processes require not only different technological expertise but also learning processes to absorb and transform tacit knowledge and skills.

Secondly, innovation requires a systematic problem solving capability (Leonard and Sensiper, 1998). However, it is closely related to participants' experiences and skills rather than technological knowledge. In some situations, problems are complex and unobvious. This leads to reliance on individual experiences and skills to diagnose the causes. This can be likened to a situation in which a doctor diagnoses a patient by taking his/her physical symptoms, which is based on a doctor's knowledge and experience to judge what is happening to the patient. Similarly, problem solving in R&D teams relies on team members' experiences and tacit knowledge. This indicates that problem solving could be an experience-intensive activity, and it might be beyond technological know-how that participants have known. Thus, a mechanism for accumulation and storage of experiences may need to be included in R&D mechanisms, such as building a stronger

information system for managing technical documents and creating activities for professional interactions.

Those two notions imply that different situations are associated with different supportive mechanisms. However, required mechanisms may not exist within a team or an organisation. Therefore, a team may need to create specific mechanisms according to projects. In this particular research context, connections, learning mechanisms, information systems and transfer of talents are the required R&D mechanisms..

In addition to different team situations, organisational R&D structure is also a factor. In a centralised R&D structure, R&D teams and their divisions may have less power to decide on the investment of facilities, the transfer of talents from outside the team, and scheduling of the project. Conversely, within a decentralised R&D structure, R&D teams and their divisions may be empowered to have decision-making power, request transfer of talents from other teams and scheduling projects. The advantages of a centralised structure are that the R&D activities may be directly conducted by senior/top management. This may lead more resources to be inputted (Cooper and Kleinschmidt, 1995; Swink, 2000). But top management's attention is sometimes a disruptive factor (Cooper and Kleinschmidt, 1987) to team innovation activities. In contrast, a decentralised R&D structure enables teams to have autonomy to carry out projects. This autonomy empowers teams to create their specific R&D mechanisms to support their projects.

Neither of those approaches is preferred by the author, as the degree of centralisation has to be matched to the innovation type.

Moreover, communication mechanism, e.g. formal/informal meetings, is a crucial element in innovation and knowledge management activities. It enables a team to communicate with internal/external experts to update specific information and access knowledge sources outside the team (McDermott and O'Connor, 2002). However, divisionism and divisional boundaries may cause difficulty in inter-divisional

communication and exchange of information and knowledge, because the knowledge is implicitly seen as a team/divisional asset rather than a shared asset. It also relates to the competition between teams or divisions. Therefore, top/senior management's involvement in encouraging inter-team communication and creating a regular communication mechanism is necessary. This is also relevant when considering knowledge sharing. Appropriate communication processes need to be in place in order to share different types of knowledge when they are needed.

2.3.4 R&D process

In recent decades, managing R&D processes has been developed and changed over time from technology-centre models to interaction-based views (Nobelius, 2004). The foci have shifted from technology itself, linkage of market demands, linkage with corporate strategy, cross-functional integration, integration with environment to a recent focus on separately managing research and development (Nobelius, 2004). This evolution shows the importance of environment change driving R&D management change in which technological contexts, market contexts, industrial contexts and organisational context are gradually integrated into R&D management to deal with new emerging situations. This is a corporate level view of R&D management. However, this research focuses on the project team level and how the methods are adopted to respond to new emerging situations and how problem solving is addressed.

R&D processes in this research can be defined as a set of designed working methods by which a project can be divided into several phases and tasks to conduct a project, to be completed within a certain time period. In this process, each phase may include several tasks, such as functions, modules, and units according to the project. Those tasks are connected by pre-setting order and check points. Each task may be further divided into several interdependent or independent work packages (Meredith and Mantel, 2000). Each work package can be performed by one or a group of members. This model is adopted here, as it is a simple process model that highlights the significant aspects that are relevant when assessing knowledge management activities.

The R&D process in different firms/industries may have different disciplines and models, which can be seen as firm-specificity (Helfat, 1994, Shenhar, 2001) and industry-specificity. Within a software R&D domain such as the one in this research, there are several software development models that have been developed and utilised, such as the waterfall model (Pfleeger, 1998), the prototyping and the spiral model (Pressman, 1997). These models are adopted depending on the organisational context and project features. Meanwhile, these models do not contain fixed procedures to be followed. In practice, adopters can modify the procedures according to their needs. Among those models, the concept of waterfall model is most commonly used in the R&D processes. However, each team practices it in a slightly different way, according to their team experiences, customs and the actual needs of the projects.

Kess and Haapasalo (2002) investigated software development processes. They compared the waterfall model (Pfleeger, 1998) with an improved model which adds project review in all phases to perform inspection, correction, and knowledge creation (creating solutions) functions from a view of sharing knowledge. They found that the traditional waterfall model neglects continual inspecting and correcting efforts in the R&D processes. This decreases the chance of problems being identified in earlier steps. This causes the project team falling into a circular pattern of forward and backward to accomplish the project as each problem leads to inspection and modification in each step. Moreover, it does not provide frequent chances to enable team members to create knowledge through solving problems in the processes. However, in the improved model, project review is set at each phase. Thus, the team can actually inspect the efforts, and correct defects or modify the specification in the early stages (Kess and Haapasalo, 2002). Moreover, inspections are considered to have a fundamental function in software development (Chatzigeorgiou and Antoniadis, 2003) because they not only allow the team to detect the defects but also facilitate the team members to coordinate tasks and create knowledge for solving problems. Their results suggest that based on this improved model, the software development process can be effectively improved and produce higher quality software. Also, it enables knowledge sharing and creation to be practiced in the

project team's daily activities (Chatzigeorgiou and Antoniadis, 2003). One may argue that this does not only apply to software R&D, but that continuous review is important in all R&D projects.

Recent research also suggests the test-driven development (TDD) model for improving software development processes (George and Williams, 2004). George and Williams (2004) investigate the effectiveness of TDD by setting structured experiments with 24 professional programmes, one of them using the TDD model, and the other using the waterfall model to develop software. The result suggests, the team that applied the TDD model in the software development process produced a higher quality programme but taking more time. The contribution of the TDD model is that the team can write unit test cases for the objective functions by which the unknown problems can be explored and pre-detected before the process sets into the coding phase. This model is considered to enhance the quality of software development processes, as well as facilitate the project team to practice knowledge sharing and creation activities through the problem solving function.

R&D processes are associated with the organisation/team's practice. Such practice is influenced by a number of factors, such as project characteristics, team experiences, organisational context, industrial structure, etc. However, there is no doubt that adoption of any R&D process impacts on knowledge interaction within the project team in relation to how and when such activities take place. Thus keeping these factors in mind is pivotal when investigating team specific knowledge related activities.

2.3.5 The influence of project characteristics on team work

The current research assumes that projects with different characteristics require different combinations of R&D contexts to support different ways to carry out the projects. For example, in a technological know-how R&D project, its R&D process may start with predicting a technology trend (Syrbe, 1995), searching of industrial standards and technical specifications. Conversely, in a consumer product development project,

fostering product concepts may be a starting point in the R&D process. The difference between these two types of projects is that the technological know-how R&D is highly associated with the application of specific scientific/technological knowledge and also relevant to the diffusion and application of efforts within the industry afterward. Thus, to study related technical specifications and predict the trend of technology development is significant.

Conversely, in a consumer product development project, customer needs and product concepts are the determinants of the development of the new product. Earlier market research and consumer involvement in the stage of product development are considered necessary (Nonaka et al., 1996; Gupta and Wilemon, 1996). This enables the products to meet customer needs. This illustrates that this sort of project requires quite different R&D processes from the key technology development project because each type of project is associated with different drivers and technological levels.

The source of funding is considered a significant factor which influences the cross-functional expertise to be recruited into a project (Collinson, 2001; Gupta and Wilemon, 1996). This means that the origin of the funding dictates how the projects are operated, such as efforts' application (technologies), allocation of expertise, utility of organisational resources (priority) and span of control. In some specific cases, a project which is supported by the public sector, such as government, may have sufficient funding to include different expertise in the project rather than sharing talents with others. This facilitates the project team to create different functional expertise to support the project. However, for a privately funded project, the considerations of cost and required technological resources usually restrict the project team to create complete functions to support the project. This involves an organisation's operation strategy in terms of effectively allocating talents in order to keep cost down. Therefore, this type of project may share organisational resources, facilities and talents with other projects. This leads a team to acquire different support, hence process the project in different ways. For example, a team may use outsourcing to deal with some tasks that cannot be supported by the team or others within the organisation.

Project characteristics shape a project and related resources that need to be inputted. R&D contexts are the supportive mechanisms which connect or process the resources to support the projects. The R&D process deals with the ways of carrying out the project based on a team's knowledge of processing the project and supportive mechanisms. These three elements guide a project where to go and how to get there. All of these processes influence knowledge related activities taking place within a project team and its innovation performance afterwards.

This section highlights the innovation contexts in the public research sectors. However, the highlighting only illustrates the factors which influence a project to be undertaken, without judging its usefulness for performance. The reason for this is that there is no clear scale that determines which context is better. These factors are contextual and each case has to be evaluated based on this. In the earlier discussion in knowledge management section, this thesis has pointed out that knowledge management is the processes as well as activities which involve team interaction and alignment of team action. Therefore, how a team operates to perform innovation and knowledge management activities is important. The following section will discuss this point.

2.4 Team operation

The above sections have highlighted that knowledge management related activities take place in relation to a team's daily operation by outlining what the R&D process is and how this relates to the suggested processes for successful knowledge management. Thus, this section will review related literature to establish what elements constitute team operation. Nonaka and Takeuchi (1995) indicate that knowledge creation activities in their case are initiated by middle managers. However, other literature indicates that top management has responsibility to initiate such activities and lead the organisation to foster related climate for any change (e.g. Mohamed and Rickards, 1996). Therefore, team leader and leadership could be an important issue for knowledge management activities. Moreover, knowledge management not only involves technically transfer of

knowledge or information between team members but also deeply involves a team's social contexts. As an earlier discussion showed (2.1.3.1 and 2.1.3.2), knowledge acquisition and sharing entail social interaction and social networks. Therefore, in order to understand how knowledge management activities are undertaken, it is necessary to explore how a team operates. A team's operation can be divided into formal and informal. The formal scenario relates to leadership, team structure and tasks. In contrast, the informal scenario relates to a team's social contexts which may include informal leadership, social interaction, norms and team atmosphere.

2.4.1 Leadership roles in knowledge management and innovation activities

The earlier discussions on learning has pointed out that leadership is an important issue in team learning. Also the innovation context section mentioned that leadership is a linkage which connects individuals and organisation and also relates to particular issues such as empowerment, decision-making and organisational support. Thus, this section focuses on the role of leadership and a team leader's role.

There are many leadership theories that have been proposed in the literature. For example, trait theories, behaviour theories, contingency (situational) theories, (neo) charismatic theories, etc. Different theories are developed by taking different perspectives and based on different contexts (e.g. politics, firms and military). However, in this research, the author is particularly concerned with the role of leadership and leaders in the research teams and a leader's influence on team dynamics. Thus, contingency (situational) theories are addressed in this research.

Robbins (2001) defines leadership as '*the ability to influence a group towards the achievement of goals*' (pp. 314). In this definition, leadership seems to be a one-way form of influence between a leader and the group members. However, Daft (1999) considers leadership to be associated with the relationship between a leader and the followers.

Therefore, he defined leadership as '*an influence relationship among leaders and followers who intend real changes that reflect their shared purposes*' (pp. 5).

Although these two definitions have different perspectives, they have pointed out the key elements of leadership which are 'influence', 'changes' and 'purposes/achievements'. A leader's influence within a group originates from several sources such as expertise, position, social status and so on. However, the way a team leader comes across to team members, by using these different power sources, is considered important for effective leadership. Fiedler (1967) suggests that an effective leadership depends on a leader's style of interacting with his/her team members and the situation that influences a leader, such as time span, task, organisational structure, etc. Thus, the choosing of leadership styles may be situational. Moreover, a team leader within an organisation also possesses the privileges that come with the position to lead the team.

However, in some circumstances, a team leader's informal influence may be more important than formal influence within a team (Robbins, 2001). This suggests that the application of leadership is associated with not only official power but also social influence (Ammeter et al., 2002). This is a concern within this research because the previous discussion has point out that knowledge related interaction within a team relies on frequent social interaction and developing a common understanding. Hence the author considers that leadership has important influence on knowledge management activities, as a leader has the potential to facilitate social ties or team interaction through his or her social influence.

Ahmed et al. (2002) indicate that leadership role in managing knowledge is to install a culture and climate that fosters and acknowledges knowledge at every organisational level. In order to build cultures for sharing and learning, the leaders in the organisation are required to identify, recruit, develop, train, encourage and allow knowledge competitions throughout the organisation (Ahmed et al, 2002; Politis, 2001). However, the leader's role in this scenario with regards to creating culture and climate is not only about what they say but also about what they do to lead organisational members to make

it happen (Ahmed et al., 2002). This initiates the concerns, how a team leader guides a team and what roles a leader acts out to enable knowledge sharing and learning to take place within a team.

Stewart (1982) proposes a demands-constraints-choices model to shape the nature of a managerial job. She identifies how these three elements influence managers' behaviour. According to this theory, the demands of superiors, subordinates, peers and outsiders determine the role of a leader within a team. They also influence a leader's time management and leadership skills. Those demands initiate the needs for relationship between the leader and superiors, subordinates, peers, and outsiders in order to coordinate work. This pattern of the relationship provides the basis to shape another pattern which is about the interaction between them. The pattern of interaction facilitates understanding the role a leader plays within his/her team, and how a leader carries out the job.

However, how a leader acts in knowledge management activities is more specific subject which has not been largely discussed in knowledge related literature. Eppler and Sukowski (2000) suggest that team leaders in knowledge management activities '*serve as a role model and coach team members to develop knowledge*' (pp. 340). A role model assists in sharing knowledge, spending time on supporting reflection and experimenting, as well as documenting important activities and processes.

A team leader's role within a team can be diverse according to different situations. Robbins (2001) suggests that team leaders are different from managers as they are not only involved in making plans and taking control, but also '*managing external boundary and facilitating the team process*' (Steckler and Fondas, 1995, pp. 20). Thus team leaders act as liaisons with external constituencies, troubleshooters, conflict managers and coaches (Eppler and Sukowski, 2000). However, in order to carry out such roles, the choosing of leadership style may be important. Mintzberg (1998) indicates that professional/knowledge workers respond to inspiration not supervision. The author assumes that in the technological innovation context, democratic leadership style may be better suited compared to an autocratic leadership style in R&D teams. A democratic

leadership style encourages participation, empowers others, relies on team members' knowledge for completion of tasks and respects individuals' reaction (Daft, 1999). These features may be suitable for leading a specialist team in which individuals are expected to be respected as an expert as well as an individual. However, as in the earlier discussion, the choosing of leadership style to lead a team is situation orientated and also involves the relationship between a team leader and the team members. Thus, an autocratic leadership style may apply to some circumstances in such teams.

The author agrees with Ahmed et al. (2002) that leadership and the role of a team leader are important elements of instilling a culture for knowledge management related activities. Therefore, this research assumes that a leader's influence on a team is through encouraging interaction and creating a shared vision to align people's actions for knowledge management related activities. Hence, a democratic leadership style appears to be more suited to this sort of activities. Furthermore, the author assumes that a leader is not necessarily someone with hierarchical power, but someone who is able to get people interacting. None of those traits exist in isolation and no team is the same, hence leadership is understood as a situational, interactive model.

2.4.2 Personal attitude

A person's attitude can influence one's behaviour, action, interpersonal relationship and so forth. This has been seen as an important factor in teamwork. A concern here is that personal attitude seems to be an important factor that influences a team to develop a supportive social context where knowledge can be openly shared between team members. There is much research (e.g., Antill, 1984; Byrne, 1971; Mcgrath, 1984) that suggests that attitude similarity is a significant factor in attraction and friendship (Harrison, Price, and Bell, 1998). Higher similarity in attitude facilitates interactions and communications between group members (Shaw, 1981; Holtz, 2004), and also increase rewards when relationships are examined based on the exchange theory (Thibaut and Kelley, 1959, Tsui and O'Reilly, 1989). This facilitates to reduce potential interpersonal conflict (Tsui and O'Reilly, 1989) and develop group cohesiveness (Harrison, Price, and Bell, 1998;

Terborg et al., 1976). However, how a group of people can form similar attitudes that relate to personal engagement in teamwork and knowledge management may be a fundamental issue within teams. As the previous discussion, this research assumes that a team leader has an important influence on the change of individual team members' attitude. The other issue this raises is that if a matrix structure is assumed to complete a project, it may be difficult to ensure that all members have similar attitudes. Thus, for this research it is important to keep in mind that individual attitudes may influence knowledge related activities and these are performed within teams.

2.4.3 Team cohesiveness

Within the social sciences, the term cohesiveness can be employed to describe '*the processes keeping members of a small group or larger entity together and united to varying degrees*' (Dion, 2000, pp. 7). Lewin (1939) considered that cohesiveness means a willingness by which members of a group like to stick together. Thus, he defined cohesion as '*the set of forces keeping members together which include the positive forces of attraction and the negative forces of repulsion* (Lewin, 1939 cited by Dion, 2000, pp. 8).' In more recent research, Carron (1988) further identified a hierarchical model to distinguish cohesion, such as task and social cohesion, and belongingness and moral cohesion. This model provides an idea for subsequent research to focus on several issues, such as the field of forces which builds the cohesion within the groups (Dion, 2000), group functioning issues, group performance (Evans and Dion, 1991; Gully et al., 1995; Mullen and Copper, 1994), and so forth.

In small-group research, cohesiveness has been evidenced as being an important element to groups (Cartwright, 1968; Craig and Kelly, 1999). Craig and Kelly (1999) suggest that task cohesiveness has a positive influence on a team's creativity and the technical quality of the solutions that the team produces. They also indicated that task cohesiveness and interpersonal cohesiveness may interact to influence a team's creativity. These results seem to suggest that group cohesiveness influences a team's innovative effects and its related activities, including knowledge management. This perhaps justifies that in high

cohesiveness groups, the members communicate more frequently for a longer period and display more openness to each other (Holtz, 2004; Kirmeyer and Lin, 1987; Shaw, 1981).

Moreover, research (Brewer and Harasty, 1996; Smith and Henry, 1996) also suggests that when *'the interactions between members becoming structurally coherent and organised, information about the group gradually becomes a cognitive representation of the attributes and the knowledge that members share. In turn, there exist qualities that appear in great distinction between team members and nonmembers'* (Holtz, 2004, pp. 113). This implies that knowledge sharing and exchange within groups may be highly associated with team cohesiveness because it distinguishes the difference between in-group members and out-group members. The in-group members are able to interpret information based on shared mental models that out-group members are not partial to. Team cohesiveness seems to be pivotal to this research, as it would support the notion that the more cohesive a team is (i.e. the better the shared mental models), the better the quality of the knowledge sharing that takes place.

2.4.4 Team structure and team size

The adoption of team structure is associated with an organisation's structure and tasks. There are many different forms of team structure. In this case study, the structure of self-managed work teams is particularly relevant to respond to a project-based R&D organisation. The reason is that such forms of team structure emphasise autonomy and responsibility by which a team is not only in charge of problem solving but also empowered to make decisions and take full responsibility for outcomes (Kirkman and Rosen, 1999; Uhl-Bien and Graen, 1998). Thus, it is often applied in technological R&D contexts as it allows teams to obtain flexibility to respond to the situations and carry out the tasks.

However, in any form of team structure, the structure represents a formal linkage between team members and between tasks (Zack and McKenney, 1995). It also shows the lines of coordination and communication within a team. A problem may arise when the

number of team members increases. Can the team maintain coordination and communication efficiently? The influence of team size has been examined aver the last decades. Most of the research reports that it influences team members' interactions and communications, outcomes/ performances (e.g. Revans, 1958; Cunningham and Chelladurai, 2004), and also team cohesiveness (Manners, 1975). Some research reported that a small team can reach a satisfied agreement easier after discussion than a large team (Manners, 1975). Also, small teams are more productive in taking action and completing tasks than large teams (Robbins, 2001). However, in problem solving circumstances, large teams may be slightly more effective than small teams as large teams may have a greater diversity in expertise. Homogeneous expertise in small team may reduce its effectiveness in solving problems (Robbins, 2001).

Increases in team size could reduce the opportunities of interaction between team members (Jehiel, 1999) and also reduce the chances for a team leader to communicate with each team member. This disadvantages large teams to reach team consensus and form team cohesiveness. Therefore, this research's concern is whether or not team size influences an adoption of a particular team structure and whether this further influences a team's operation. Considering the assumptions this research has made about knowledge, knowledge sharing, and the relationship of those to individuals and teams, it seems that team size may prove to be a factor that determines how knowledge management and its related activities are undertaken.

2.4.5 Team atmosphere

There is not a clear definition for team atmosphere as it is a psychological perception of team members of the team environment and membership. However, the way it acts within teams is related to team climate. Thus, this research conceptualises team atmosphere as team climate.

Past research has focused on team climate or workgroup climate (Anderson and West, 1998; Ashforth, 1985; Glick, 1985; Schneider, 1975; Woodman and King, 1978). The

conception of climate is often difficult to define and measure as it is influenced by several factors across different subjects. Among those different definitions or aspects, there are two approaches which are widely adopted: the cognitive schema approach (structuralist/objectivism) (Ashford, 1985; James and Sells, 1981) and the shared perceptions approach (membership/subjectivism) (Reichers and Schneider, 1990; Patterson et al., 1992; Payne, 1990). To combine these two aspects, the third viewpoint is an interactionist viewpoint which is based on a reconciliation of the cognitive schema approach and the shared perceptions approach and considers the role of the workgroup, affect, corporate culture, symbolic management, and physical setting (Ashforth, 1985).

In the cognitive schema approach, the conception of climate is described as '*individuals' constructive representations or cognitive schema of their work environment, and has been operationalised principally through attempts to uncover individuals' making sense of their proximal work environment*' (Anderson and West, 1998, pp. 236). In this perspective, individuals' psychological perceptions of team environment and its meaning are considered significant. This suggests an important point that individuals are the basis of a team. However, it lacks a significant notion of a team as a whole. Individuals cannot work without co-operating with others. Thus, some researchers define climate a little more clearly as *'a shared perception of organisational policies, practices, and procedures'* (Reichers and Schneider, 1990, pp. 22). In this statement, team climate is seen as a formation of shared perceptions, namely, a team's members have a consensus of insight or cognition to their team and its environment. In other words, team climate is a common understanding among team members. It conducts team members' perspectives and guides their behaviour in a given direction.

With regards to this research, how is this relevant? Von Krogh (1998) suggests that a team with an atmosphere of '*high care*' (Von Krogh, 1998) will generate better knowledge outcomes, especially knowledge sharing and knowledge creation (Zárraga, and Bonache, 2005). However, Zárraga and Bonache (2005) also reveal that such a climate is a '*black box*' which is rarely discussed within the literature. With this viewpoint, this research assumes that team atmosphere is an important element associated

with team members' behaviours in knowledge related interaction. Considering the lack of unambiguous definition and clarity of concept, this research may shed some further light on the role of team atmosphere in relation to knowledge management.

2.4.6 Modes of interaction

2.4.6.1 Face-to-face interaction

The literature has shown that face-to-face interaction and dialogue are the best ways to transmit and share knowledge and experiences, especially for tacit knowledge and skills (Nonaka and Takeuchi, 1995). The argument is that in face-to-face interaction not only voice and words, but also individuals' emotions and body language facilitate messages that can be expressed and received exactly; it also facilitates transmission and understanding of implicit meaning. An effective face-to-face communication is influenced by several elements, such as types of communication networks, communication channels, and use of languages. Research indicates that the use of language is highly associated with cultural barriers (Munter, 1993) and context (Hall, 1976; Dulek et al., 1991) as the same word in different cultural context may have different meanings or extended meanings. This is relevant to how knowledge or information is transmitted and interpreted in different cultural contexts or in different group contexts. Within a high-context culture, communication implies more trust between people, and it also implies a desire to develop relationship (Dulek et al., 1991; Kim et al., 1998; Hall, 1976; Robbins, 2001). This can be seen as a significant factor to the sharing of knowledge and information between people or within a team in a high-context cultural society. The sharing of information and knowledge does not only mean the sharing of a piece of information and knowledge but also means the development of relationships between two people. Based on this social context, knowledge networks can be developed, as well as personal networks and social relationships. In this social context, face-to-face interaction becomes much more important because it not only influences the quality of communication but also influences the development of social relationships.

It is clear from an earlier discussion that this is relevant to this research, as it was outlined that Nonaka and Takeuchi's model only deals with one particular cultural context and provides no indication how the may translate to different cultural contexts. Furthermore, the context chosen for this research is generally associated with a high context culture, thus the concept seems to be important to keep in mind when undertaking this research.

2.4.6.2 Virtual community and interaction

Since the advent of Internet Technology, the way people interact and transmit information has been changed dramatically. There is a range of research (Driskell et al., 2003; McKenna and Green, 2002) that shows that e-mail, intranet and various websites have become the main media by which people interact, communicate, exchange, and diffuse information; no matter whether it is inter-group or intra-group. A virtual community is built on the Internet (McKenna and Green, 2002) and it increasingly replaces the functions that people used to act out face to face. Within this community, people with similar interests can be connected through the Internet. In this scenario, the interest groups apparently become significant sources of obtaining related information and finding out solutions for solving problems (Adamic and Adar, 2003; Cai, 2005; McKenna and Bargh, 2000). Through chat rooms and discussion boards, amateurs and professional people can interact and exchange each other's experiences. Moreover, this use of the Internet is suggested to remove the boundary between people and impacts organisational hierarchy and its procedures (Lucas and Baroudi, 1994). In fact, the use of Internet not only increases the online interaction between team members and between supervisor and subordinates through employing e-mail or other IT tools, but also shortens the distance between individual team members and their external environment (Cairncross, 1997, Olson and Olson, 2000).

However, in some circumstances, online interaction cannot replace face-to-face interaction as it cannot make an association with specific context. Research has shown that face-to-face meetings were still the most effective way to reach group decision (Lantz 2001).

One may need to keep those emerging communication modes in mind when looking at knowledge related activities, especially knowledge acquisition and knowledge sharing.

2.4.6.3 Social networks and social interaction

Literature indicates that knowledge sharing often occurs via social networks and social interactions (Abrahamson and Rosenkopf, 1997; Cross et al., 2001; Leonard and Sensiper, 1998; Rulke and Galaskiewicz, 2000). This indicates that the formal structure/authority chain and the social networks are important elements in knowledge management activities. The formal structure shows the relation and connection between team members or tasks in which each team member interacts or communicates with co-workers. However, some research (e.g. Rulke and Galaskiewicz, 2000) reports that, especially with regards to knowledge related activities, social networks and relationships are more important than the formal structure to exchange or distribute knowledge. This reflects that in a social group, knowledge can easily be diffused across the group because people have similar interests and knowledge (Liang, 1994). This seems particularly relevant because the focus of this thesis is on teams and their interactions.

However, people within a formal organisational structure have respective responsibilities and it is not an essential case to bring people together to broadly discuss and exchange knowledge and experiences. All communication, in fact, is related to the tasks and goals. Therefore, knowledge may not be easily diffused through formal interactions. This indicates that social networks within teams or organisations impact on team members' interaction and communication with regards to acquisition of knowledge and break down organisational boundaries to connect with surrounding internal and external sources. In addition, some research further indicates that a team's social network constructs its social structure, and social structure represents the patterns of interaction (Jablin et al., 1987; Zack and McKenney, 1995). This indicates the importance of social networks within teams, which may be seen as knowledge networks or information networks. Considering the focus on teams, in particular innovation teams that have different knowledge

requirements, the way in which such knowledge is obtained may become an important aspect.

2.5 Summary

In the above discussion, the author has defined knowledge and knowledge management. The author believes that the nature of knowledge is complex and dynamic. Therefore, managing knowledge is not only about managing knowledge itself and methods used to manage knowledge, but also about managing people and knowledge within dynamic environments. Various theories were introduced, some of which were dismissed or criticised for their simplistic understanding of knowledge, or the generalist nature of knowledge management. Based on this discussion, the author assumed knowledge to be contextual and personal in nature, whereby individual cognitive process are as important as the social context in which knowledge is created and received. Knowledge management was then clarified based on this assumption. By investigating different models of knowledge management the author assumed knowledge management to be a process that connects individuals as much as it involves the use of technology. The defining factor was the ability of knowledge management to respond to specific needs of a specific context. Furthermore, it was established that current knowledge management models explore little the influence of learning theories, on an individual and team level. Thus this thesis highlighted various notions on how teams and individuals learn and how such processes are relevant to knowledge management. This leads the author to believe that contexts, team dynamics and learning are fundamental issues in knowledge management. Ideally, the management of knowledge should be developed in response to the situation in which it is placed. This leads the author to consider that knowledge management is a context-based activity in which the contexts distinguish the needs, behaviour and the way of managing knowledge. Thus, one cannot initiate such activities without considering what situations a team may encounter and what purposes these actions are aimed at.

In order to understand what contexts mean to innovation team, this chapter therefore reviewed innovation related literature to outline the contextual factors involved in innovation and how this is relevant to knowledge management related activities. In this section, the author outlined three elements: project characteristics, R&D process and R&D contexts. These three elements were considered important factors in R&D teams as they influence teams and how they undertake their daily activities, especially in regards to knowledge management.

However, knowledge management and innovation are integrally related to a team's operation and interaction, as neither of those process happens in isolation. Thus, the review also looked at how teams operate in order to approach innovation and knowledge management. This provides a fourth focus of this review, namely team operation. This element involves team contexts and how a team operates to achieve project objectives, including knowledge management, as the author believes that knowledge management activities are built upon a team's day-to-day work and team member's interaction. Thus, team operation is considered an important element of team context.

By using these four discussed themes (R&D context and process; project characteristics; team operations; knowledge related activities), the author constructed an initial conceptual framework (Figure 2.1) by using those themes as elements of the model. This reflects the author's understanding of how knowledge management takes place within R&D teams.

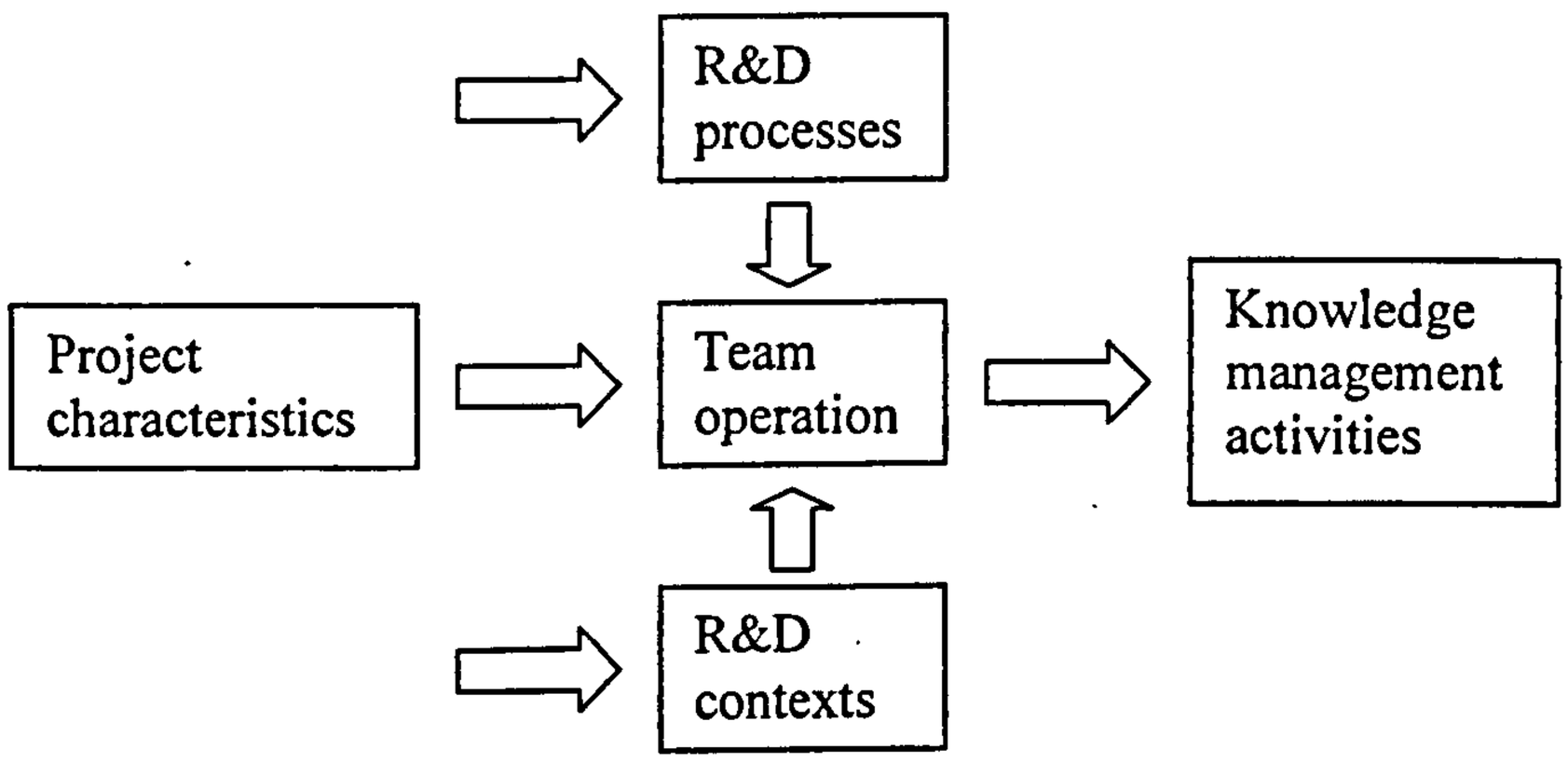


Figure 2.1 Conceptual process of team knowledge management activities

The above review of the literature brings together the main strands of thinking that influence knowledge related activities and innovation teams within this thesis.

In terms of the purpose of undertaking knowledge management, the literature shows that knowledge management needs to be connected to clear purposes (Davies, 2001; Hoegl and Schulze, 2005) to implement knowledge related activities. This thesis agrees with Nonaka and Takeuchi (1995) that knowledge creation is an important purpose of knowledge management because it leads to innovation and enables teams/organisations to sustain competitiveness through innovation. However, by examining Nonaka's model of knowledge creation, this thesis suggests that if there are no learning processes as a foundation to support these conversion processes, the model may not be performed effectively. This indicates that learning is an important element when conducting knowledge management processes.

Based on the above discussion, this thesis believes that project and R&D contexts, team dynamics and learning are important elements in all knowledge management activities within R&D teams. By taking the initial framework (Figure 2.1) as a basis, this thesis explores in more detail how knowledge management is undertaken in R&D teams.

Subsequent chapters discuss how this research was undertaken and what the research found. The thesis starts with outlining the methodology and methods adopted to answer the research questions, where the research took place, and then focuses on discussing the findings of this research.

Chapter 3 Research methodology

3.0 Introduction

This study explores R&D teams' knowledge management and innovation activities through the use of a team knowledge management model. In addition, the thesis provides a detailed empirical investigation of knowledge management achievement in high technology R&D teams. The objective is to show how knowledge management relates to team contexts and to other team processes. This chapter starts by refining the initial research question that has been raised in Chapter 1 to several more detailed research questions. Based on these refined research questions, the second section discusses the research design. A case study design is adopted as the research approach which enables this research to focus on particular issues and cases. The third section focuses on how this research is implemented. It introduces the methods adopted for data collection, such as face-to-face semi-structured interview, team observation and documentary review. The subsequent section discusses the techniques for analysing free-flowing qualitative data and also illustrates other techniques used in this research. The last section will summarise the use of the different methods in this research.

3.1 Research questions

On the basis of the previous discussion in Chapter 2, the author considers that knowledge management in organisations is likely to be undertaken to fulfil different purposes. This relates to the needs of what is required at management level and performance level, for example in project teams. There are many different frameworks which are aimed at different purposes and provide different approaches to practising knowledge management.

Based on the literature (e.g. Teece, 2000; Tidd et al. 2001) and the author's experience of the IT industry, this thesis considers that an important purpose of knowledge management is the improvement of R&D capabilities. However, the author's experience within the IT industry also indicates that the predominant focus of knowledge management in organisations was the documenting of tasks and problem solving rather than motivating the enhancement of R&D capabilities in that particular context. It was

argued in the previous chapter that the problem solving focus may only trigger single-loop learning at individual and team level (Ahmed et al., 2000; Argyris, 1992), which may not lead to building new insights or capabilities. Thus, how new insights or new knowledge can be generated through knowledge management is important. Based on the conceptual framework (Figure 2.1), knowledge management within teams is influenced by project characteristics, R&D contexts, and team operation. This is guiding the direction of the project. However, what purposes (roles) knowledge management has in such context is a question. This thesis considers that purposes are guiding the actions. Thus, the purposes of undertaking knowledge management are a significant point which facilitates understanding the process associated with the initial research question: **'How are knowledge management activities initiated and undertaken to enhance innovation activities?'** (Chapter 1).

The earlier discussion in 2.2.2 showed that knowledge creation and problem solving all can be the purposes of undertaking knowledge management in organisations. However, they may lead to different outcomes. Thus, to understand the purpose of knowledge management and how teams achieve that purpose is important. Thus, based on research question in Chapter 1, brought together with the insights from the literature review, this thesis refines the question to the following new research questions:

Question 1: What is the purpose and initiator of knowledge management in innovation teams?

Furthermore, innovation processes involve many variables, which in turn dominate how a project is processed. Thus, this leads to the second research question:

Question 2: How are knowledge management activities integrated with innovation processes?

Knowledge management is usually discussed by focusing on knowledge management processes (Alavi and Leidner, 2001). However, the author of this thesis considers that

knowledge management processes should be connected to what teams are doing and the ways they process their tasks or projects. In this research, the main focus will be the innovation processes. Literature (Fernie et al., 2003; von Krogh et al., 2000) suggests that knowledge management not only involves managing knowledge itself but also entails the management of content, narrative and contexts (Snowden, 2002). However, there is limited literature supporting what is meant by contexts. Thus, the author raises another question:

Question 3: What factors underlie the processes of undertaking knowledge management activities by teams?

3.2 Research process

In order to answer the above questions, this research was implemented based on the research process portrayed in Figure 3.1. This research started with an experienced-driven intention to explore how knowledge management can be performed better and what factors influence knowledge management within the specific context of innovation teams. Therefore, the research start with the question 'How are knowledge management activities initiated and undertaken to enhance innovation activities?' In order to gain a better understanding, the research built up a theoretical basis by reviewing knowledge management and innovation literature. As part of this review, team dynamics emerged in knowledge management and innovation literature as important; thus literature on this subject was introduced. Based on the literature review, this thesis further refined the research question into three sub-questions (3.1). As managing knowledge within organisations involves complex situations with regards to the complex nature of knowledge, organisational contexts, organisational dynamics and learning, a case study approach is adopted for this research which enables this thesis to explore specific incidences, occasions, and details to understand knowledge management and capture organisational dynamics within the chosen research setting. The research site is based on an IT research organisation in Taiwan. The research investigates four R&D teams. Different methods are adopted for data collection. Semi-structure interviews, team observation and documentary review are applied and the use of different methods provides a way of triangulating the findings. In order to obtain robust conclusion, free-

flowing text analysis is adopted for data analysis in which coding and summary are used to reduce data and generate themes and findings.

The elements of this research process are described separately below. In order to logically outline how the research has been undertaken, the first section will discuss the overall methodology chosen. The second aspect will provide details on why the research sites were selected. The subsequent section introduces the methods of data collection and the data analysis framework. As a reflected researcher potential limitations of the research design and how these are counteracted within this research are discussed towards the end of the chapter.

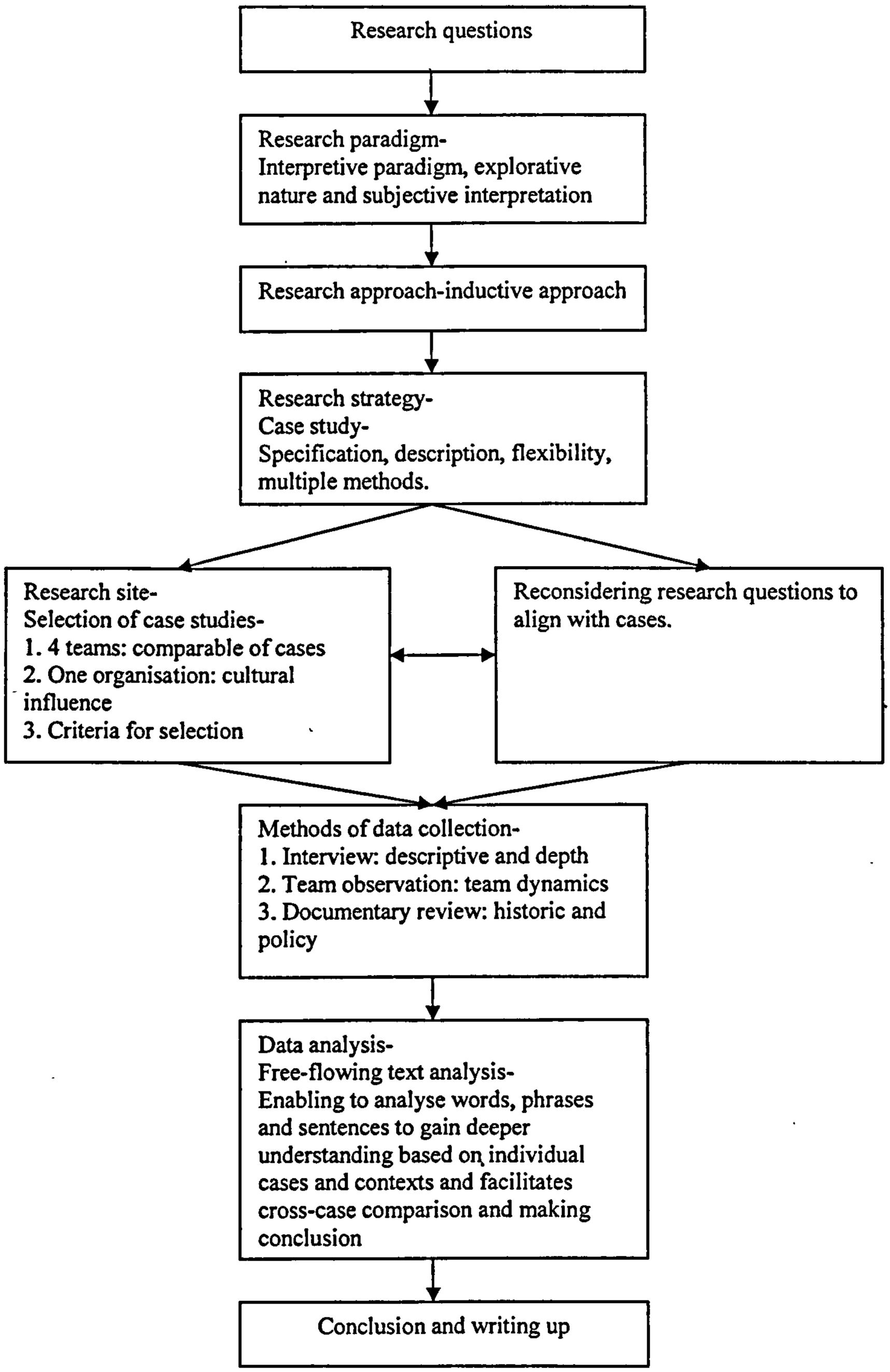


Figure 3.1 Research Process

3.2.1 Research paradigm, approach and strategy

Saunders et al. (2003) suggest that research should be undertaken step by step in a systematic way from research philosophy, research approach, and research strategy to research method. This guides a researcher to find a suitable approach to answer research questions. By considering their suggestion, this section starts with a brief discussion of which research paradigm this thesis sits in and then discuss research approach and research strategy.

3.2.1.1 Research paradigm

The nature of the research questions proved vital in the choice of the research approach. In this thesis, the research questions involved the types of 'how' and 'what' questions. This means that this research looks at a 'process' and the factors that relate to the process. However, there are many approaches that can be used for the research. In order to choose an appropriate research approach and methods to answer research questions, one firstly ought to think about where the research is situated compared to other research.

Burrell and Morgan (1979) suggest four paradigms to approach the analysis of social theory and research. The paradigms are distinguished along a spectrum of two dimensions. The first dimension is the subjective-objective spectrum which is associated with assumptions about the nature of science. This is based on the four sets of assumptions which are relevant to ontology, epistemology, human nature and methodology. For example, if 'reality' is assumed to be of an 'objective' nature, one assumes a positivist view point. In such a contention one assumes that reality exists independently of human cognition. Furthermore, if reality is seen as objective, usually a realist ontology is taken for granted. This means that one believes that reality can be represented in an objectified manner by assigning a name or a property to it (realism). The opposing viewpoint would be to assume reality as a subjective, cognitive experience (Anti-positivism), which also incorporates a nominalist viewpoint. This means that reality only has the properties which are the production of individual cognition (Burrell and Morgan, 1979).

The second dimension is about the purpose of social science research, namely regulation or radical change. This is associated with assumptions about the nature of society. In

terms of the sociology of regulation, it is concerned with the need for regulation in human affairs, and also emphasises the nature of social cohesion and solidarity. In contrast, sociology of radical change is concerned with finding explanations for radical change, deep-seated structural conflict, modes of domination and structural contradiction (Burrell and Morgan, 1979). These two dimensions construct four paradigms: radical humanist, radical structuralist, interpretive, and functionalist. Radical humanist emphasises the nature of subjective consciousness within the sociology of radical change. Conversely, radical structuralist focuses on objective approaches. Moreover, the interpretive and functionalist paradigms are distinguished within the sociology of regulation. The interpretive paradigm is associated with the subjective end of the spectrum, and the functionalist paradigm represents the idea of objective end of the spectrum.

By taking these four paradigms into account, the author thus considers that knowledge in this thesis is seen as a product derived from the interactive processes between an individual's mental process, sensory experience and practice with relation to specific contexts. Therefore, to manage knowledge within organisations not only involves managing knowledge bodies but also involves managing people's interaction with and within their environment. For this thesis, this means to understand how knowledge is managed within organisations one needs to look at and investigate the cohesion and regulatory functions of an organisation in order to know how the organisation works and manages its assets. For the thesis this implies a closer relationship with Burrell and Morgan's (1979) sociology of regulation.

Moreover, from this thesis's definition of knowledge, an individual's knowledge is influenced by what an individual experiences and acts. Thus, a researcher has restricted knowledge to the objective that he/she wants to investigate. With this situation, for a researcher to understand an organisation and its regulation may rely on a researcher's interpretation based on his/her knowledge and observation to interpret a social phenomenon within an organisation. Based on this definition, this thesis can only assume Burrell and Morgan's (1979) subjective end of the spectrum.

Also, this research considers that knowledge management within organisations is a social phenomenon associated with social order, consensus, social integration and cohesion. Consequently, to combine both spectrums, this thesis places its position in the interpretive paradigm.

The interpretive paradigm aims to understand society and human behaviour and is based on a subjective point of view. Saunders et al. (2003) suggest that the context of interpretive paradigm derives from and corresponds to interpretivism. Interpretivism claims that social reality is constructed by human being's subjective perceptions (Saunders et al., 2003). Therefore, reality may not exist. Indeed, it is dependent on who observes it. Thus, Saunders et al. (2003) suggest that generalisation may be difficult because social reality is changeable and complicated. In order to explore what happens within a society and gain deeper understanding, researchers within this paradigm rely on qualitative methodology and use methods such as interview or observation to implement their research (Saunders et al. 2003).

3.2.1.2 Research approach

Different research paradigms lead social scientists to adopt different approaches to implement their researches. Research approach is seen as the process which leads to theories and how those are appreciated and proven. There are two widely accepted approaches: inductive and deductive approaches.

The inductive approach refers to the use of empirical observation to develop theories or hypotheses. It is applied to when there is little literature in the subject or research area; therefore, a researcher can use empirical observation to develop theories and hypotheses. In contrast, the deductive approach is particularly applied when a topic is clearly defined and is relatively mature within academic field (Creswell, 1994). Therefore, the use of deductive approach usually starts with studying literature in order to seek appropriate theories and construct hypotheses, which can then be tested.

Considering this thesis's research questions, this research is exploratory and the literature within this specific area is not as well developed. In addition, one of the objectives of this research is to build a model of factors that influence knowledge management within innovation teams. This means to the thesis that empirical observation is important sources to achieve the research. Therefore, an inductive approach is adopted by this thesis to conduct the research.

3.2.1.3 Research strategy

Based on the above discussion, the author considers what is suitable research strategy and methods for the current research to enable the research to gain a deeper understanding of social phenomena within organisations and outline the processes of knowledge management within an organisation. There are many research strategies within an interpretive paradigm that could be adopted. Some examples include case study, ethnography, participant observation, performance ethnography, phenomenology, ethnomethodology, to name just a few (more details see (Denzin and Lincoln, 2000)). According to Yin (1994), a case study is an appropriate strategy to be adopted for research which addresses 'how' and 'what' questions. There are several features in this study that justify a case study approach to be considered suitable. These are outlined below:

Firstly, a case study provides an approach to concentrate on specific cases, in order to explore details of events and phenomena within the cases. This feature is in response to a need for exploratory research to discover an undeveloped area and substantiate knowledge with a limited theoretical base (Harrison et al., 2000). This feature is considered valuable for this research, as the relationship between knowledge management, innovation, and team operations are not well explored. Furthermore, by focusing a small number of cases, this research aims to identify particular events and phenomena in more detail.

Secondly, a case study approach enables researchers to concentrate on an individual case so as to further understand the meaning of information within the context here and gain a holistic view of the said phenomena (Hussey et al., 1997; Yin, 1994). This is considered a valuable feature when dealing with context specific information and trying to make sense of the information with regards to specific events or phenomena. This enables the research to compare differences between cases. By choosing a case study approach, this thesis is able to gain a deep insight into the meanings attached to knowledge related activities within a specific context.

Thirdly, every approach has its rules; however, it may be difficult to follow these rules completely. When researchers encounter a dilemma between the rules and the demands of a social situation, the rules are often bent in order to meet the needs of real situations (Waddington, 1994). Taking into account the frequency of such a situation, the case study approach is considered the most suitable approach to be adopted. Stake (2000) indicates

'*case study is defined by interest in individual cases, not by the methods of inquiry used* (pp. 435).' This is a significant point as this research aims to outline the patterns of knowledge related activities in a particular context. Such an approach therefore provides the freedom of adopting methods to manage data according to the demands of social situations within the cases, as Stake (2000) indicates,

> *'Case study is not a methodological choice but a choice of what is to be studied. By whatever methods, we choose to study the case, we could study it analytically or holistically, entirely by repeated measures or hermeneutically, organically or culturally, and by mixed methods-but we concentrate, at least for the time being, on the case.'* (pp. 435)

Finally, a case study approach 'simplifies' matters when it comes to exploring the cases by not involving the hypothesis (Hussey et al., 1997). For this research this means that the investigation is less about proving a particular point, but being able to explore what happens within innovation teams. Whatever the findings are, these are still providing insights into a specific context. This point is consistent with an inductive research approach.

To summarise the above features, this research utilises a case study as it fulfils the demands of the contextual situation. The reasons are, first of all, that this is exploratory research which seeks to address knowledge management activities in technology R&D teams. Secondly, knowledge management activities involve many social interactions and are of specific contextual nature. To understand such interactions, the research strategy should be able to focus on a case itself; to look at its particular events, team interactions, and phenomena in detail. This drives the third reason in advocating the use of the case study as it is traditionally associated with the use of a variety of methods for data collection. In this thesis, the use of different methods of data collection is discussed in section 3.3 in form of triangulation.

3.2.2 Research site

The number of cases is an important consideration when adopting a case study approach. One has the choice of a single case or multiple examples. It is often criticised that the choice of cases could be subjective (Silverman, 2000). However, the choice of cases in

this research is informed by the research questions and how the cases best help to answer these.

In order to explore knowledge management activities in innovation teams, four cases were selected for this thesis. One of the reasons for choosing four cases was that a smaller number of cases would allow the researcher to investigate those cases in more detail. Liiphart (1971) supports this by suggesting that a small number of cases allows for a large number of variables to be explored. Increasing the number of cases – on the contrary – may thus result in either too much detail, or in a lack of opportunity to explore variables more closely. The rationale of this research follows the principle: '*The fewer cases investigated, the more information can be collected about each of them*', with given resources (Gomm et al., 2002, p.3).

Another reason for choosing the four cases was accessibility of data. In this research, the host organisation agreed access to four cases during the negotiation process. An advantage of this arrangement is that the agreed number enables the research to answer questions about different purposes of knowledge management, the influence of project characteristics and the consequences of these characteristics on undertaking knowledge management.

In this research, the author chose the cases from one organisation rather than from different organisations. The reason is that knowledge management is a context-influenced activity and associated with culture (Ahmed et al. 2002; Bresnen et al., 2003; Glisby and Holden, 2003; Weir and Hutchings, 2005). Different organisations, industries, and nations, have different factors influencing their culture. By choosing the cases from one organisation, the author assumes a general existence of an organisational culture that is somewhat reflected in each project team. This avoids any discussion about cultural differences between organisations.

In terms of selecting cases from the organisation, the cases were selected based on a number of guidelines that will enable appropriate data collection to answer the research

questions. Question 1 addresses the purpose and initiators of knowledge management. Based on the literature, the research assumes that different project characteristics are associated with different needs in knowledge sources and organisational supports (Senker, 1998). It was outlined that project teams are often classified according to various characteristics. By choosing four teams with differing characteristics, the research is able to address potential differences in purposes and initiation of knowledge management activities.

The second influencing factor in choosing the cases was the experience of the members of the project teams. If a team has experiences in undertaking innovation projects, it may facilitate the research obtaining data from past projects and allow interviewees to express their experiences easily. Also, based on their experiences, team members can point out the differences between past and current projects and what progress they made relating to knowledge management activities in their teams and organisation.

Thirdly, research and development in the IT industry is challenging for teams. For example, the integration of IT and communication technology and a short product lifecycle (Teece, 1998) are two of the challenges. The increasing demands in the integration of IT and communication technology pushes firms to shift technological focus from IT to communication technology, and develop the capabilities to manifest both technologies and integrate both technologies. However, for Taiwan's IT firms, communication technology is not their strong point. Thus, it has become one of the challenges with the advent of the integration of IT with communication technology. This implies that in order to speed up new product development, introducing new knowledge and the speed of knowledge flow have become very important issues to the firms in this industry. The choice of cases for this research reflects these challenges, as reflected by the selection of cases that work on knowledge intensive projects – involving incremental and radical development. This allows for a comparison to establish how knowledge management is undertaken in different types of innovation projects. Hence finding teams that undertake radical innovation and teams that work on incremental innovation projects was important.

Moreover, focusing on the information technology industry in Taiwan allows the researcher to make several contributions. The research will provide robust data and information for this research to explore the insight of R&D teams in this particular

industry and region; in particular characteristics at project team level and how these might influence knowledge related activities. The institute, which this research focuses on, is a leader in software research and development in Taiwan. It has run many key technological R&D projects and has successfully produced spin offs from those projects since the 1990s. This leading capacity makes the cases more significant for the IT industry in Taiwan. As it is a public organisation, its operations and organisational mission are not the same as private firms. However, its closeness to industry and leading capability in R&D make it a case to be focused on and explored.

In addition, selecting four cases, which is synonymous with four project teams, made it possible to investigate the widely accepted notion that self-managing teams are often adopted in IT R&D for its knowledge intensive feature. It is also considered to have high efficiency and effectiveness in knowledge sharing and creation (Ayas, 1996; Nonaka, 1995; Davenport and Prusak, 1998). Whilst it can be assumed that an organisational culture influences a team's knowledge related activities, this research aims at considering potential differences among the self-managing teams.

In this research, four teams are investigated. One team focuses on improving current products, two teams are engaged in developing prototypes of new products, and one team develops industrial services (Chapter 4, 4.5). Table 3.1 summarises the above discussion. Project characteristics indicate if the project is incremental or radical and what the funding sources for the project are. The other categories provide information on what the project tries to achieve and why it was created. The last three categories in the table show if teams have worked together before, if the projects are seen as knowledge intensive and if they are self-managing teams.

Having outlined why the teams were chosen and how this helps in answering the research questions, the author decided on the data collection methods most suitable to investigate the research questions within the chosen teams. In order to gather robust data, the concept of triangulation is adopted in this thesis in which interview, team observation and documentary review are adopted. These methods will be discussed in next section. Furthermore, the chosen method for data analysis crucially influences the outcomes of this research; thus, following the data collection section, the method of data analysis will be discussed.

Table 3.1 Summary of team selection

Teams	Projects	Team selection				
		Project characteristics	Purposes and initiator	Project experience	Knowledge intensive	Self-managing
Team A	GSM/GPRS mobile testing specification design & environment development	• Incremental • Private • System	R&D capability, sustaining knowledge	Yes	Yes	yes
Team B	Automatic testing equipment (ATE) development	• Incremental • Organisation self-funded project (since 1999) but apply to privately funded project • System	R&D capability, sustaining knowledge	Yes	Yes	yes
Team C	Digital content industry promotion office-investment financing team	• Radical • Public • Service	Service capability	Yes	Yes	yes
Team D	Enhanced secure gateway operation system	• Radical • Public • Technology	Creation knowledge	--	Yes	yes

3.3 Multi-method of Data collection and data analysis

In order to obtain robust data to answer these questions, the choice of methods for collecting data and analysing data needs to be considered carefully. This section will discuss the methods that are chosen in this thesis for collecting data and analysing data. After this discussion of data collection, a synthesis outlining the relationship between methods, research questions, data sources, and justification will be summarised in Table 3.3.

Some argue that qualitative research is inherently multi-method in focus, as it intends to seek an in-depth understanding of the phenomenon (Denzin and Lincoln, 2000). The purpose of multiple methods or triangulation is to use different methods to rationalise the case(s) studied. Yin argues that a '*case study not only provides researchers with flexible research possibilities, but also has an opportunity to use different resources to investigate the phenomena or group studied*' (Yin, 1994, pp. 91-92). For this thesis this means that the researcher is able to provide a picture of the phenomenon from a variety of perspectives.

In addition, through triangulation, researchers can balance the advantages and disadvantages of each research method and thus gain a more robust view of the situation. Moreover, researchers are able to look into different aspects of the phenomena such as, organisational structure, regulations and the event itself. More important is that through a triangulation process the findings of a case study may become more convincing and accurate.

Denzin (1978) identified four types of triangulation. The first is data triangulation, which is using different 'data sources' to examine the same event. For example, in this research, the data was collected from a team leader level, a team member level and the internal documents. A second form is investigator triangulation which is using different researcher or evaluators in a study. Due to the nature of this research, this form of triangulation could not be used. The third way to triangulate research is theory triangulation in which multiple perspectives are used to interpret a single set of data. For instance, there were different perspectives discussed during the literature review which may provide different interpretation lenses for this research. The last form of triangulation suggested by Denzin is methodological triangulation which is using multiple methods to study a single problem. In this research, interview, team observation and documentary review are adopted as methods to study issues, such as team interaction and network. The convergence of multiple sources of evidence for the study described in this thesis can be concluded in Figure 3.2. In order to explain how these three methods are used to affect the fact/information box in Figure 3.2, an example is given from the data. For example, a member of Team A indicates '*if you encounter a problem and need help, you just shout, some one will come to you.*' This information is reflected within the team observation data in that Team A has random but frequent interactions between team members (Table 7.1 and Figure 7.5). This strengthens the information from the member of Team A, as it seems to be confirmed by other methods of data collection. By using both data sources, this thesis thus deducts that spontaneous interaction is an important factor in problem solving and knowledge sharing. This explains the use of triangulation enabling this thesis to generate robust conclusion based on multiple sources of evidence.

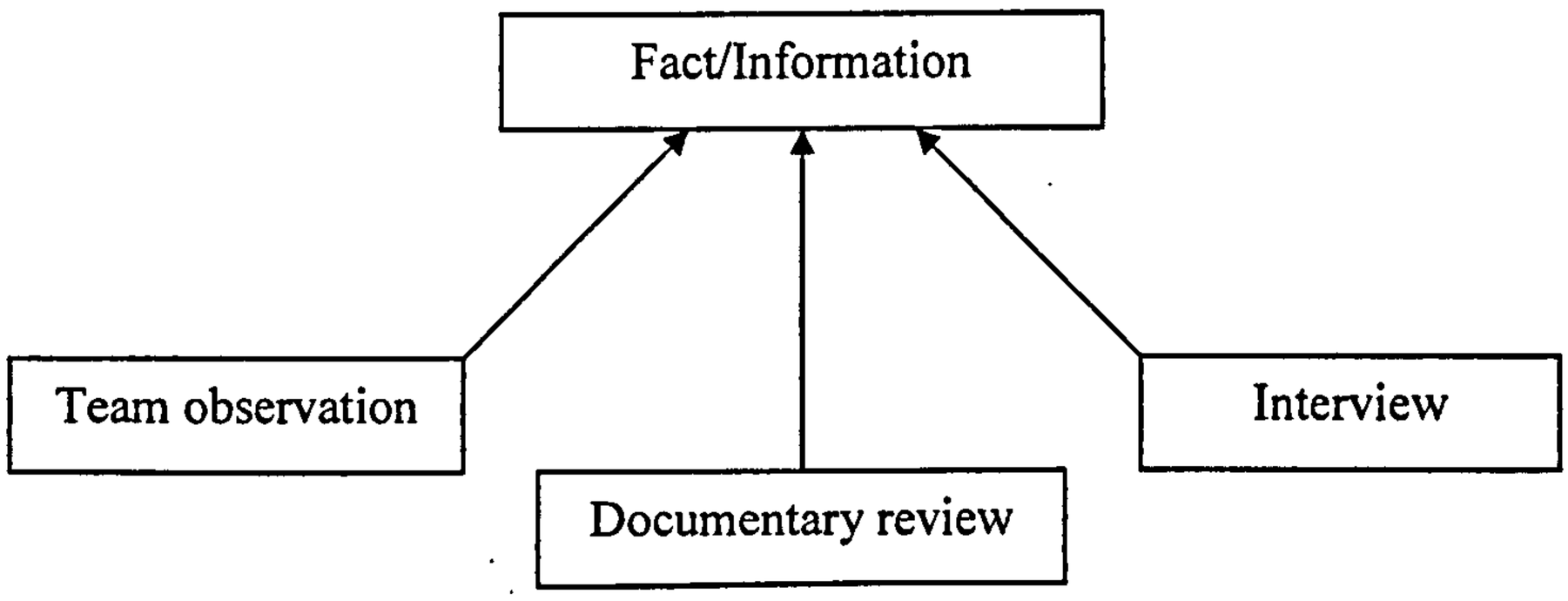


Figure 3.2 The convergence of multiple sources of evidence

3.3.1 Data collection

The choice of methods for data collection is dependent upon the research questions and the research approach. In this research, there are three questions that are addressed (Table 3.2). In order to answer these questions, three methods are adopted to collect data: 1.) interviews with team leaders and team members, 2.) periods of non-participant observation of team work, 3.) documentary review of projects, reports, team records, and organisational policy.

The collection of data within the organisation was divided into two stages. The first stage focused on understanding general information about teams, team knowledge management activities, R&D processes, team work and organisational information. The second stage focused on observations of team work and team interaction to examine engineers' work and how they interact. In order to understand general information about teams, interviews were used to obtain essential information about how the teams are influenced by a team's situation, R&D processes, experiences, and knowledge management activities.

An interview is a useful method for capturing individual stories and particular experiences. A successful interview is associated with several factors, such as question design and interviewer's skills to assist interviewees to focus on the relevant issues. In this research, the interviews were arranged as one-to-one interviews. Through one-to-one interviews, environmental interruptions can be eliminated and it also facilitates

interviewees to concentrate on the issues at hand, as well as assisting the researcher in obtaining a variety of perspectives from interviewees.

However, individual memory is sometimes confused by various situations, or restricted by the ability of expression which could cause wrong information to be obtained. Therefore, team observation is adopted as the second method of data collection to substantiate the interview data. Moreover, documentary review is another method of obtaining team/project information detail and substantiating data. Some examples of such documents are reports, memos, and internal journals. This facilitates the research to pursue and re-form significant events and their influences. The implementation of three methods are summarised in Table 3.2 and further discussed respectively below.

Table 3.2 Summary of data collection

Teams	No. of formal interviewees/ total team member	Team observation	Documentary review	Footnotes
A	6/7	yes	Project proposal, report and internal documents	
B	4/5	3 informal interviews	Project proposal and internal documents	▪ 3 informal interviews instead of team observation.
C	5/9	Yes	Codified documents and internal documents	
D	3/10	1 informal interview	Project proposal	▪ Interview with three key persons. ▪ 1 informal interview instead of team observation.
Total	18/31	2		
Summary	▪ 25 hours tapes for 18 formal interviews	▪ One week observation in each team ▪ 5 hours tapes for 4 informal interviews		

3.3.1.1 Interview

Interviewing is a method of acquiring information through interaction between two people or a group of people. It may not be a neutral method of collecting data but it is an active method that leads to negotiation between people (Denzin and Lincoln, 2000). Through interviews, an interviewer can pursue in-depth information about a topic in a specific context. This facilitates the interviewer to underline and construct 'how work is done' and 'what is happening'. The interview can take place in different ways such as individual/group face-to-face interchange or via mail or telephone, and it can be

structured, semi-structured, and unstructured (Denzin and Lincoln, 2000). Moreover, the approach of interviewing can take place formally or informally.

In this research, formal and individual face-to-face semi-structured interviews were applied to all teams. Moreover, there were two set of questions separately applied to the team leader group and the team members group. The formal approach facilitates the interviewer and interviewees to cope with unfamiliarity and potentially embarrassing situations which may happen at first time meetings; it also helps to focus on particular topics. Face-to-face interaction enables the interviewer and interviewees to reach the process of negotiation to ensure the messages are received and sent. It also allows fragile pieces of information to be captured (e.g. body language, attitude and emotion) (Denzin and Lincoln, 2000) and control the progress of interviewing. This enables the information of 'how knowledge is shared' and 'what is happening' to be expressed and acquired. For example, the literature (Senker, 1998; Nonaka and Takeuchi, 1995) suggests that most knowledge sharing is through individual social interaction because it is highly associated with individual mental models, thinking, and mutual trust. Thus, in order to access these personal experiences and perspectives, communication and face-to-face interaction is required. Moreover, through face-to-face interaction, the embarrassment between an interviewer and an interviewee can be gradually removed. This also facilitates the information to be shared between both parties.

The semi-structured questions in this research help the interviewer to focus on certain issues and control the progress during a limited time period. They also help to guide the interviewees' thoughts. This avoids the inflexibility problem in structured interviews and the infinity problem in unstructured interviews, and draws attention to certain issues which the research intends to discover. However, between told information and reality, there may be a gap which may be caused by false memory, or being influenced by the situation, an interviewer's skills and an interviewee's recognition. In order to substantiate the findings from interviews, team observation and documentary review are adopted. Both methods will be discussed in subsequent sections.

People with different organisational status are likely to have varying perspectives on the same event or situation. For example, a team leader's viewpoint may consider the whole team or the whole division to judge a particular event, whereas a junior member may not. In order to address this distinction and acquire substantial data from different view points, this research developed two different versions of questions (Appendix 1-1 and 1-2). One

was for team leaders and the other was for team members. Therefore, the interviewees were divided into two groups in each team: leader and team member group. For leaders, the questions were focused on team context, team operation (e.g. leading the team and integrating team members), experiences of managing knowledge, and project management. Through the interviews, the researcher expected to obtain data on team history and the future, the experiences of undertaking knowledge management activities, teamwork, R&D management, significant experiences in the innovation projects and how they operated teams in terms of coordination, incentive, and arranging resources.

For team members, individual specific experiences in past projects, individual social interactions, access to internal and external knowledge sources, how they acquired and shared knowledge were the main issues of the interviews. The author considered that knowledge-related issues within the organisations were ambiguous and un-systematized; thus, the interviews focused on illustrating teams' and individuals' past experiences. This facilitated the research to shape the patterns of knowledge management activities within the teams.

The formal and semi-structured interviews in this research focused on access to individuals' experiences and perspectives related to the teams' knowledge management activities and operation. The interview questions (Appendix 1-1 and 1-2) were developed based on the literature review and the initial concept framework (Figure 2.1). Moreover, the information about organisational history, strategy of knowledge management, organisational procedures and routines, organisational R&D function and processes were also collected through the interviews and complemented by the documentary review which is discussed in the following section.

The interviews were applied to three R&D teams and one industrial service team (see Chapter 4, 4.5), and produced more than twenty five hours of tapes from eighteen formal interviews that were supplemented by informal interview notes during team observation. All interviews were transcribed to ease analysis.

3.3.1.2 Team observation

Observation is a fundamental technique for the social and behavioural sciences to generate data (Adler and Adler, 1994). It is a method that can be practised on its own, or in conjunction with other methods, such as interviewing (Denzin and Lincoln, 2000;

Mason, 2002) in order to account for non-verbal clues. Interviewing can also take place during the observation to clarify specific events or phenomenon. This combination is dependent upon what the observer intends to find out. In this research, team observation took place at the second stage of data collection. It aimed to observe actual team work to develop insights of the teams and clarify the ambiguous questions which appeared in the earlier interview stage.

The observations were set in each team's office in which individual team members' activities and interactions with others were observed and recorded with a five minute break between observations. An observation sheet was developed according to preliminary findings during the interviews. This observation sheet was developed based on two dimensions, time and actions (see Appendix 2, team observation sheet). The research recorded individual team members' actions alongside time series. This observation sheet provided data relating to what individual engineers were doing during office time how many times interaction took place between them and the ways they interacted (e.g. formal or informal). It also captured some of their conversations relating to exchange of information or knowledge. Moreover, through this observation, a team's atmosphere and the ways in which engineers act can be outlined. Observation also substantiates what they emphasised in the interviews that knowledge sharing within the teams takes place in the informal way and through individual social networks, as well as during task coordination between engineers. Each member of the team was aware of the researcher as an observer.

However, although team observation can outline how the engineers interact, it cannot tell what actually is exchanged between them or why they act in a particular way or what they actually do. Therefore, informal unstructured interviews were undertaken during the team observations. This enabled the author to clarify and understand the meanings behind the team members' actions in specific contexts, and also verified what they said during the interviews. Meanwhile, documents were also reviewed and collected during team observation which enabled the researcher to understand specific cases and situations.

Team observation produced a number of observation sheets and notes which were employed to create the team interaction figures to demonstrate how team interaction took place. The notes provided the explanation and meaning to those team interaction figures. Moreover, the notes from informal interviews were used to substantiate semi-structured interviews and were analysed using the same process that was applied to semi-structured

interview transcriptions analysis. In this research, team observation was applied on two teams. The other two teams were unavailable; instead informal interviews with the senior team member or the team leader were done.

The author is aware that participant observation can have a number of disadvantages. Usually participant observation is associated with an extended period of time within the research setting in order to understand and integrate (Spradley 1980). However, this was not seen as a problem within this research, as the researcher used to work for this organisation, thus, an understanding of the organisation already existed. Furthermore, as the researcher was only an observer, extended periods of interaction to become part of the setting was not necessary.

Capturing the data is also often described as a problem for researchers undertaking participant observation. When being in the middle of a situation, note taking or recording are often not possible. Thus, there are situations where the researchers have to rely on memory. However, this is an accepted disadvantage of participant observation and can be addressed by contentious and meticulous note taking (Hammersley & Atkinson 1983). This research was able to take notes throughout the observations, as no active participation took place. Furthermore, during the breaks, the notes were revised to ensure accuracy.

Another difficulty is objectivity of observations. It is clear that a researcher can not observe everything at the same time. Therefore, the researcher is selective, usually without knowing, about what is recorded and it is a subjective form of data collection (Jorgensen 1989). This thesis addressed this point by developing an observation sheet and asking for clarification. Whilst this does not guarantee objectivity, the research tried to eliminate some of the problems. Also, this research is aware that all our perceptions of knowledge are about individuals' interaction and mental models. This means the researcher can only observe according to his own mental models. The presence of the observer may alter the finding (researcher-caused bias) (Silverman 2000). However, the researcher believes that his presence did not influence the observations significantly, as he was introduced by senior members of the organisation as a research who has worked in the institute before. The relevance of social relationships in negotiating access is significant within the high context culture of Taiwan and the author believes that through this formal introduction, no significant biases occurred.

3.3.1.3 Documentary review

The use of the documentary review method involves the researcher's understanding of the purpose and context of the documents to be reviewed. This can be called the researcher's ontological position and epistemological position (Mason, 2002). Most documents are existing objects which are recorded or written for specific events or purposes. Therefore, the use of documents needs to be seen in the context where they were generated. Furthermore, the use of documents is also related to a user's understanding to identify what can be taken as evidence or how such data can be used as evidence. Most documents are constructed in a visual form which facilitates comprehension. However, this constructed form is underpinned by the author's perspective and selected from what the author wants to show. This selected information content may provide incomplete or simplified information. Thus, for this research documentary evidence is used to verify or clarify the data from interviews or observation (Mason, 2002, p. 108), rather than being a source of evidence.

Documentary evidence was used as a complementary method to understand the history of particular events within the organisation. In this research, some of the project proposals, the project final reports, and memos of specific activities were reviewed alongside semi-structured interviews and team observation. Such documentation was used as complementary information to outline those teams' experiences, their projects, and organisational history and structure. This information helped the researcher to build a general context of the teams and the organisation.

Moreover, during the team observation, one of the teams allowed the author to access their intranet to browse the internal bulletin, company documents, work reports, and the public folders (which are the shared online stores for collecting project related documents, such as project proposals, project season reports, project annual reports, and interview reports). This provided valuable sources of information on the team and the organisation. It also directly demonstrated how information and data are stored and shared within the teams.

So far this chapter has discussed the research questions and the methods used for collecting data. In order to bring them together to show how they are connected and developed, this thesis summarises them in Table 3.3. The table shows how the research questions informed the data collection methods and why particular methods were used.

The last column indicates which interview questions were used to elicit the needed information. Following this section, the next section will discuss data analysis.

Table 3.3 Connection between research question, data collection and interview questions

Research question	Data and methods	Justification	Interview questions
Question 1: What is the purpose and initiator of knowledge management in innovation teams?	• Data source: -Team leaders -Team members • Method: -Interview -documentary review	• Interviews and documentary review will provide relevant information about organisational policy, management level's viewpoint and attempts, how is it done in practice, i.e. based on their own aspects and experiences. • Analysis of data focuses on understanding of why it is beginning and the process • Interviews with team leaders will facilitate the researcher to recognise the context of the organisations and management; Interviews with team members facilitate underlying knowledge acquiring and sharing between individuals.	Leader group 8 Member group
Question 2: How are knowledge management activities integrated with innovation processes?	• Data source: -Team leaders -Team members • Method: -Interview -Team observation -Documentary review	• Interviews, team observation and documentary review will provide relevant information about how processes are and how they perform and why they perform. • Analysis of data focuses on the underlying knowledge processes and who it involves, when it takes place and how it works within teams. • Interviews with team leaders will facilitate the researcher to recognise mechanisms, procedures and the practice of knowledge processes, also the coordination of team members. Interviews with team members facilitate the underlying knowledge network built between individuals.	Leader group 3, 5, 7, 10 Member group 4, 5, 6, 7, 8, 13
Question 3: What factors underlie the processes of undertaking knowledge management activities by teams?	• Data source: -Team leaders -Team members • Method: -Interview -Team observation	• Interviews will provide relevant information about communication between specialists and non-specialists, and cross-functional members. • Analysis of data focuses on social networks and social interaction in workplace which enable members to share knowledge, solve problem and coordinate work. • Interviews with team leaders will facilitate the researcher to understand the social contexts and their influence on knowledge related activities. Interviews with team members will facilitate understanding how they interact.	Leader group 4, 9 Member group 2, 3, 9, 10, 11, 12,
	• Data source: -Team leaders • Method: -Interview -Documentary review	• Interviews and documentary review will provide relevant information about project management, R&D process and function. • Analysis of data focuses on underlying how project is managed and how it influence knowledge management activities • Interviews with team leaders will facilitate the researcher to understand the project and processes.	Leader group 1, 2, 6 Leader group 1,

3.3.2 Data analysis

In order to enable the data to be analysed, data are transcribed into written texts (Denzin and Lincoln, 2000). Written text includes words and phrases and free-flowing texts (Denzin and Lincoln, 2000). Words and phrases are usually generated by techniques for systematic elicitation such as constructed interview or questionnaires and free-flowing texts usually appear in responses to open-ended questions. In this research, the data was collected from open-ended interview questions and observation. Thus, this section will focus on the techniques for free-flowing text analysis.

3.3.2.1 The techniques for analysing free-flowing qualitative data

Denzin and Lincoln (2000) suggest two types of analysis for free-flowing text: word analysis and text analysis. Word analysis techniques are usually applied to research which attempts to discover the relationship between specific words in the texts, or discover the themes in the texts, such as analysing key words in context (KWIC), word counts, structure analysis, semantic networks, etc.

The techniques for text analysis focus on discovering the meanings in large blocks of text by using a set of codes or categories to code text for building conceptual models, or testing hypotheses, such as grounded theory, schema analysis, classic content analysis, content dictionaries, etc.

However, the techniques for analysing data in research do not essentially follow a constructed method. Flick (1998) indicates,

> *'The combination of multiple methodological practices, empirical materials, perspectives, and observers in a single study is best understood, then, as a strategy that adds rigor, breadth, complexity, richness, and depth to any inquiry.'* (Flick, 1998, P231 quoted by Denzin and Lincoln, 2000, p. 5)

In fact, it depends on the expected achievements of the research and research setting. Based on this point of view, the above methods can be taken as guidelines for analysts to deal with data analysis according to the individual research setting. In this research, the data analysis was divided into several steps which will be described as follows.

3.3.2.2 The processes of data analysis

Data analysis is an iterative process where techniques are used to reduce data, display data and draw conclusions or verification (Miles and Huberman, 1994). The reduction of data relates to the processes of selecting, focusing, simplifying, abstracting and transforming the data (Miles and Huberman, 1994). This process enables irrelevant data to be eliminated and combines relevant data into issues of interest. This process continually occurs until the final report is completed. Data display refers to how information is assembled and compressed to allow analysts to understand configurations and draw justified conclusions (Miles and Huberman, 1994). Drawing conclusion is the final stage of data analysis in which the analyst is not only verifying what they have processed but also confirming or replicating the findings (Miles and Huberman, 1994).

Data analysis in this research aims to outline the activities of knowledge management undertaken in the teams in order to answer the research questions in chapter 3 (3.1). This is done in order to map these activities and deduce some potentially special features that support and enhance innovation activities in this organisation. Therefore, reducing the data and sustaining categories' implications are the significant tasks. This allows the researcher treating the data as unfinished sources to enrich the implication of the categories rather than treating it as a set of variables.

In this research, the data analysis followed processes (see Figure 3.3) which were divided into five steps: reading texts, labelling and creating categories, merging responses and summarising categories, building relations and finding themes and building a conceptual model . In order to label texts, a set of categories were developed based on the literature including the areas of innovation, knowledge sharing, knowledge integration and application. In each area, the categories were identified from the literature and grouped under interview questions. In other words, each interview question included several categories. This enabled the texts of the interview questions to be classified and labelled and also allowed the research to explore how those categories took place in the teams and what they meant. These predetermined categories were applied to all teams for labelling texts during the first reading of the data.

As Figure 3.3 shows, data analysis consists of a series of 'back and forward' processes. Therefore, the preliminary categories were either extended or non-useful categories were omitted after reading and labelling the text. Similarly, in each step, the author might go back to a previous step to modify the efforts according to new

discoveries and contextual situations. This data analysis process is discussed as follows.

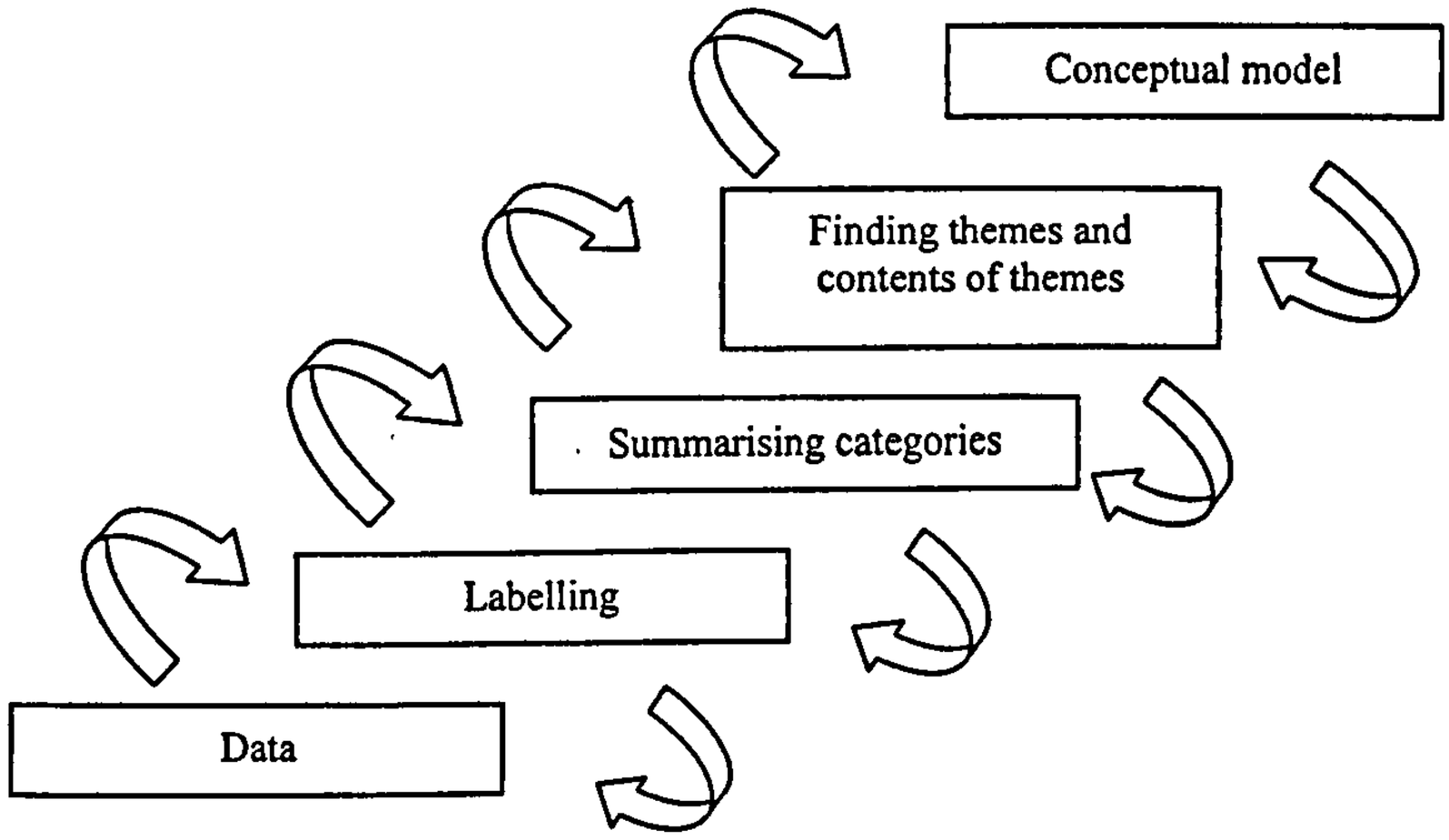


Figure 3.3 The process of data analysis

3.3.2.2.1 Creating and indexing categories

Indexing categories or coding is one of the fundamental tasks in qualitative data analysis (Denzin and Lincoln, 2000, p. 780; Mason, 2002). The process of coding texts, according to Denzin and Lincoln (2000), starts at sampling texts and identifying basic analysis units, followed by finding themes before and after data collection. In this thesis, the categories predominately stemmed from the literature review in which each category represents the feature related to a certain issue. For instance, knowledge sharing includes six categories which are identified based on literature (e.g. Fernie et al., 2003; Koskinen et al., 2003; Nonaka and Takeuchi, 1995; von Krogh et al., 2000): 'timing and occasion', 'method', 'content', 'difficulty', 'overcome' and 'organisational support'. Through labelling these categories in the texts, a team's knowledge sharing activity can be roughly shaped by gathering these six categories' texts and phrases from the team's interviews. However, pre-created categories do not essentially fit in with the whole data. Thus, there may be more responses that do not belong in any categories; this means that a new category has to be created. In this research, this back-and-forward process took place several times to eliminate and add categories until categories covered all the useful text from the data. In this research, the categories were applied to all four teams. This enabled the researcher to do a cross-team comparison and further refine the themes.

The data was collected by taping interviews and taking notes in Chinese. All interview records were transcribed into text, enabling the researcher to have a permanent record of the data. Moreover, the key words and phrases within their contexts were translated from Chinese to English in order to reach consistency and enable further analysis. The understanding of key concepts was based on the researcher's preliminary categorisation of themes and on his understanding of the context in which the data collection took place. The data analysis in this research started with reading those transcriptions and notes literally to understand the content in general. The author then re-read the text in order to identify specific words, phrases, languages, and their meanings in the text. This exploration was a more detailed application of the categories and themes established earlier. However, qualitative research is an endless creative and interpretive process (Denzin, and Lincoln, 2000, p. 23). Besides the re-reading, the researcher also had to begin to interpret words, phrases and languages to gain a better understanding of their meanings and to decide which category they would fit best. Some information needed to be re-categorised as part of this process. Therefore, new categories were created and added and some information moved from one category into a more appropriate one.

Based on the initial conceptual framework (Figure 2.1) summarised from the literature, this research started with 36 categories covering innovation and knowledge management related activities as well as covering different aspects from team leader and team members. After various readings of the text, seven categories were changed through renaming, replacement, and additions (Table 3.4). The seven changed categories are highlighted in the Table 3.4. The modified categories were then used to recode the text.

Table 3.4 Code list and modification

Starting categories	Category Code	Modified categories	Category Code
Innovation (INN)			
INN: R&D process	INN, RDP	INN: R&D process	INN, RDP
		INN: team experience	INN, TE
INN: R&D context	INN, RDC	INN: R&D context	INN, RDC
INN: project characteristics	*INN, PC*	*INN: project characteristics-innovation type*	*INN, PCt*
		INN: project characteristics-product	*INN, PCp*
		INN: project	*INN, PCf*

Starting categories	Category Code	Modified categories	Category Code
		characteristics-funding	
		INN: performance	*INN, P*
		INN: Project selection	*INN, PS*
Team Knowledge Management-Managerial point of view from team leaders (TKM)			
		TKM: purpose	*TKM, P*
TKM: sharing	TKM, S	TKM: sharing	TKM, S
TKM: integration	TKM, I	TKM: integration	TKM, I
TKM: codify	TKM, C	TKM: codify	TKM, C
TKM: store	TKM, ST	TKM: store	TKM, ST
TKM: application	TKM, A	TKM: application	TKM, A
TKM: leader's attitude	TKM, LA	TKM: leader's attitude	TKM, LA
TKM: task distribution	TKM, TD	TKM: task distribution	TKM, TD
TKM: organisational procedures	TKM, OP	TKM: organisational procedures	TKM, OP
TKM: effectiveness and evaluation	TKM, EE	TKM: effective and evaluation	TKM, EE
Problem Solving (PS)			
PS: definition	PS, D	PS: definition	PS, D
PS: method	PS, M	PS: method	PS, M
Knowledge Acquisition (KAc)			
KAc: access-internet	KAc, AI	*KAc: sources*	KAc, S
KAc: sources-internal	KAc, SI	*KAc: access*	KAc, A
KAc: access-external	KAc, AE		
KAc: sources-external	KAc, SE		
		KAc: connections	KAc, Cn
		KAc: content	KAc, C
Knowledge Sharing (KS)			
KS: timing and occasion	KS, TO	KS: timing and occasion	KS, TO
KS: method	KS, M	KS: method	KS, M
KS: content	KS, C	KS: content	KS, C
KS: difficulty	KS, D	KS: difficulty	KS, D
KS: overcome	KS, O	KS: overcome	KS, O
KS: organisational support	KS, OS	KS: organisational support	KS, OS
Knowledge codification and storage (KCS)			
KCS: coding method	KCS, C	KCS: coding method	KCS, C
KCS: store	KCS, S	KCS: store	KCS, S
Knowledge Integration (KI)			
KI: team interaction	KI, I	KI: team interaction	KI, I
KI: team communication	KI, C	KI: team communication	KI, C
KI: team coordination	KI: TC	*KI: task coordination*	KI, TC
KI: people integration	KI, PI	KI: people integration	KI, PI
KI: subject integration	KI, SI	KI: subject integration	KI, SI
KI: controversy solving	KI, CS	KI: controversy	KI, CS

Starting categories	Category Code	Modified categories	Category Code
		solving	
Knowledge Application (KAp)			
KAp: teams interaction	KAp, TI	KAp: teams interaction	KAp, TI
KAp: teams communication	KAp, TC	KAp: teams communication	KAp, TC
KAp: Information transmission	KAp, IT	*KAp: information exchange*	KAp, IE
KAp: knowledge sharing	KAp, KS	KAp: knowledge sharing	KAp, KS
		KAp: technical transfer	KAp, TT
Team operation (TO)			
		Team experience	*TO, TE*
		Leadership and leader role	*TO, LLR*
		Team cohesiveness	*TO, TC*
		Personal attitude	*TO, PA*
		Team interaction	*TO, TI*
		Team atmosphere	*TO, TA*
		Team structure	*TO, TS*
		Team size	*TO, TZ*

3.3.2.2.2 Merging responses and summarising categories

In order to reduce the data, simplifying the categories, eliminating irrelevant responses and merging relevant responses is necessary. However, the merger of responses relies on the author's interpretation of the responses and categories. In this research, there were certain criteria that were employed to reduce and merge responses: 1.) A number of respondents where the phrases and text had higher numbers of respondents were sustained and those that had minor number of respondents eliminated, 2.) Word similarity where similar words and phrases were alternatively used were merged, 3.) Semantic similarity in which different words or phrases used in the text to express a similar idea were merged and 4.) Context similarity where texts were considered to be describing the same contexts were also amalgamated.

The 'knowledge access' category exemplifies the process undertaken in order to create meaningful categories that helped to reach data saturation. In this category several responses were recorded that related to accessing knowledge, such as through *colleagues*, *friends*, *seminars*, *meetings*, *internet*, *intranet*, *team public server*, *books*, *documents*, etc. Among these responses, *colleagues* and *friends* were merged into 'social networks' in which people were the medium to access knowledge sources.

Seminars and *meetings* were merged into 'meeting' in which particular group/team activities were the channel to access knowledge sources. Moreover, the responses *team public server*, *books*, *technical documents* and *recorded documents* were merged into 'technical documents'. The reason that *team public server* was classified into 'technical documents' was because it was used as storage for e-documents in the teams, and it was not open to other organisational members. Through this merging process, the category of 'knowledge access' within a team was condensed to 'social networks', 'meeting', 'internet', 'intranet', and 'technical documents'. This facilitated the research to deal with information redundancy and summarise categories for cross-team comparison and further building of relations and finding themes.

3.3.2.2.3 Overarching themes and a conceptual model

Once the responses were reduced and summarised in each category; the categories were treated as '*unfinished resources*' (Mason, 2002, p. 157) for further use in analysing and deducing the relations between categories in context. These unfinished resources provide '*a wider range of analytical and explanatory logics*' (Mason, 2002, p. 157) to bridge categories within a case's context and in cross-case comparisons. The reasons for that were: firstly there was an initial conceptual framework which has been proposed in chapter 2 (Figure 2.1). However, what the themes in this conceptual framework mean in actual R&D teams is unknown. Thus, to understand what these themes mean relies on the data to give the contents. Secondly, knowledge management in Figure 2.1 is an open area which is expected to be explored through this research and hopefully able to answer the research questions. Therefore, two tasks were focused in this stage.

The first task was completing the themes that emerged from literature review and appeared in Figure 2.1 (project characteristics, R&D process, R&D context). Thus, grouping summarised categories from the data which related to these themes were undertaken. However, the theme team operation was related to team situations and interactions which were embedded in knowledge management and innovation activities. Therefore, the second task focused on two jobs. The first job was identifying categories from the data which relate to the theme team operation and the second job was finding new themes which emerged in data.

In first task, the initial conceptual framework (Figure 2.1) provided the themes which helped this thesis to develop interview questions and subsequently also used as preliminary categories for coding. Thus, the responses from interviews related to these themes were coded and summarised through the previous process (Figure 3.3). Hence,

they were grouped into the initial themes. The processes were described as the following. For example, category 'project characteristics' – the types of innovation – was summarised including radical type and incremental type of project, which are related to outlining a project's features. Thus, this category was grouped into the theme **project characteristics**. Category '*R&D process*' was summarised including the R&D models, R&D schedule and task distribution; these were grouped into the theme **R&D process**. Category '*R&D context*' was summarised including professional technology function and supportive function; these were grouped into the theme **R&D contexts.**

In the second task, the categories related to the theme team operation were identified dependent upon two data sources. First was interview data that related to knowledge management activities and included different views from the team leaders and the team members. Second was team observation data. Based on these two data sources, this thesis identified team operation related categories from the interview data that has been summarised through the processes discussed in 3.3.2.2.2. These team operation related categories were summarised as team experience, team leader and leadership, team cohesiveness, personal attitude, team atmosphere, team interaction, team structure and team size. Hence, these summarised categories were grouped into the theme **team operation.**

The process of identifying these categories and grouping categories is described as below. For example, in each team, team atmosphere was mentioned during interviews and emphasised that this influenced participation and knowledge sharing within the teams. This led team atmosphere to become an important category which not only influenced knowledge sharing but also influenced team operation and other knowledge related interaction (Figure 3.4). Thus, this category was grouped into team operation. This classification was based on the author's understanding of when a team has a supportive atmosphere it enhances team members' engagement of teamwork and openness of sharing experience with other team members. To foster such atmosphere is related to leadership and team interaction. Thus, this factor was grouped into the theme **team operation.**

In addition to the above four themes, there were several themes that emerged from the data. These themes were information technology, individual and team learning, knowledge management activities (knowledge processing) and innovation practice and performance. However, how these themes were identified from the data was slightly different from the predetermined themes.

In this thesis, these four themes were identified based on summarised categories from interviews and complemented by documentary review and team observation data. In order to identify themes from these summarised categories, this thesis adopted two guidelines. Firstly, a response within a summarised category was emphasised as important factor if relevant to specific situations in a team. Secondly, a response that has been suggested as important factor influencing knowledge management and innovation in literature; however, some of those responses seen as important in one of the two ways did not receive as extensive coverage in interviews as other categories. The author included those because he felt these responses added to answering the research questions.

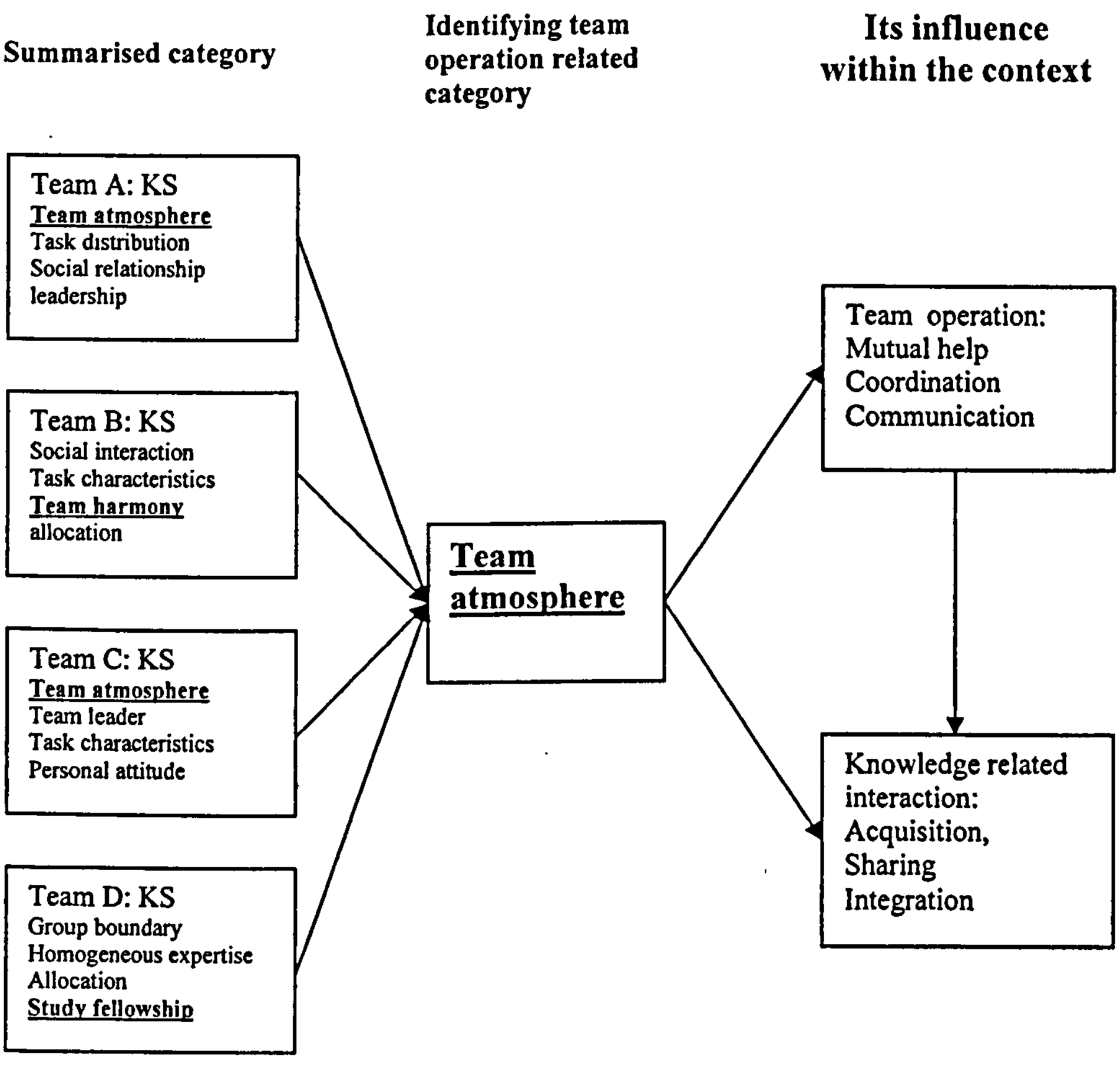


Figure 3.4 Identification of team operation related category

For example, learning has been mentioned as a significant factor in interviews when interviewees talked about acquisition, sharing knowledge and enhance expertise. It emerged in the teams being considered as part of knowledge management and R&D activities. This responded to innovation literature in which learning is considered an important factor of innovation processes referred to as learning organisation (Tidd et al., 2001). Therefore, category learning not only related to knowledge management activities but also related to the whole process of innovation. Therefore, it was identified as a theme influencing knowledge management and innovation activities in this thesis.

Moreover, information technology has been suggested as an important enabler in knowledge management (e.g. Nonaka and Takeuchi, 1995). This also appeared in interview data in which information technology was mentioned in many summarised categories such as R&D process, knowledge acquisition, sharing, storing and team interaction. The influence of information technology was is on all innovation and knowledge management activities. Therefore, information technology was identified as theme in this thesis.

'Knowledge management in practice' in this thesis was a converged theme which related to the practice of knowledge management within the teams. This theme was created based on the summarised categories (team knowledge management (TKM), knowledge acquisition (KA), knowledge sharing (KS), knowledge store (KCS), knowledge integration (KI) and knowledge application (KAp)) as an overall theme to refer to the aim of this thesis.

The last theme is innovation practice and performance. This theme in the thesis was based on the impact of knowledge management on innovation. This theme was identified through interview and observation data categories (team knowledge management (TKM) and R&D context (RDC)) and documentary review which related to team performance evaluation and project selection. The reason that this theme was identified was that the effect of knowledge management ultimately emerges in visible ways through the outcomes of the projects. This is also supported by the innovation literature (e.g. Tidd et al., 2001). Therefore, innovation practice and performance was identified as theme in this thesis.

Based on the processes (Figure 3.3 and Figure 3.4), this thesis identified eight themes; four resulting from the predetermined analysis categories and four emerging through

the data analysis process. The below table (Table 3.5) shows each theme and it's relation to analysis categories.

Table 3.5 Theme list

Themes	Merged categories	Categories (relates back to Table 3.4 modifies categories)	Summary of category contents
1. Project characteristics	Type of innovation	Type of innovation	Incremental innovation, radical innovation
	Funding sources	Funding sources	Public funding (government), Private funding, Self funding
	Products	Products	Technology know-how, prototype of the product, and industrial service
2. R&D contexts	R&D contexts	R&D contexts	Professional technical functions, supportive functions
3. R&D processes	R&D processes	R&D processes	R&D Models, R&D schedule, Task distribution
4. Team operation	Team experience	Team experience	Team history, work habits
	Team leader and leadership	Team leader and leadership	The role of leader, leadership
	Team cohesiveness	Team cohesiveness	Mutual help, participation
	Personal attitude	Personal attitude	Attitude, openness
	Team atmosphere	Team atmosphere	Harmonious, family-like
	Team interaction	Team interaction	Formal interaction, informal interaction, social interaction, task coordination
	Team structure	Team structure	Team organisation (team observation data)
	Team size	Team size	Size (small team size)
5. Information technology	Information technology	Knowledge acquisition	Internet searching, public server, KM system,

Themes	Merged categories	Categories (relates back to Table 3.4 modifies categories)	Summary of category contents
		Knowledge sharing	KM system, Intranet
		Knowledge storing	KM system, public server
		R&D process	Simulation and testing
6. Individual and team learning	Individual learning	Knowledge acquisition	Lectures, seminars, internet searching
		Knowledge sharing	Meeting, presentation, master-apprentice
	Team learning	Knowledge sharing	Team cohesiveness, common language
7. Knowledge management in practice	Purpose and initiator	Purpose	Enhancement of capability, sustaining team expertise
		Problem solving	problem solving
	Knowledge management related activities	Knowledge acquisition	Social networks, Internet, intranet, meeting ad technical documents
		Knowledge sharing	A number of methods, informal occasion, language, type of question, social relationship
		Knowledge storing	Public server, KM systems, personal computer
		Knowledge integration	Communication, task distribution, leadership
		Knowledge application	Problem solving, project creation
	Knowledge community	Knowledge community	Cross-team communication, team boundary, top management involvement
8. Innovation practice and performance	Innovation practice	R&D processes R&D contexts	Problem processing, testing and project solving
	Performance	Performance	Performance evaluation
	Project selection	Project selection	Building core capability

With identification of the above eight themes, the following stages took place, using these eight themes, to describe how knowledge management is undertaken and how it is integrated with innovation processes to enhance teams capabilities. Teams are a complex, adaptive and dynamic system (McGrath et al., 2000). They exist in context and perform across time (Ilgen et al., 2005). Thus, for this thesis, a team achieving effectiveness can be seen as a process from time to time. In order to show how knowledge management is performed within teams, this thesis adopts a traditional perspective of team research--input-process-output (I-P-O) framework (Hackman, 1987) to develop a team knowledge management model. However, in order to make sense of the relationship between themes and this team knowledge management model, the following chapter (Chapter 5) will show how this model was developed from the initial conceptual framework (Figure 2.1) to a completed model. The chapters following chapter 5 will discuss these eight themes in detail, providing the underlying evidence.

3.3.3 Data interpretation

Interpretation in qualitative research takes place across the whole process of data analysis. It is showing a writer's initial intention in fieldwork, and makes sense of what he/she has found and learned from the fieldwork (Denzin, and Lincoln, 2000, p. 23). Most qualitative data exists in the form of text which includes talks, documents, video, etc. However, every piece of data is written or recorded on purpose and within a specific context. This may cause gaps between producers and users of the data and the subsequent interpretations. Therefore, the texts need to be understood and interpreted in the context of the conditions in which they have been generated (Denzin, and Lincoln, 2000). In addition, there is a gap between '*what people say*' and '*what people do*' (Denzin, and Lincoln, 2000, p. 705). This also needs to be addressed, because *what people say* could be influenced by people's recognition and common images which do not necessarily match what they actually do. It falls on the interpreters to understand the context beyond the research setting. Thus a researcher's interpretation is very much influenced by the understanding of what he or she has of that context. Identifying significant and relevant information and data depends on the researcher's ability to read the context.

In this case study, the author's past experience helped to understand the organisational contexts. The researcher was once part of the institute and so has familiarity with idiosyncrasies of behaviour and actions that may be specific to this context. This helped to reduce any misunderstandings that occurred during the data interpretation

stage of the research, as the researcher could identify previous actions and behaviours and thus can interpret them more accurately.

3.4 Research limitation

Every research has its limitations. Some of them have already been discussed in regards to the specific methods used for data collection and data interpretation. The researcher has also outlined that these choices were deliberate in response to the research questions and how the author has tried to address those challenges throughout the research process.

Another limitation of this research appeared in access to data. Firstly, this research was able to observe two teams; one week was spent with each team. Therefore, addressing issues of how social networks are developed and how knowledge and information are transmitted through social networks was difficult. However, the research focused on understanding team members' interaction and their use of facilities such as social networks, rather than aiming at explaining the creation and details of such facilities. This helped the author to understand and explore existing social networks within the teams and capture node individuals who connect team members and influence information flow. Due to his previous membership of the institute, aspects of familiarisation did not prevent access to data and therefore time spent with teams did not affect the research. Also, the author did not use observation as the only source of data, but to corroborate other findings.

Secondly, due to privacy policies, the author was unable to access public server documents in order to assess the accessibility of these documents and their use by the teams. This limited the research to access details about the organisation's IT-based knowledge management system. In order to address this, the author requested the interviewees to describe how they coded documents and used the IT-based knowledge management system to carry out exchange of information and knowledge. However, no consistent documents or structures were relevant to all of the four teams. Thus, it is suggested that even though access to this public server was limited, the impact on the research is minor. The lack of relevance of any one set of documents or structures on this server for the teams suggests that this IT-based knowledge management system is used more as a document storage facility, rather than a facility to foster, enhance, or facilitate knowledge management related activities.

Thirdly, although Internet and on-line interaction feature largely as part of day-to-day activities, the author could not observe what was communicated and exchanged through the Internet. This was due to security and privacy and was also impractical as it is difficult to observe conversations of various team members at any one time. Therefore, this research can only comment in a limited manner on the way knowledge is shared and transferred through on-line interaction and communication. By asking interviewees about the reasons for using online/internet tools and the type of conversation they have when using such tools, some of this access difficulty was compensated. In addition, frequent use was observed and the textual data also emphasised the importance of these tools. Thus, the researcher is confident that it is part of the team members' daily routine to access and exchange knowledge.

3.5 Summary

The nature of the research questions leads to the choice of research approach, namely a deductive, exploratory investigation. In this thesis, a case study strategy was adopted for exploring knowledge management and innovation activities in IT R&D teams in Taiwan. A model of team knowledge management is constructed based on eight themes that were identified from the literature and the data.

In this research, semi-structured interviews, team observation and documentary reviews were employed to collect data. Among these three techniques, interviews formed the major technique to collect data regarding organisational structure and procedures, knowledge management system, team R&D activities and team operation. This method was chosen to access data for outlining team context and answering the three research questions at the beginning of this chapter. Team observation was used to gather data for understanding intra/inter team interaction, and team operation in real situations. This method is useful to access data for analysing team dynamics which relate to research question 2 and 3. Documentary reviews were a complementary technique to obtain information about organisational procedures, project information and knowledge record system. This method is also useful to access data for outlining team contexts. The techniques of semi-structured interviews and documentary reviews were applied to all teams. Team observation was only applied to two teams as the other two teams were not available for observation. For these two unavailable teams, informal interviews were undertaken instead of team observation.

Data analysis in this research is based on a detailed context analysis by following qualitative research disciplines running through the steps of reading texts, creating

and labelling categories, merging responses and summarising categories, finding elements and constructing a model. The model itself and contained themes are able to answer the research questions. In this analysis process, data interpretation takes place iteratively through the whole process to make sense of the meanings in which the author's past experiences with the organisation enable the author to understand the information and further interpret the information. Although the research is limited by access to data, the use of multi methods of data collection complements some weakness in obtaining evidence.

In order to provide full understanding of this research and the discussion in following chapters, the next chapter provides the information about the IT R&D institute in Taiwan and the teams that this thesis investigated. This will give an extra dimension of context.

Chapter 4 Case description

4.1 Introduction

The organisation that this research investigates is a technology development institute which is responsible for developing advanced information technology, and also engages in services of technology for the whole information industry. Therefore, this organisation can be seen as a supplier of the technology in the value chain of the information industry. In this organisation, most of the projects involve technology innovation and technological application innovation. The technology innovation projects are mostly supported by government funding and target key technology development. This technology is usually transferred to industrial companies. This kind of technology innovation usually aims at catching up with the leading technology companies in the world in order to sustain the competitiveness of Taiwan's information industry in the global market.

The projects involving technological application innovation are mostly created for private companies. This type of project mainly focuses on specific development modules by using existing technologies. One of the team leaders indicated that some of the projects are neither advanced technology development nor commercialised product development, they are rather customized projects according to specific companies' needs in which the projects are mainly focused on specific module development. Moreover, this kind of project also requires consultative services to assist them to implement a particular technology.

In this study, technology innovation can be seen as a kind of radical innovation to the whole information industry in Taiwan; it may be a little behind the leading companies in the global market, especially when the projects involve specifications set in the global market. Thus, the projects that the organisation performs usually focus on the research and development of key technology. The application innovation can be considered as incremental innovation, where existing technologies are employed to achieve specific functions that enable manufactures to develop new products. In this study, Team A was involved in this kind of innovation, and Team B was comprised of both characteristics. Team C was involved in industrial services in which the team created a new model for the industry. Team D's project was between two types of innovation but the concepts of the project were fairly new to the whole industry. Each team's project and background will be discussed in the following section.

4.2 Organisational context

4.2.1 Organisational structure

The organisation has more than 1300 employees. The organisational structure is designed based on its missions: R&D and industrial service. Therefore, its structure consists of three R&D institutes (information engineering, networks and multimedia, and advanced e-commerce), one digital content education institute, six industrial promotion and service divisions (IT promotion, industrial support, project resource, education and training, market intelligence centre, and science and technology law centre), and four administration offices. Each institute consists of three levels which are institute, labs/centres and R&D teams. The industrial promotion and service divisions have a similar structure to the institutes. The administration offices are in charge of human resources, accounting, planning and evaluation, and public affairs.

The top management consists of a chairman (of board of directors), a president (CEO) and two vice presidents (VP) who are responsible for research and development, industrial promotion and services respectively. The VP of technological affairs is in charge of managing institutes, organising resources and making decisions in terms of the investment of R&D facility and the cross-lab arrangement of human resources. The VP of industrial promotion and service has the same responsibilities but is in charge of industrial affairs.

In terms of institute level, each institute involves different technological domains and is in charge of developing strategies and integrating R&D resources to support labs/centres to negotiate important projects from sponsors. In this organisation, lab/centre level is an executive unit that is in charge of managing R&D facilities, expertise and arranging R&D related resources. Moreover, lab/centre level is an evaluation unit of annual performance and a distribution unit of bonuses in the organisation. Thus, this level has a direct influence on R&D activities. Each lab/centre consists of several teams who are responsible for carrying out the projects. However, each team may have more than one project on hand at the same time, which is dependent on a team's capabilities. Thus, some teams only carry out one project whilst others may carry out two or more projects simultaneously, where a team can be further divided into several temporary project teams. In this research, there were three teams (Team A, B, and C) that managed one project, and a fourth team (team D) was a temporary project team which consisted of four groups from different organisations.

4.2.2 Project management

In this organisation, project management is divided into two parts: professional affairs and administrative affairs. Professional affairs management is mainly conducted by team leaders and heads of centres in terms of creating new projects, organising projects and general project operations. However, in specific situation; such as large projects and significant government projects, heads of labs or VPs directly conduct projects.

Team leaders are normally empowered to spend budgets but each project's account is managed by the accounting office. Therefore, the accounting office can ensure each project is monitored appropriately. Moreover, the evaluation of project performance is conducted by the planning and evaluation office. According to their annual performance report, the organisation awards labs and divisions different rewards. This reward will be distributed by labs, centres and teams. Therefore, each level's leader is involved in the distribution of the rewards.

Project performance evaluation in this organisation is based on customer satisfaction, project return and technological achievement. Each factor has equal contribution to the performance evaluation. However, project returns seem to have a great influence on the distribution of rewards, especially in the industrial promotion and service divisions. In addition, this performance evaluation system is focused on labs, centres and teams, rather than individual performance. However, the performance of a lab, centre, or team will influence leaders' individual performances which may be associated with their promotion and career development within the organisation. This will be shown in the following section.

4.2.3 Human resources and career development

Human resource management in this organisation is divided into two systems. One is for engineering personnel and the other is for industrial service, general personnel and administration. The systems divide personnel into several scales: assistant engineer, engineer, senior engineer, engineer advisor and senior engineer advisor according to individuals' education, experiences and period of working for the organisation. A team leader is normally on the scale of senior engineer. A head of centre is usually on the scale of engineer advisor, and a head of lab is normally in the position of senior engineer advisor. This shows the path for organisational employees and their career development within the organisation. Moreover, an individual's promotion requires them to have an A rank in individual performance for two consecutive years, especially if promotion to a higher position or leader position is at stake.

In addition, there is a specific human resource policy within the organisation. Due to its support for the national compulsory service (NCS), this organisation has to recruit 150 to 200 new engineers every year with four year contracts. This creates advantages but also causes problems. The advantage is a decrease in turnover during their four-year service but when they finish their four-year service individuals leave. This may be a disadvantage to the organisation because they become mature engineers with specific skills and knowledge during those four years and their knowledge and experience therefore leaves the organisation if they decide to leave.

4.2.4 Organisational knowledge management system

An organisational knowledge management system has been established in this organisation since 1999. The knowledge management system is based on an intranet with the function of categorized data base which is open to all organisational members. The system collects all labs' and divisions' project related documents including project proposals, progress reports, results and final reports. Through this system, these documents can be shared across the whole organisation. Moreover, the system is allowed to be updated by individual organisational members through their computer. In order to promote this system, the organisation has set up an office to take responsibility to integrate organisational procedures within the system since 1999. However, this system seems to be of little interest to organisational members. An alternative solution has been created at team or centre level, namely public files built on teams' or centres' servers. This alternative solution refuses access from other networks and is only open to users on the same network. This restricts cross-centre/labs information transmission and exchange. However, the intranet is used to make up this disadvantage in the organisation. So far, the organisation has paid attention to knowledge management and most efforts are focused on documentation. However, the effects of documentation seem not to achieve what the organisation expects. The data suggests that this may be influenced by organisational specific working contexts.

4.3 Innovation strategy and performance

4.3.1 Innovation strategy

Innovation strategy in this organisation basically underpins the mission of leading the way for the use of IT in industry in Taiwan. Therefore, the R&D is aimed at advanced and core information and communication technologies. The R&D is basically divided

into three different levels and associated with different sponsors. The highest level is advanced technology development which is supported by the government. The second level is technological application which is supported by the organisation itself or industrial firms. The third level is technology transfer and promotion which involves industrial services and business. As the organisation possesses the advanced technology, it is able to contribute significant resources to support second and third level R&D. This influences the teams to develop an innovation strategy and to create projects. In general, there is a model that the teams can adopt, see the Figure 4.1. This shows that when a team achieves an advanced stage of a particular project, it has successfully created a project for applying the technology that it has developed in previous projects or created a project for the transfer of such technology. This is dependent upon the situation at the time. It is not a necessity that the teams follow this loop. It sometimes occurs at the same time; if a team has enough engineers to implement more than one project. One might not reject such a possibility.

4.3.2 The creation of project

Project selection in this organisation is affected by several factors: team expertise, performance criteria, technological trend, organisational intention and commitment. Therefore, it is not unusual and not necessary that teams are committed to stay with the same research focus. The organisation permits the teams to recruit new members from either internal teams or external agencies when a new project is established. However, the recruitment of new members will have to meet certain criteria.

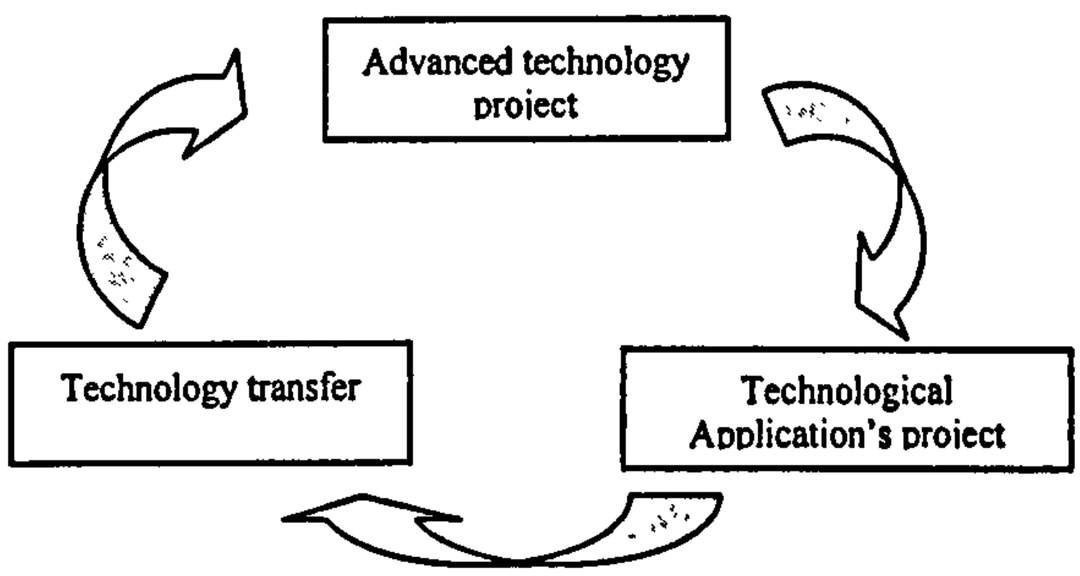


Figure 4.1 Innovation loop

4.3.3 The evaluation of performance

The performance of a team in the organisation is evaluated according to three criteria: technological success, technology diffusion, and project return. The first criterion, technology success, is evaluated by the number of patents that a project has created and publications in professional/academic journals. The second criterion, technology diffusion is evaluated by the number of technology transfers that have occurred since the beginning of the project. This performance evaluation criterion is usually applied in the centre level as teams may not be available to be fully responsible for transferring their technology. The financial return is evaluated by the profit margin that a team generates through the project. This criterion influences project selection, recruitment and team composition.

4.4 Specific working contexts influential for organisational knowledge management activity

One of the significant issues within the knowledge related activities in any organisation is to transform individuals' knowledge and experiences into documents which may record the processes of operating tasks and show a number of details relating to what/how the teams deal with variations. These documents present the techniques and expertise which are beyond the designers and engineers, and also show the context where the tasks are accomplished. This is considered a precise knowledge asset to the organisation and its members. It also explains why documentation is seen as a central task in the organisational knowledge management system. However, the data of this research shows that documentation seems to be rooted in a deep working culture which defines the efforts and production that should be made by an individual or a team.

The working values reflect the judgement of employees on their work and also indicate the criteria for the employees to allocate their efforts and behaviours. This may result in the local organisations having different definitions and requirements as to how they undertake tasks and also lead the employees to accomplish the tasks in different ways. The data suggests that working values influence the definition of outcomes and efforts, a general expectation from management level, organisational attention on cost control and technological success. The culture related issues are not the main topic within this research; however, these cannot be neglected because they may have a fundamental impact on knowledge related activities within the

organisation. Hence some aspects of culture are discussed below, which are believed to be significant for the research context.

4.4.1 The definition of the outcomes

Within and among organisations, it is possible to have a different understanding of what constitutes an outcome. For example, a senior software engineer from Team A indicated,

> *'an outcome for us, even for our boss or top management, is equal to a successful program which achieves the setting functions and meets a certain criteria in terms of technical specification. This is a traditional perception that we are used to work with.'*

This statement represents the view of the engineers in this organisation, as they seem to have the same perception. This drives their attention on practising techniques and pursuing technical success in their day to day work. The paper work, for them, seems not to be a part of their work. On the contrary, an engineer of Team A was surprised when working for another European mobile team. He said,

> *'....it's surprising when I worked there.....I saw my European colleagues write a comprehensive document which I have never seen in my entire life. He showed all the procedures in very detail in his documents. Of course, he spent a lot of time to accomplish them...this is what he thought an outcome, which is a program with a completed document.....'*

Those two different perspectives result in two different definitions to clarify an individual's outcomes or a project's productions. The first one is grounded in the idea of a successful program and the second one defines a successful program with a comprehensive document as the whole. This raises the issue of what, in fact, causes those two different thoughts and how different knowledge related activities influence organisations. Some of the engineers considered that it was a cultural difference between Western and Eastern society in terms of the conception of the work. However, some of the engineers did not agree with this perspective, they considered that it was related to personal attitude with regards to their work. This research takes these two perspectives and puts them into different contexts. First of all, the national culture, industrial culture, and organisational culture may impact on the organisation

and their members in terms of beliefs, values and the way they work (Cardinal, 2001; Sackmann, 1992; Salk et al., 2000; Schneider, 1986). However, these influences can be partly changed by the organisation under certain circumstances. Therefore, cultural difference is only a partial influence. Secondly, personal attitude to work is partly influenced by the environment in which people grew up and were educated. However, different people have different personalities which are based on their socialisation. For example, some people may have traits that are tuned to details, but some people work on the direction or principle and ignore the details. Therefore, within a team, there is always someone who concentrates on detail, which the team relies on. However, in general, the data shows that in the four teams, there was no team that has consistent habits to produce a working diary and most documents consist of a formation of notes by using short sentences and signals, which are for personal, rather than public use. More detail is shown in the final report which is normally generated for customers/funding agents. It demonstrates the results by using the abstract of the project. Some engineers consider this to be the case because the bosses seem to be only concerned with accomplishing a program on time. They never require engineers to produce comprehensive documents to show to others. Their basic criterion for documentation, generally, is acceptability by customers or sponsors. Therefore, most documents they produce achieve this basic requirement. The reasons are, first of all, they do not have time to produce detailed documents. Secondly, most of the engineers consider that it wastes their time. For most of them, producing a successful program is an engineer's main job. They would spend the majority of their time on the program development rather than spend time on doing paper work. This perception seems to be inherently embedded in their minds which deter engineers from paying attention to writing their documents no matter what the purpose of these are.

Moreover, one of the senior members of Team A indicated that within the team, the work of documentation is usually assigned to junior engineers because senior engineers do not like to take it when they distribute tasks. This is quite different from what he has experienced in the European mobile team. As he said,

> *'In this team, only the senior engineer is allowed to generate documents for programs [...], because senior engineers have more experience, this leads them to produce better quality documents and also much more detail.'*

This raises another question. First of all, in the work place, senior members are allowed to dominate work distribution. This gives them power and freedom to choose the tasks they want to undertake and lead junior members. This power is generally accepted and respected by team leaders and junior team members, as it has become a part of social structure for gaining informal power. Therefore, when most senior team members do not take the job of generating documents, junior team members have no choice but to take these jobs, even though senior engineers may be able do it better than junior engineers. This seems to be a trade-off between professional judgement and social norm in the work place. However, the data also shows that it could be slightly changed when a team leader strongly involves and uses his/her influence, authority, or power. This norm can be changed by the team. This means that if a team leader clearly defines rules and sets out job and responsibilities for senior and junior team members, the task can be distributed properly. Within the data of this research, Team B is a team that shows a different way to assign documentation jobs. In this team, each engineer is in charge of generating his own documents according to their individual realm of responsibilities. As the leader said, '*only real producer who knows much about what he/she is doing for his/her case, it is not possible to ask someone to take this job without being deeply involved.*' In the other teams, this job is often assigned to specific team members; however, this team member may not have been involved fully in the whole process of undertaking the tasks. This seems to build up a barrier to document individuals' experiences and knowledge and also stifles the teams or organisations to sustain those experiences and knowledge.

4.4.2 Organisational expectations

In some cultural contexts, an assumption is that employees should unconditionally make high contribution to the organisations. This assumption can be transformed into an expectation from the organisation. It is concretely shown in two scenes: work loads and working hours. As a senior member of Team A indicated,

> *'...they want you take all the responsibility but only pay you normal salary. Too many things have to be done, but unfortunately you cannot manage it. Therefore, you have to work during out of office time. For example, they would like you to write your documents by using out of office time rather than using office time [.....], ex president (CEO) sometimes checked each office at 8 or 9 o'clock in the evening to make sure that most engineers were still working. He liked engineers to make more efforts in their work....'*

This raises the question of how they arrange jobs and manage human resources. The question seems to be related to the issue of cost management which will be further discussed in the next section. This section will focus on the organisational expectation. As one of members of team A said,

> *'While we worked for that European mobile team, the team recruits hundred of engineers for one project, but in here, a similar project, we probably only recruit 30 engineers as a team. Therefore, in average, each team member has 3 times the load that we did in the European team. Also, in that team they have very clear job design and fairly equal loads which include developing program and writing up documents...'*

Similar responses also come up in the other teams. Most engineers within team A considered that it is a specific working culture in Taiwanese organisations. The management level neglects individual capability and they think one should cope with higher work loads and make greater contribution to their job if it is necessary and that one should use private time to complete a job without asking for extra payment. With this working culture, it seems to be difficult to convince employees to make efforts to generate documents if it needs to be done by using private, non-paid time.

4.4.3 Cost orientation

Organisational profit is generated by revenue creation and cost control. The data of this research shows that the organisation's annual revenue mainly comes from government's technology development projects (40%) and industrial co-operation research projects (60%). The funds invested by government are a stable income for the organisation. The industrial co-operation research projects are a relatively unstable income source. In order to sustain the organisation's operation, effective control of costs is becoming a significant issue. In this organisation, a policy has been made to control each project's cost by setting a standard for recruiting team members into a project. With this formula, the number of team members that can be recruited is fixed according to available funding. The data also shows that there are different standards for different departments. For example, the standard for R&D labs is NT$2,000,000 (£33,000) per head, but for industrial service departments the standard is set at NT$3,000,000 (£50,000) per head. With this limitation, each project can recruit a limited number of members and the loads are shared between team members who are

recruited for the project. However, the budget of the project does not reasonably account for all the effort and resources which have to be invested. Therefore, extra effort and investment of resources are put onto the work loads of individual team members. This is one reason why members are unwilling to generate quality documents within the teams.

With limited investment in human resources, knowledge management efforts are also ineffectively undertaken within the teams. A solution that solves this problem is to assign a junior team member to manage all the documents that are done by other team members and to put those documents in the knowledge management system. The situation is represented by a statement of a member of Team B,

> *'...nobody has time to deal with this job and also none comes back to read or update their documents again. Only I, I do sometimes use this system to search for data, but it is not really useful for my work, just because I am in charge...'*

This statement seems to suggest that human resources are a significant problem for an organisation or a team to effectively run a knowledge management system. However, this is directly related to funds, spending, and controlling.

The above three issues are considered to have a significant influence on documentation of knowledge within R&D teams. In practice, turning individual experiences and knowledge into documents is considered one of the significant methods for the organisations to sustain knowledge and also manage knowledge. However, the data shows that working values, organisational expectations and cost control impact knowledge management activities within the organisations.

4.5 The teams

Four teams were investigated in this case study. The details of the teams are as follows.

4.5.1 Team A: GSM/GPRS Mobile Testing Specification Design and Environment Development

This team ran a project involving GSM/GPRS mobile phone testing specification formulation and environment development. The purpose of the project is to develop the essential testing specification, testing software and documentation for WAP,

MMS, Java and Data. The project was funded by [company] which is the third biggest professional mobile manufacturing company in Taiwan. The outcome of the project will finally be transferred to this company. The project will take eighteen months to complete. The duration is divided into two phases; the first six months are for the development of testing specification documents and software system. The second phase is technological transfer and system testing and maintenance. At the time of the interviews, the project was at the beginning of the second phase.

The team consists of six members. Three of them are senior engineers and the rest are junior engineers. All three senior engineers have had six to ten years experience in their areas of expertise respectively. They have also had experiences working on international co-operation projects with two international communication companies in their local laboratory in Germany and Japan before they joined this team. The three junior engineers respectively have one to three years experience working on other projects. Moreover, these three junior engineers are under technological compulsory service so they will work for this organisation for at least four years. All members in the team have similar education and expertise, either a Master in information engineering or a Master in information management.

4.5.2 Team B: Automatic Testing Equipment (ATE) development

This team was initially created by the government to develop a specific aircraft electronic system. The project was started in the mid 1980s, and ended in 1999. Since 1999, the team has been sustained and funded by the organisation. However, the team size has been reduced from an initial fifteen members to five members at present. In order to sustain the technical capacity and the existence of the team, the team leader has taken a strategy. On one hand, the team continues to develop new versions of products based on the outcome of the initial project. On the other hand, they continue providing after service for previous customers, as well as consultancy.

The technical capacity of this team is mainly focused on developing testing platforms and software systems for the automatic testing of electronic equipment (ATE). This system can help maintainers to monitor electronic equipment and also rapidly detect broken electronic components. At present, the team's main contract is with the air-force, metro transportation and several other companies. In the air-force project, the system is used to maintain the air fighter radar system. In the metro transportation project, the system is adapted to detect faults in the electronic boards on board the trains as well as the control station.

In order to sustain the capacity of the team and its future operations, there is a new project which relates to the applications of the Radio Frequency Identification (RFID) technology. The new project was proposed at the beginning of 2004. It will start in February or March 2004. The project will be contracted with a petroleum corporation and a health department.

4.5.3 Team C: Digital content industry promotions office-Investment Financing Team

This team is a subproject of an Internet multi-media development project that is supported by government funding for five years. The purpose of the main project is to promote the development of Internet multi-media (the internet content) and the digital medium (such as Internet games and interactive television) industry through providing technological assistance, technology approval, subsidies for research and development (R&D), industrial consultation and seeking funding (venture capital). The team's objective is to assist technology owners to search for essential funding from bank and venture capitalists. Meanwhile, the team also plans to develop an assessment system for intangible digital assets such as internet games, digital contents and so on. The purpose is to give an estimation of the potential value of the technologies and ideas to the owners of the technologies and potential investors or banks which the owners can use to obtain adequate funding or investment to achieve commercialisation of the technologies or ideas.

In order to achieve the project, the team consists of members with a diverse background including industry research, information technological expert, financing, banking and intelligent property consultation. This team had only been formed for six months during the interviews. The team leader said, '*although it is a very young team, and has in total only eight team members at present but the team size is growing fairly fast.*' In this team, most of members have six to eight years working experience in their subjects respectively, such as banking and information industrial research.

4.5.4 Team D: Enhanced Secure Gateway Operation System

This is a cross-unit R&D project, and is supported by government technology funding. The participants include this leading IT research organisation, a national university (NU), and two of other universities (U1 and U2). The leading research units are this leading IT research organisation and the Information Engineering Department at the national university. The team includes two engineers from this organisation,

two scholars and seven postgraduate students from NU including two PhD students and five MSc students.

The project was based on the standard of the Common Criteria for Information Technology Security Evaluation (CCITSE) and used open sources which could be searched from the Internet and numerous related databases to construct an enhanced secure gateway for operation systems. This was an experimental project. The aim of the project was not to develop a commercial product or technology, but its purpose was to test and verify the feasibility of products through integrating present solutions and tools to enhance gateway security to protect systems. The project has been running for a year up to the date of the interviews. The continuity of the project will be decided later this year.

The project was divided into three tasks: system development and integration, auditing module, and intrusion detecting module. The processes of the project were divided into five phases. The first phase was a broad study in terms of the subject in which the team members were assigned tasks to explore and study related information and data, and then shape the profile of the secure functions. The second phase was to make specifications for the project and then to seek and collect related open sources. The third phase was to analyse the open sources and eliminate useless open sources. The fourth phase was the integration of the open sources and the test of the system and solving any potential problems. The last phase was producing an instruction CD.

4.6 Summary

To sum up, the organisation's specific mission, position and culture will lead the organisation to generate different innovation strategies which allow the organisation to continue its operations. However, this strategy also influences knowledge management related activities taking place within the organisation. Four R&D teams are investigated in this research. All four teams were running different projects. Based on these teams' specific contexts, this study investigates how knowledge management is undertaken to help in the completion and success of the projects undertaken by each of the teams. The information of the organisation and the teams provided in this chapter is helpful to understand the following discussion in each chapter.

The following chapters will present the findings of this research. Each theme resulting from the data analysis is discussed individually. Subsequent to the discussion of the findings, a proposed model of team knowledge management is introduced that builds on the initial conceptual model outlined in chapter 2.

Chapter 5 The influence of project characteristics on knowledge management in innovation teams

5.0 Introduction

So far this thesis has outlined its intention and has begun to place those within the context of current research thinking in the literature review. After defining the research questions and describing the process which this research undertook to answer those questions, the case studies were introduced. From this chapter to chapter nine, the thesis discusses the eight themes identified during the analysis process and also presents the evidence emerged from interview, team observation and documentary review data.

This chapter focuses on three different characteristics of projects and discusses their impact on team knowledge management and innovation activities. Project characteristics are the project contexts which are set at the beginning when a project is created or selected. They highlight the features of a project related to the outcomes and what needs to be considered for the project teams. They guide the teams to plan the implementation of the projects and organise the resources. Also, in this specific organisation, these three project characteristics have certain connections in which government funded projects are associated with radical innovation and privately funded projects are associated with incremental innovation which aims to assist industrial firms to develop prototypes of products and transfer technology. The interview data shows that both types of innovation teams are associated with different knowledge inputs which lead to different team dynamics and appear different emphases in their knowledge management activities.

A project's characteristics are centred on the funding sources in which sponsors' intentions condition the type of innovation and final products in this particular organisation. The influences of funding sources on the projects are associated with the definition of final products and their innovation features. To achieve a final product involves many inputs and ways of processing the projects in order to cope with emerging problems during the project time. In this case study, problem solving emerges as an important driver to initiate knowledge related interaction between team members. However, how this knowledge related interaction takes place to meet

problem solving is associated with the adoption of R&D contexts, the construction of R&D processes, the way knowledge is managed and innovation performance. The data from the interviews reports that differences in project characteristics causes different problems to emerge, which lead the teams to perform innovation and manage knowledge in different approaches. This implies that knowledge management within teams or organisations are situational activities in which project characteristics are one of causes.

Although the theme 'project characteristics' in this thesis not directly influences a team's knowledge management, it is an important contextual factor which influences a team's management of R&D and subsequently influences its knowledge management activities. This relates to answering the research question 1 and 3 in chapter 3. In order to show the influences of this theme on team knowledge management, this chapter is divided into four sections. The first section discusses three characteristics of projects. The second section will highlight the connection between project characteristics and R&D contexts and processes which will be discussed in next chapter. The third section will discuss the influence of project characteristics on problem solving and is followed by required knowledge sources to solve problems. The final section will summarise each project characteristic and its influences.

5.1 Product characteristics—Funding, types of innovation, and products

5.1.1 Funding

Funding is a crucial input. The funding sources in this research are classified as public funding, self funded and private funding. Publicly funded projects in this research are usually associated with government industrial and technological development policies. Therefore, those publicly funded projects usually focus on advanced technology and breakthrough technology development. The efforts are usually transferred subsequently to industrial firms for further commercialisation. Conversely, privately funded projects are usually focused on specific functional modules which tend to be adopted in commercial products. This means that most of the privately funded projects have incremental innovation features, and the efforts tend to be early prototype or functional modules. This highlights the differences between publicly and privately funded projects in terms of the ways to undertake the projects and the

requirement of the knowledge sources. This difference was explained previously in chapter 4. The influences of funding differences on the project teams appear in two events: the association with internal and external knowledge sources and expertise composition. In terms of self-funded projects which are associated with organisational strategy, most are aimed at radical innovation.

The reason for the features appearing in privately funded projects is that Taiwan's IT companies are mostly middle-sized companies in comparison with leading global companies. Most of these companies are engaged in manufacturing components and also manufacturing customised products for specific international IT companies, such as IBM and Dell. Therefore, the R&D in those companies tends to focus on developing commercialized products, manufacturing processes and specific functional modules/components. With this understanding, this research assumes that the differences in funding sources may lead the R&D project teams to be associated with different R&D contexts and R&D processes to accomplish the tasks. This leads the teams to have different team operations and ways to undertake knowledge related activities. In fact, the knowledge related activities in this type of project tend to be associated with transferring knowledge from senior engineers to junior engineers through practicing knowledge.

> '*I have joined this project from at the very beginning. Any hardware problem I can share my experience to help my team members to solve a problem*' the leader of Team B said.

This facilitates the teams to sustain knowledge and technical skills.

For example, this research investigated four teams where projects were respectively funded by private company (Team A), the institute itself (Team B), and government (Team C and D). In Team A, the project employs incremental innovation because the techniques and related knowledge that the project needs have been developed by some of the senior team members who have been engaged in similar projects early on (e.g. a GSM mobile testing system). The project is divided into five tasks based on five functional modules. Each experienced senior team member is assigned to take responsibility for one or two modules and to supervise junior team members to carry out the tasks. This arrangement is also followed by project reviews and peer reviews to ensure the tasks to be undertaken are on schedule and on the right track. Under this arrangement, the team's operations are underpinned by the automatic coordination between senior team members and the interaction between senior and junior team

members. Therefore, based on this project, knowledge related activities in this team are addressed on the transmission of knowledge and experiences through collectively solving problem by gathering senior and junior engineers in which knowledge sharing takes place flexibly and informally according to the progress of the project. For example, a senior member of Team A indicated,

> *'Because of my previous experience in a Sony Ericsson team, I have been assigned to supervise a junior team member to help him to transform testing specification. Other senior engineers who have the same experience as I do are assigned to help others as well.'*

Moreover, in order to respond to the project sponsor's requirements, the team has fixed meetings to communicate to sponsors. In this project, organisational R&D contexts were pivotal. The team had higher decision power to decide the details of the project in terms of the investment of resources and the arrangement of team composition. However, due to budget limitation, some of the team members were on secondment to other projects.

Team B is a self funded project team. The project is a continuation of a successful achievement from a publicly funded project. The specific features of this project team are its small size, and its involvement in hardware system development is different from the majority of software development teams in the organisation. Due to funding source and organisational human resource policy (further discussion in Chapter 4, 4.3.3), this team's size is limited. This causes the team to have different arrangements during the performance of the project. In this team, the project is divided into hardware and software tasks and mainly relates to hardware work. Therefore, all team members are hardware engineers. However, there are two engineers who are also in charge of software system development. Due to its specific feature, this team cannot be supported by the organisation in terms of technological resources. This leads the team to create their own connections with external knowledge sources, such as equipment suppliers and customers. A senior team member indicated,

> *'For our current project, equipment suppliers are important knowledge sources because they know their components better than us, so we need to keep close to them just in case we need their help.'*

The knowledge related activities in this team stem from solving problems and sustaining techniques and experiences. Therefore, their team operation emphasises

automatic communication and coordination by which the problems can be solved through team members' co-operation. This is also considered to facilitate team learning. With this encouragement, the knowledge related activities in this team tend to be very informal and spontaneous. A member of Team B said, *'in our team, any problem comes out, we all get together to discuss and give help.'* It means that such activities can happen any time when any of them encounters problems. In this team, the small team size is also considered an advantage to support knowledge related activities because team members have much more frequent interaction and communication (further discussion in Chapter 8).

Team C is a government funded project team which engages in industrial service, rather than technological R&D. However, one of its tasks is to develop an intangible asset evaluation model which can be seen as R&D. The organisation cannot provide related knowledge sources; therefore, the team adopts outsourcing to develop its model. Meanwhile, the team also creates a group which includes several team members familiar with intellectual property law and financial expertise to provide consultancy. These team members are also responsible for assisting potential digital content producers (firms) to obtain financial investment from investment banks or companies. Due to the diverse team composition and also the fact that each team member works independently, the knowledge related activities within this team rely on formal meetings and specific activities, such as training courses, seminars, and external experts. A member of Team C indicated,

> *'Because we all work with different agencies, such as R&D teams, bankers or consultancy, and we all directly report to our team leader, so the occasion that we can actually exchange information are team meetings.'*

Moreover, the team leader plays a significant role in transmitting information and communication. A member of Team C said,

> *'Most information in our team comes from our team leader. He likes to talk to us individually to know what we are doing and sometimes transmit information if he has time.'*

Team D is also a government funded project team which is engaged in an experimental R&D project. This project can be positioned as a radical innovation because it possesses a feature of high innovativeness in the IT industry and there is not a mature product that has been launched in the global market. The project was

originally taken by the NU team; however, due to the project sponsor's requirement, the project was opened to other research teams. Therefore, U1 and U2 teams were invited to join the project in the middle of the project life cycle. This project was divided into two phases. The first six months was the study phase in which the NU team tried to explore related technologies and decide which technical platform to base the knowledge on. In this period, the NU team consulted external experts and also started to search and collect open resources from the Internet. Since the other two teams joined the project, the project has been divided into three tasks and moved to the phase of development. In this phase, the project is implemented by those three teams separately and fixed meetings are held every two weeks for reviewing the progress. Meanwhile, during the meetings, the problems are represented to all team members for seeking advice. The team members indicated that they hardly interact with other teams outside the meetings except when the project reached the integration phase.

> *'We pay all attention on our own work during the development stage. When we gradually start to integrate the systems from different teams, we have more interaction between meetings,'* a senior member of team D said.

The knowledge related activities in this team are triggered by solving problems. Fixed meetings in this project provide an opportunity to exchange knowledge and solve of the problems. However, in this project, before any decision is made, the leader group would confirm with the sponsor, as one of team members said,

> *'in our team, before any decision has been made, the leader group always confirmed with the institute....'*

This quotation indicates that funding sources/sponsors may have a determinant influence on the project team when they are intensively involved in the project. This may lead the project team to have limited choices and power for making decisions, especially when the decision is relevant to the adoption of technologies and the use of budgets. With the above understanding of the influence of funding on the teams, the following two sections will discuss the types of innovation and products which are mostly associated with who sponsors the project.

5.1.2 Types of innovation

An earlier discussion in the literature review has illustrated different types of innovation. In this research context, radical and incremental changes in innovation are

addressed. An incremental innovation is usually based on implementing existing or new technologies to improve product quality or efficiency. A radical innovation is usually associated with either technological success or product conceptual innovation which may change the game rule in the market. The literature (Pavitt, 1984, Senker, 1998, pp. 229; Tidd et al., 2001, pp. 8-9) suggests that these two types of innovation are associated with different initiative factors and the use of knowledge sources. For example, Pavitt (1984) indicated that '*most innovations are derived from equipment or material suppliers.*' (cited by Senker, 1998, pp. 229) A more recent example is Intel pushing personal computer and software producers to intensively upgrade their products by rapidly launching new Central Process Units (CPU). This implies that suppliers of equipment and material are an important force for triggering industrial firms to carry out incremental innovations by adopting new equipment or materials. In contrast, radical innovation is involved in the decision of entering a new or unknown technology area. In fact, it is affected by many organisational factors, and also '*the technology sources often come from outside that industry*' (Tidd et al., 2001, pp. 11). This means that this kind of innovation takes place dependent upon an organisation's flexibility of moving in and out of different technology domains and its associated knowledge sets. In fact, organisations are often incapable of supporting this sort of radical change in terms of technology sources and knowledge base. Therefore, this research makes a significant distinction in innovation characteristics. Also, this research defines radical innovation as a kind of innovation which is involved in advanced or breakthrough technology development.

In this research context, the organisation is involved in rather large amounts of radical/advanced projects (40% government funded projects, 4.4.3). The project teams thus may not be able to obtain essential support from the organisation itself in terms of knowledge sources. In order to achieve the projects, the project teams therefore need to build associations with either specific experts within the areas or external organisations to acquire essential expertise and knowledge.

The data from the interviews shows that to access to or to build close connections with external knowledge sources often relies on either the use of project leaders' personal social networks (also discussed in 8.1.3), or joining inter-organisational co-operation projects to learn:

> '*Our team leader knows many people within this organisation, which helps us to find some one who can help us to solve problem,*' a senior member of Team A said

For example, the technology of building GSM testing environments, which is aimed for by Team A, is obtained from a co-operation project with a cross-national communication company. This technical capacity has never been possessed by this organisation or other related companies in the information industry of Taiwan. Another example is the advanced gateway security protection system which is held by Team D, which is a conceptual innovative project. Due to the uncertainty in the technology at the beginning, the project team contacted external experts to seek help to clarify their problems. In this case, a team leader (NU team) used his personal social relationships to consult external experts privately and also ask to access their knowledge sources. These interactions with external experts enabled the team to clarify the doubts and address certain issues to seek breakthrough in the technology.

5.1.3 Products

In this research, the products are defined as technology know-how, prototype of the product and industrial service, as this category reflects the features of the organisational mission and the data sources.

The development of specific IT know-how is usually focused on a certain item of technology to seek technological breakthroughs. This kind of R&D has an advanced feature of leading the industry. Therefore, forecasting technology development and building close connections with specific labs and experts are necessary. The knowledge acquisition activity in such teams tends to be associated with external knowledge sources. This facilitates the teams to generate ideas and update information. In contrast, development of prototypes of products in this particular organisation usually entails using existing technologies which means such R&D teams tend to concentrate on internal interaction to use in-house knowledge in which a diversity of expertise and cross-divisional co-operation may be necessary. Team A and B are examples. The leader of Team A indicated,

> *'We have know-how about mobile testing which no one knows in this organisation, so we need to take care of it ourselves.'*

The differences between those types of teams may cause knowledge related activities to be undertaken in different ways. For example, Team B, its previous project (before 1999) aimed at developing the know-how of the systematic testing platform and produced a prototype. Its expertise composition at that time included a majority of software engineers and a few hardware engineers. This composition enabled the team

to undertake re-engineering of a system which was developed by a U.S company to understand the system design and then develop their own system. Once the system had been developed and a prototype produced, the team turned to downsize the team and simplify the expertise composition to be unique. The majority of team members are hardware engineers and one is a software engineer. The remaining team members were responsible for improving the system and developing commercial versions to compete for contracts for the industrial market. In this case, the associated R&D contexts changed over time. From an early stage, it possessed the capacities of hardware re-engineering, hardware design and software design until its recent stage. Its R&D functions were constructed for supporting system maintenance, hardware improvement and software upgrade. With this change in the R&D purpose, this team's knowledge related activities seemed to become different. As the leader of Team B described,

> *'At the initial stage, nobody knew the system; therefore, we distributed the team members into several functional groups. Each group was responsible for a module to undertake re-engineering...once the system was completely understood, we started to develop and design our own system structure and then produced a prototype.'*

During this period, they exchanged experiences and efforts mainly through discussions and meetings in each group. They also consulted external experts to help them to solve problems, especially concerning hardware domains because the organisation had no relevant resources to support them to deal with hardware systems:

> *'We are the only team within this organisation has hardware capability,'* the senior member of Team B said.

Once the project finished they had gained the key technologies and improved the capacity. Therefore, in the later stage, the team's work focused on improving and upgrading the system. The knowledge related activities in the team tended to focus on maintenance of knowledge and experience through transferring the knowledge from senior to junior engineers. Moreover, in terms of the improving the system, they relied more on in-house R&D rather than associated with external experts or organisations. A senior member of Team B revealed,

> *'Our boss encourages us to help each other and share experience, which enables knowledge to be kept within the team because our current project is*

very specific in this organisation. If we leave, all the knowledge related to this particular subject will be gone.'

This section shows that funding sources, the types of innovation and the products have rather strong influences on the project teams' R&D and knowledge management activities through encountering different problems and solving problems. They may not be the dynamic factors but they provide the contexts for the project teams to manage knowledge related activities and implement a project at the same time.

5.2 R&D context and process

Project characteristics shape a project's technological feature and purposes. Based on these given characteristics, a project team can arrange its associated R&D contexts and processes to support the project to be completed. R&D contexts here are associated with the access of knowledge sources and the adoption of R&D resources. R&D process is associated with the ways of performing the projects.

R&D contexts and R&D processes are associated with a team's collective intelligence and team knowledge. They connect with resources and provide working processes to conduct team operations. However, both factors are rather situational according to the situations that the project team faces. Both themes in this research are seen as the initial themes providing the dimensions and contexts to investigate knowledge related activities in the R&D teams. A further discussion will be provided in Chapter 7. The following sections will outline how different project characteristics influence knowledge related activities.

5.3 Project characteristics and problem solving

The previous section 5.1 has outlined that different types of projects face different problems which may not be generalised. Some problems in the projects may be detectable and predictable, but some problems are unpredictable. Problem solving is a crucial mechanism to trigger knowledge related activities. Knowledge related activities enable knowledge to be used in R&D to solve problems. However, different types of innovation may be associated with different knowledge sources. This justifies why project characteristics are the important initial theme in this research, because projects with different characteristics are associated with different problems and

access to knowledge sources. This allows different ways to undertake the projects and knowledge related activities. The following section will discuss project characteristics and their associated problems and ways of solving those problems.

5.3.1 Problem solving in differently sponsored project

Public funding is usually used to support advanced and key technology development. Also, this sort of funding is mainly supported by the government under the policy of science development or industry development. Thus, the projects often involve high risk, higher dominant power in the technology domain and market and high potential value for the whole industry. Thus, it tends to require more specific technological scientific sources to support the projects. Also, the time period of the project often covers several years like the project team in this research. In this kind of project, the problems that the team encountered are more complex and require specific resources to support.

> *'We knew not much about this project at the beginning, which requires a lot effort to find the direction and focus for the project,'* a senior member of Team D said.

The leader of team B concurred,

> *'When we started This ATE project 10 years age, we had no idea what it was about. It started with a mess and changed project leaders a few times to get it right.'*

Also, this kind of advanced technology was unable to be supported by internal resources or industry because it went beyond the capabilities that the organisation or the local industry possesses. Therefore, problem solving relied on external scientist or leading organisation.

> *'We started with consulting a well known expert in that area from [a company] to clarify and find our focus,'* a senior member of Team D said.

Thus, the interaction and communication with those knowledge sources became very important (Senker, 1998). Moreover, senior experts' and engineers' experiences and skills are crucial resources to support solving those complex problems, as a senior member of Team D said,

> *'Our leader group is an important knowledge sources to guide us to solve problems as they are all experienced.'*

In a privately funded project, risk and cost often constrain innovativeness (Link and Scott, 2001) and the input of resources. Thus, there are two different models to run this kind of project. The first one is to concentrate on a team's core technological capability and employ outsourcing to develop associated subsystems. The second one is completely based on in-house technological capability to develop the project. These two different models require different R&D inputs and processes. The first model requires R&D teams to allocate all resources on concentrated part, and through cooperation with external agencies to solve the outsourcing problems. In the second model, the R&D team tends to be responsible for solving all the problems in which in-house technological knowledge becomes very important. These two models denote that privately funded projects are much more reliant on the use of in house knowledge sources rather than external knowledge sources. Evidence within this research supports these assumptions as the following shows:

> *'Based on previous performance and experience, our senior engineers can handle the project and solve major problems...'* the leader of Team A said.

Also, the leader of Team B concurred,

> *'...problem solving....., three team members will discuss first, if they cannot solve it, the hardware system is usually solved by myself....the software system...If I cannot help, I will help them to seek relevant sources. Most sources are from hardware manufacture/suppliers.'*

The characteristics of the project do not only influence the project's practice but also influence its status and priority within the organisation. The status and priority are

associated with the access to resources and organisational support. If a project is relevant to organisational core capabilities, it can access more sources within the organisation. Conversely, if a project is irrelevant to organisational core capability, the project would be isolated in the organisation and obtain limited support from internal resources. In this circumstance, the project usually tends to develop connections with external sectors to obtain essential knowledge sources.

The data of this research provides evidence that when the project overlaps less with the core research stream of the organisation, the project obtains less assistance from other internal sectors in terms of technological knowledge. The leader of Team B indicated,

> *'...in this organisation, I don't think there is anyone who is interested and needs our knowledge...because our tasks mostly focus on the development of hardware system. However, 90% of tasks in this organisation are related to software development. Thus, I think from what our team is engaged in is unusual in this organisation because not any one team does the same thing as us.'*

This explains the status of the project within the organisation. When it is isolated from the main technological stream in the organisation, the project team will rely on external sources and rarely interact and communicate with other internal sectors.

5.3.2 Problem solving in different types of innovation

Different innovation types are associated with different problems and ways of solving problems. In a radical innovation project, the problems that a team might face could be unpredictable and beyond a team's ability to solve. Thus, replicated experiments and seeking new knowledge sources from outside the team are necessary. However, to obtain explicit knowledge may not be difficult, but to obtain sufficient experiences to manipulate the processes of experiment or R&D is not easy. Thus, through interaction with external scientists and experts to obtain not only explicit knowledge but also their tacit knowledge is necessary and significant[4]. In this case study, radical

[4] Dynamism in the knowledge base of established technologies may demand that researchers interaction with the sources of new knowledge in order to acquire any associated tacit knowledge, skills and techniques (Senker, 1998, pp.241)

innovation teams (Team C and D) appear to rely on connections with external experts to obtain essential new knowledge for the project. For example, a senior member of team D said,

> *'...at the beginning, we did not fully understand (safety gateway), we went to [a company] to see Professor X to ask for advice about this topic. Also, we asked other (external/internal) scholars as well when we held meetings... '*

This situation also appeared in Team C, a senior team member indicated,

> *'...we don't know much about how to evaluate intangible assets so, we work with a consultancy. They helped us to create this model.'*

Also, even a team member from an incremental innovation project (Team B) confirmed,

> *'...we usually relied on customer, customers sometimes have different background from us, they often propose some ideas which may be impossible, but some ideas are really good,...interaction with externals (organisation/team) is really important.'*

In contrast, in an incremental innovation project, the innovation often focuses on improving the functions or designs of existing products by adopting new technology. In this scenario, the problems that the team faces may be predictable at the beginning and can be solved by using in-house technology or equipment/component suppliers' solution[5]. Thus, problem solving relies on team members' experiences and skills to deal with situations. A member of Team B said,

> *'...if I have problem, I usually ask one of our senior engineers or my boss (team leader), they both have a lot experience and have worked on this project for a long time. It always works (solving technical problems)...'*

[5] Most innovations derive from their suppliers of equipment or materials (Pavitt, 1984)

The above evidence shows that problem solving is a tacit skill which involves an individual's experiences, skills and tacit knowledge which are accumulated from past work. It enables an experienced engineer to diagnose the problems and seek possible solutions according to his/her experience, such as the leader of team B who has been in charge of hardware system since the previous project was established.

5.3.3 Problem solving in different types of products

In a key technology development project, problems and the ways of solving them are different from a product development project. This kind of project may require team members with similar expertise in order to focus on a specific technology through continuous trial and error to develop a set of process and method which enable the technology to be applied. Thus, the research teams may not only consider how technology works but also its application in the future. To develop this kind of technological know-how involves a deep understanding of scientific knowledge and the skills of implementing them. This relies on co-operation between scientists and engineers to transfer scientists' experiences and tacit knowledge to engineers. For example, team D has to interact with external experts to help them to locate research focus and develop ideas. During the development period many unpredictable problems arose and this required continuously new knowledge inputs and many decisions needed to be made. A senior member of Team D indicates,

> *'...every time that new problems come up, we either called group meeting or assign tasks to team members to search the solutions from the Internet or..., and then report possible solutions to leaders in the team meeting, they make decision about what we are going to do next...'*

In contrast, in a product development project, the team may consist of a diversity of experts to support project needs. Because each expert group is responsible for different functional modules, the integration of separated modules could cause serious problems for the team. To avoid this kind of problem frequent cross-functional coordination is important. To solve the problems relies on internal engineers' experiences and technological knowledge. This influences the way the teams solve problems and operate projects. For example, the leader of Team A said,

'...the beginning of the project is very important. We need to discuss how to perform this project, what sources we need.....when we need to check the progress and exchange details for later system integration...for all of these, we need to make decisions.'

'...a lot of problems come out when the project is in the field test stage, we have very intensive test and correction of errors.' [A senior engineer of Team A]

A senior team member of Team D also indicated their situation,

> *'...because our tasks (three teams) are quite independent, so most meetings we just present the progress respectively...till integration phase, we start to face increasingly problems, then three of us have more frequent interaction for solving problems...'*

It is evidenced that in product development projects, the system integration stage is the period of time that most problems emerge and need to be solved. This is different from the key technology development project in which problems may come up in the very early stages and last through the duration of the developing period.

The above discussion shows that different project characteristics are associated with different types of problem. In order to solve problems, the teams need to access different knowledge sources. This outlines that knowledge management activities within the teams is associated with solving different types of problems and obtaining knowledge from different knowledge sources. This leads to the further discussion in the next section in which the thesis discusses project characteristics and knowledge sources.

5.4 Project characteristics and knowledge sources

As discussed in the last section, the project characteristics impact the pathways of problem solving in the project teams. This inherently stems from the locations of knowledge sources. This actually implies that project characteristics respond to knowledge sources, and conduct the ways of solving problems in the teams.

The knowledge sources which the team can access are determined by the scope of the project team's association with whatever internal teams/divisions, external sectors, or individuals. If a project relies on external sources to solve problems, the team tends to acquire knowledge from external sectors, rather than internal sectors. Conversely, when the project employs in-house fostered technology as a source for solving problems, it would emphasise internal interaction and cross-functional interaction to sustain and acquire knowledge. The leader of Team B said,

> *'...within this organisation, is there any team that needs our knowledge? I have never thought about it. Maybe there is someone who needs our knowledge, I am not sure.....90% of tasks are software programmes within this organisation...customers and hardware suppliers are the very important knowledge sources for us.'*

Moreover, each team has their preferences to access knowledge sources to support their R&D activity according to their project features. The leader of Team A indicated,

> *'The first step is surfing the Internet to seek answers ..., the second step is seeking related technical knowledge sources within the organisation, then going to visit..., before those the steps, we usually ask our customer....'*

The leader of Team B said,

> *'...I paid NT$ 2000 per night to invite the previous engineers to come back to train my junior team members to shoulder their responsibilities and tasks when they worked for this project... customers and hardware suppliers are the very important knowledge sources for us.'*

The senior team member of Team D also indicated the way they access related knowledge,

'...there is one third of information and data which relies on Google to find...open source itself sometimes offers hyperlink to connect to FAQ or discussion boards by which the information and data can be found easier...'

Due to intellectual property laws, new technological knowledge normally has some kind of access barriers which not only relates to new technological explicit knowledge but also to its tacit knowledge components. If the in-house scientist and engineers lack the ability to absorb and manipulate new technological knowledge, they have to closely interact with new knowledge sources to obtain scientist and engineers' experiences and skills (Senker, 1998).

In the incremental, systematic product and privately funded projects, due to the explicit knowledge that has been cultivated by in-house scientist and engineers, the demands of new knowledge should mainly focus on tacit knowledge, rather than explicit knowledge. Most of the explicit knowledge in this kind of project takes the form of documentations. Thus, it can be seen as the specific information, and can also be acquired from the Internet, intranet, internal KM system, internal public server, and documentary files. In other words, in this kind of project, the problems the teams encounter normally tend to be experience or personal skill based problems, rather than scientific or technological based problems. A senior member of Team A said,

'Because junior team members have had much experience or knowing how to do it, so we need to help them.'

Therefore, in-house engineers' and scientists' experiences and skills are very important knowledge sources for solving problems. The leader of Team B indicated,

'...when a problem comes up, the senior team members can normally sort it out by themselves, the junior members often ask for help from senior members...the hardware problems are terminally sorted out by myself. As to software problems, I will tell them the possible sources, suppliers, ...because some problems have happened before, if the problems have never happened, I may not give help, only can give some direction...'

The data of this research shows (56% of interviewees see the Internet as the first access point) the Internet is one of the most important sources for acquiring explicit knowledge and information in the four teams. The Internet is also a first access point for software engineers when they need relevant explicit knowledge and information. This results from a number of specific phenomena in the software development domain. The first phenomenon is software's comparability. In order to ensure the programmes can work in certain environments and operating systems (OS), operation system development companies, tool providers, and programme language providers all tend to provide essential information and solutions for users (software engineers) to access, in order to aid problem solving in their particular areas. An engineer of Team A shows an example,

> *'Microsoft is the best by providing related documentation for solving problems...if you use its tools to develop programmes, you can easily find the solutions from their NSPN....'*

The second phenomenon is that there are many chat boards in the global internet community which provide the space for professional experts and amateurs to discuss or share their individual experiences and related information. This facilitates the engineers to access related information or sources flexibly and efficiently. For example, an engineer of Team A indicates how he acquires related information and knowledge. He said,

> *'In terms of technical knowledge, we skim through chat rooms in the Internet to see if anyone else has encountered the same problems, and they solve the problems...'*

The third phenomenon is that software tends to be highly systematic and logical in structure. This results in a situation that can be easily imitated. Most software programmes are developed based on the same software languages such as high end language Java, and composite language C+, C++. Most functional programmes are coded based on the same languages but with different logic and system structure. Thus, one can learn or reference other programmes through re-engineering and imitating the programmes easily when he or she has the programmes to hand. Due to

the Internet being widely used, the referencing programmes can be found from the Internet. This causes the phenomenon that software engineers highly rely on the Internet as a significant resource to acquire information and knowledge as a member of Team A said,

> *'You can find a similar programme that you want from the Internet. You can revise them or reference them to develop your own program.'*

This also indicates that innovation in the software development domain mostly tend to be idea innovation and skill innovation. Also, this kind of innovation highly relies on the engineers' experiences and individual skills in order to develop an effective and efficient programme to realise an idea.

These phenomena not only influence knowledge acquisition activities in the R&D teams but also influence other knowledge management activities especially at the individual team members' level. A strong influence of the Internet is changing team members' ways of working and acquiring/learning new knowledge in their workplaces. This will be discussed in Chapter 10.

5.5 Summary

Several project characteristics are identified but only three dimensions, funding, type of innovation and products are taken into account for project team's knowledge management activity in this research. This is in line with the organisational context in this research.

Funding is an important feature which defines a project's innovation types and products and influences association with knowledge sources. This impact on a team's R&D and knowledge related activities. Moreover, it also relates to a project's status and priority in obtaining resources and support within the organisation. In this research, Team A and B were associated with privately funded projects and Team C and D engaged in publicly funded projects. This corresponds to the discussion in 2.3.2 that publicly and privately funded projects have different aims which results in different project characteristics.

With regards to the types of innovation, incremental and radical innovations are associated with different knowledge sources and ways of solving problems. Incremental innovation tends to rely on in-house fostering knowledge sources. In contrast, radical innovation is associated with the use of external knowledge sources. This difference in knowledge sources influences knowledge related activities as those activities enable knowledge sources to be connected and applied in the teams. In this research, Team A and B were associated with incremental innovation, and Team C and D were related to radical innovation. This corresponds to Senker (1998) that different types of innovation are associated with different knowledge inputs. In order to obtain essential knowledge sources, R&D teams need to closely interact with knowledge sources to access knowledge.

In the product dimension, key technology R&D and product development projects are respectively associated with different arrangements of expertise composition and face different situations that a team has to deal with. Key technology development projects tend to face complex situations and unpredictable problems over the project period. Therefore, it requires more knowledge inputs. In contrast, product development projects tend to deal with system integration problems which are more complicated and rely on senior or experienced engineers' experiences, skills and tacit knowledge. In this research, Team A and B engaged in product development. Team C engaged in evaluation technology development. Team D is associated with key technology development. This corresponds to Cardinal (2001) that different products are associated with different knowledge inputs and ways of operating the teams.

There are several specific phenomena in knowledge sources, such as virtual community, use of open sources and standard system platform. These are important factors in influencing R&D teams' ways of accessing knowledge sources in the software industry. They are also significant reasons to justify why the Internet is highly relied upon in software development teams. This can be seen as a specific industrial context.

Project characteristics in this research context involves a set of dimensions which outline a project's R&D features and associated knowledge sources based on the data.

Those characteristics influence a project's R&D processes, adopted R&D contexts, team operations and knowledge management activities. In this research, to fill the gap between current capabilities and future capabilities is core to why knowledge related activities are required in R&D activities in which solving encountered problems is an important initiator.

In summary, this theme answers Research Question 1. The above discussion has shown that different types of projects are associated with different types of problems and the use of different knowledge to solve problem. Problem solving within such context is an important initiator to trigger knowledge related interaction and it is also considered an important purpose of undertaking knowledge management related activities within the teams. This also provides the answer for Research Question 3 in which project characteristics are important contextual factor which influences a team's practice of knowledge management through planning R&D processes and arrangement of R&D contexts. The following chapter will discuss these two themes in detail.

Chapter 6 R&D contexts and R&D processes in the innovation teams

6.0 Introduction

This chapter is related to two themes, R&D contexts and processes. In recent research, the perspective on managing R&D has moved from technology-centred to an interaction-focused view (Nobelius, 2004). R&D in the twenty first century not only focuses on the technology itself but also on cross-organisational interaction and intelligent sharing and exchanging. This reflects the importance of R&D as a knowledge-specific and knowledge-intensive activity.

The previous chapter has outlined that project characteristics influence knowledge management practice within the four teams through arrangement of R&D contexts and processes. The interview data shows that the teams' R&D contexts are associated with the decision-making, expertise composition and access to knowledge sources, as will be evidenced below. However, these mechanisms underpin organisational R&D contexts. In some circumstances, they may not sufficiently support a project's needs. Therefore, creating supporting R&D contexts, according to project and the situations is needed for the teams. Moreover, R&D processes define the methods to undertake the work and define the relationships between different works. In different stages, different knowledge inputs are required to support the tasks. For example, if a team adopts the waterfall model as the R&D process, the knowledge management related activities at the beginning may focus on the building of concept and frameworks to shape the overall project. Solving technical problems emerges in the middle when the project is implemented. At the end of a project, the knowledge management related activities are focused on solving system integration problems. However, if a project adopts a different type of R&D process, such as test-driven development (TDD), the required knowledge inputs may be different in each phase. This results in knowledge to be input in different stages in comparison with adopting the water-fall process. The following discussion will show how R&D contexts and processes influence the teams' knowledge management activities taking place and their foci of knowledge related interaction during the different stages.

This chapter aims to show that knowledge management related activities takes place along the time frames of projects in which the projects move forward in a dynamic pattern. Problem solving and knowledge inputs dominate knowledge management related activities within the teams on the way towards finishing projects. This chapter is divided into three sections. The first section demonstrates and discusses R&D contexts and processes of the four teams. The second section compares and discusses

their differences and situations. The final section summarises the influences of R&D contexts and processes on knowledge related activities.

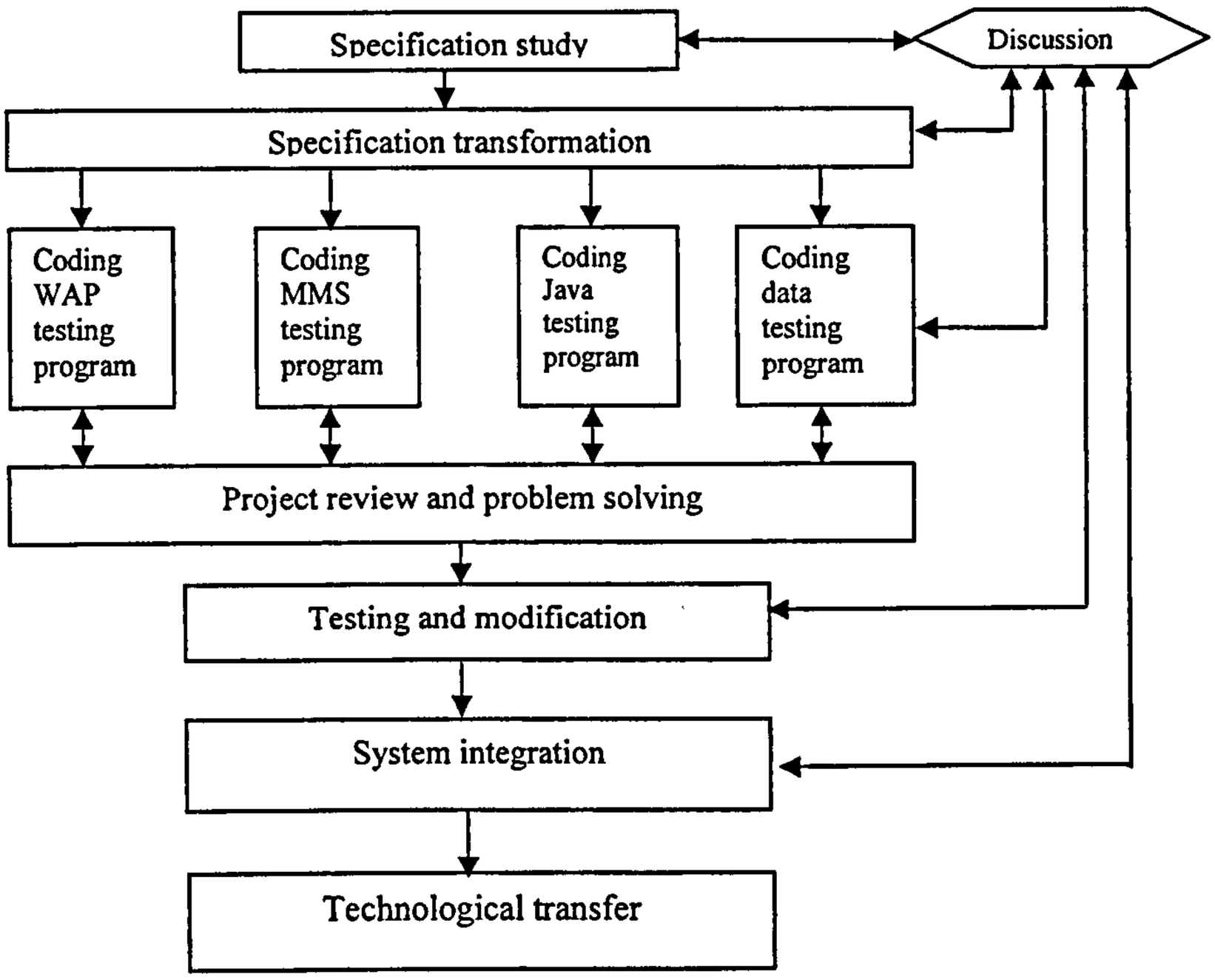
6.1 R&D contexts and processes in four teams

This research investigates four teams (Team A, B, C, and D) in a Taiwanese information technology research institute. Three of the four teams (the exception is Team C which engages in industrial services) engage in R&D projects. Their R&D contexts and processes are demonstrated as follows. The models presented for each team are based on discussions with senior team members, who outlined their perceived R&D processes.

6.1.2 Team A

This team runs a project involving GSM/GPRS mobile phone testing specification formulation and environment development. This project is defined as an incremental innovation project. The purpose of the project is to develop a testing platform for testing the transmission of four different types of signals WAP, MMS, Java, and Data. The project is scheduled to complete in eighteen months. The R&D process was divided into two phases, see Figure 6.1. The first six months focused on studying and transforming system specification of mobile phone into testing cases according to the items that needed to be tested and then developing a testing platform that included all testing items. In this stage, the project is divided into four program coding groups (WAP, MMS, Java, and Data) and one testing operation group. In this phase, four program coding groups work independently and each group is led by one senior engineer. Moreover, this team adopts a modified waterfall model to develop the program. This means development is followed by testing in each progression. This is why there is a group responsible for testing the operation from the beginning. Moreover, a test-driven model is also adopted in this team which is utilized by individual engineers to test their work when they make progress or finish a small module. Once the four programs are finished, the process moves onto system integration and defect correction.

The second phase is system setting up and field testing and then followed by technological transfer and system maintenance. In this stage, the team works with the sponsor's team to make sure the system is completed and also transfers related technology to the team.



Source: data of this research

Figure 6.1 Team A R&D processes

In this process, discussion is an important mechanism for problem solving and sharing knowledge and experiences (4/6 responses from interviews, see Appendix 3, item 1, Team A). It takes place when any team member faces problems. However, this discussion does not require all team members' involvement. It normally takes place in an informal way, may be only the responsible engineer and a senior team member, but it welcomes any team member who is interested to join the discussion. The project review takes place when a piece of the program is completed. The engineer responsible will inspect the program with senior team members and then test the program him/herself. In this process, the problems are normally solved quickly through spontaneous interpersonal discussion (senior engineer and junior engineer) or group discussion. A senior member said,

> '*We are in charge of a junior member's work, our discussion occur any time once he has problem.*'

The R&D contexts in this team include professional technical mechanisms and supporting mechanisms. The professional technical mechanisms include technical

decision, facility investment, expertise composition and knowledge inputs. The supporting mechanisms include knowledge management system, intranet facility and cross-unit communication mechanism. In this case, technical decision and knowledge inputs are made at team level, which includes project scheduling, adopting technology, rearranging expertise, accessing external knowledge sources and spending budgets. Facility investment and team composition are handled by the team and its centre through the coordination between the team leaders and the head of centre as talent transfer within the centre is available, as outlined in chapter 4. The decision of facility investment can be made by team leaders and the head of centre within the budget but it needs to be approved by the chief of the laboratory and the vice president (VP). Recruitment of new members from an external and another internal laboratory needs to be approved by the VP.

In terms of supporting mechanisms, an organisational wide knowledge management system has been built for all members' access. This system provides technological information and project documents including project proposals and results. However, due to the uncomfortable interface design, work load and project characteristic differences, this system is not widely employed among team members. A senior member of Team A said,

> *'We do not like the system that is applied in our organisation. It is not a convenient interface design. It also causes a lot effort to use and update the information, so we don't really use it.'*

Another team member concurred,

> *'We do not have time to write a proper document for that system because a lot work is to do.'*

An alternative system is created instead which is based on an intranet to create public files on the team's server or centre's server for managing project related documents. This system is available for users who are in the same local net. In this case, the server is available to the entire centre.

Moreover, the cross-unit communication mechanism is under organisational formation structure. This means that cross-team communication is done through team leaders and the head of centre will act as a coordinator between teams. Furthermore, cross-centre communication takes place through the head of centres, with the chief of

the lab as coordinator between centres. However, the data shows that the communication between teams or centres does not often take place and it does not usually go through the formal channel. The leader of Team A said,

> *'Each team has its own responsibility and our projects are quite different between teams. So private communication takes place sometimes, but not for business...'*

Person-to-person communication with someone outside the team sometimes takes place in this team and it is normally based on team leader or senior members' social networks within the organisation. This is also implicitly encouraged in the organisation as it appears efficient. However, employment of cross-unit technological knowledge requires payment. For example, any team within the organisation is charged for access to the Market Information Centre's data, as was evident from informal conversations when investigating the background of the institute.

In this team, the centre or organisation can provide limited resources. Therefore, emphasised R&D contexts are associated with autonomy and team learning because it is the only team in the organisation possessing such technical capability and experience. In this situation, decision-making power becomes important because only team leader and senior team members know what they need. Moreover, senior team members are the significant knowledge sources to support the project. Therefore, knowledge sharing between senior and junior team members becomes a crucial activity for the project to sustain knowledge in the team. A junior team member said,

> *'I have technique but I have not had much experience, I need their help to know how to do so and what to do if I want to complete my task.'*

6.1.2 Team B

The technical capacity of this team is focused on developing testing platforms (hardware) and software systems for the automatic testing of electronic equipment. This system can help maintainers to monitor electronic equipment and also rapidly detect broken electronic components. The project is based on the efforts of a government funded project to develop a customised system. Thus, it is defined as a radical innovation project.

The system consists of three technical elements: 1.) the operating platform of the system, 2.) the drivers which conduct electronic apparatuses, 3.) the body of the

system which consists of a number of electronic apparatuses. The first part, the operating platform, is constructed by a series of software programs including user interface, data base, operating procedures and instructions and computing. The second part is the connection between instructions and apparatuses in which the drivers are transformed to electronic circuits to connect the apparatuses. The last part is the body of the system in which the body consists of many different testing apparatuses and performs testing of the electronic boards.

The R&D process, see Figure 6.2, in this team is the hardware and software synchronised development. The task coordination, problem solving, and system integration rely on engineers' person-to-person discussion. There is no formal schedule to review the progress of each task but the project is aimed to be finished within a certain deadline. The team leader said,

> *'They coordinate their work all the time. If any problem comes out, they just go for it immediately.'*

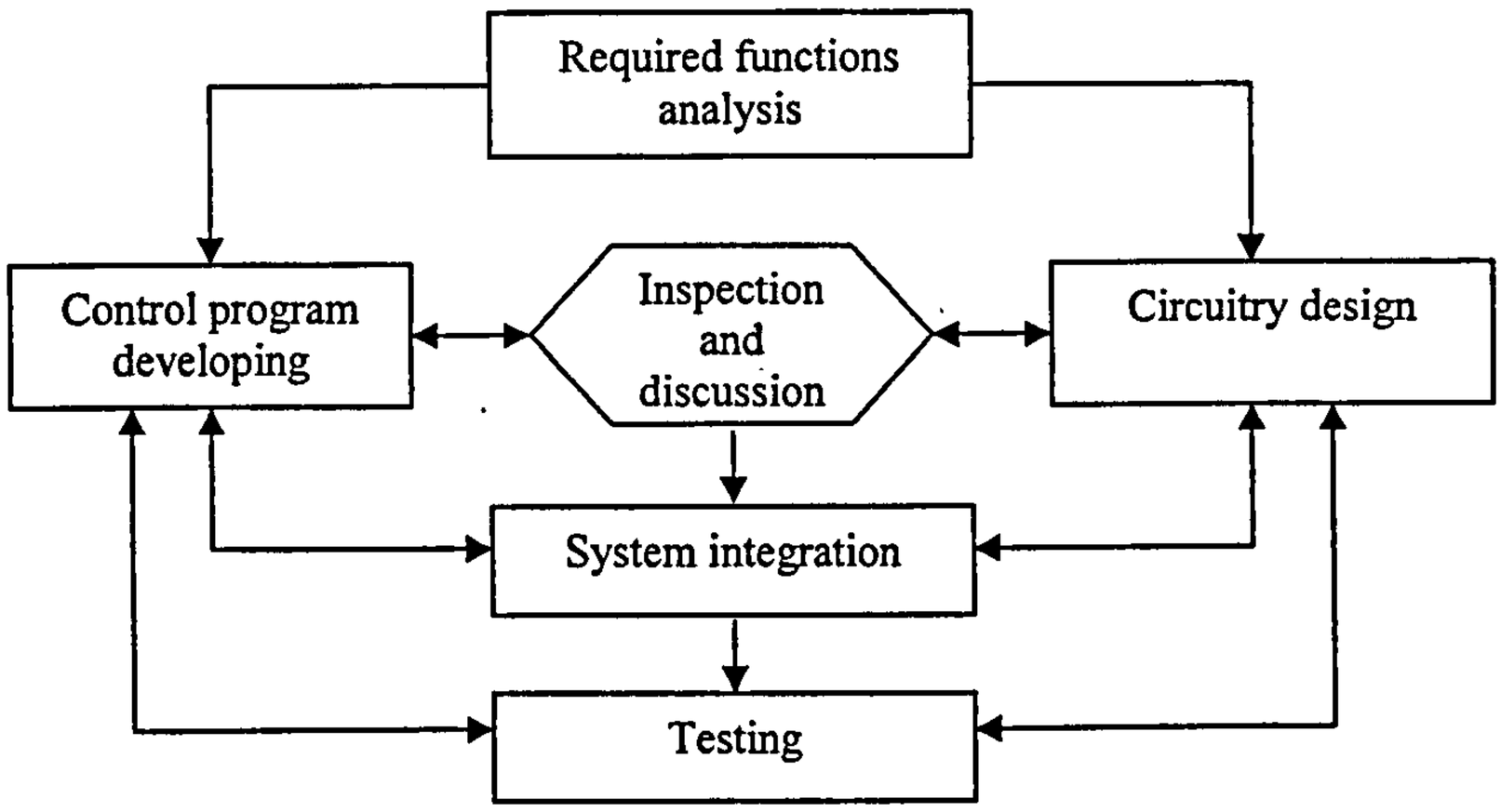
The R&D process in this team is also classified as modified waterfall model. Each task is divided into a number of work packages. Each work package will be tested when it is finished. However, this testing is run by individual engineers. Once any problem comes up engineers will discuss together to solve the problems. This enables different task groups and individuals to know each task's progress and individuals' progress. In this team, discussion is an important mechanism for the team members to share knowledge and experiences and also coordinate tasks and it is also a spontaneous behaviour without any force. A senior member said,

> *'We do not have any team meeting, maybe once a year. Any problem comes out we just talk to each other.'*

Therefore, two task teams can co-operate and share any information with each other.

The R&D contexts in this team also consist of professional technical mechanisms and supporting mechanisms. In the professional technical mechanisms, technical decision and knowledge input are controlled by the team leader. He can decide on the adoption of technology and the expenditure of acquiring knowledge resources. An example of this is where the team leader invites previous team members to come back to the team to train the junior team members. In this case, the team leader made a decision to pay a fee for the team members' training. This presents the autonomy that the team

possesses. However, the decision of facility investment and team composition is constricted by organisational procedures in which those requirements need to be decided by the team leader and the head of centre and has to be approved by the chief of lab and the vice president.



Source: data of this research

Figure 6.2 Team B R&D processes

In terms of supporting mechanisms, the organisational knowledge management system in this team is not usually accessed by the team members because *'we are the only team engaged in hardware and software system development, which is unusual in this organisation,'* a senior team member said. The alternative system is the public files which are built on the server and available to the whole centre. The cross-unit communication mechanism in this team is tied to the team leader. However, it is also conducted by organisational bureaucracy. Cross-unit communication needs to be coordinated by higher management, so it underpins personal social networks within the organisation.

Required R&D mechanisms in this team tend to be associated with external connections because the team has a rather different background and subject area from other teams. The team leader said,

> *'...because there is never only one solution for solving a problem, the information and assistance from customers and hardware suppliers are very important.'*

Therefore, the centre and organisation cannot provide support for this team's R&D. This feature forces the team to have a slightly higher autonomy than others because the centre and organisation cannot give sufficient support as well as make decisions for the team. This may be seen as a disadvantage but the advantage is that it gives the team an opportunity to exercise more freedom than other teams.

6.1.3 Team C

This team is a subproject of the Internet multi-medium development project that is supported by government's funding for 5 years. The purpose of the main project is to promote the development of an Internet multi-medium (the internet content) and the digital medium (such as Internet games and interactive television) industry through providing technological assistance, technology approval, subsidies for research and development (R&D), industrial consultation, and seeking funding (venture capital). The team's objective is to assist technology owners to search for essential funding from banks and venture capital companies.

For this purpose, the team not only provides the services of matching technology teams and investors but also engages in developing an assessment system of intangible digital assets such as internet games and digital contents. This model is developed through cooperating with a consultant company. This project is defined as a radical innovation project. The purpose is to give an estimation of the potential value of the technologies and ideas to the owners of the technologies and potential investors or banks by which the technology owners can obtain adequate funding or investment to achieve commercialisation of the technologies or ideas.

The team possesses a variety of functional expertise including industry research, financing and banking services and intellectual property consultation. The interaction between expertises is not very frequent because each task can be performed independently. A senior member said,

> *'We mostly work on our own and report to our team leader, the coordination of different team members is through our team leader or team meeting.'*

The research in this team is mainly associated with external organisations. The most important mechanisms in this team are the Internet facility and the connection with external experts to collect related information and access to knowledge sources. A team member indicated,

'We need to access to a lot of research reports in terms of financial industry and IT industry. So the Internet is very important to our work.'

The team leader also said,

'Connection with bank and government offices are important to this project; I intend to control this on my own.'

Moreover, empowerment is also important to this team for decision making that allows the project to move forward.

6.1.4 Team D

This is a cross-unit R&D project, and is supported by government technology funding. This project is defined as a radical innovation project. The participants include the organisation, one national University (NU), and two other Universities (U1 and U2). The leading research units are this organisation and the Information Engineering Department at the national University.

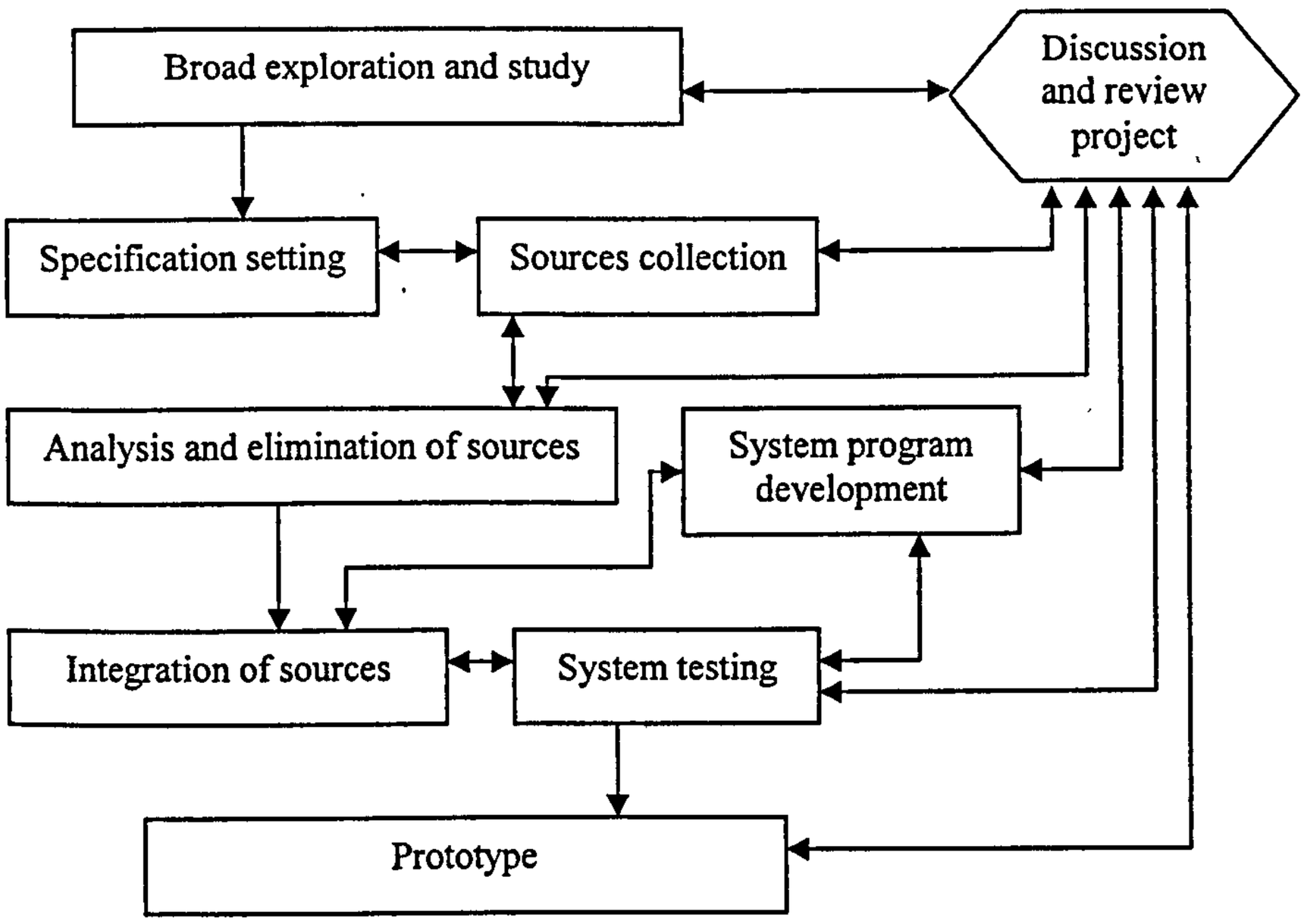
The project is based on the standard of the Common Criteria for Information Technology Security Evaluation (CCITSE) and uses open sources which can be searched from the Internet and numerous related databases to construct an enhanced secure gateway for operating systems. This is an experimental project. The aim of the project is not to develop a commercial product, but its purpose is to test and verify the feasibility of technology through integrating present solutions and tools to create an intelligent gateway security and protection systems.

The R&D processes in this project are divided into five phases, see Figure 6.3. The first phase is a broad study in terms of the subject in which the team members are assigned to explore and study related information and data, and then shape the profile of the secure functions. The second phase is to make specifications for the project and to seek and collect related open sources. The third phase is to analyse the open sources and eliminate useless open sources. The fourth phase is the integration of the open sources and to test the system and solve potential problems. The last phase involves producing a prototype instruction CD for demonstration.

At the beginning, the R&D activities in this team were limited to *'searching open sources, testing and modifying those sources, and making specifications,'* a senior

member said. This is NU team's responsibility at the beginning. Then U1 and U2 teams joined the project in the middle of the project life cycle. They were responsible for the development of the audit programme and intrusion programme. These two tasks are considered to be independent, which is suggested to be the reason that U1 and U2 joined the project late. A senior team member said,

> *'...these two tasks can be performed separately, but we need to finish ours first. So, our team leaders decided that U1 and U2 join this project later.'*



Source: data of this research

Figure 6.3 Team D R&D processes

In this team, team discussion and project review are the most significant activities that bring the three groups together. A senior team member said,

> *'We have team meetings every two weeks. During team meetings, we report the progress and discuss problems that we encountered.'*

The functions of discussion and project review are distinguished as controlling the progress of the project, coordinating teams' tasks, and solving problems. Moreover, the decision-making power in this team is held by the leader of the group which consists of three scholars and a consultant engineer. Due to the project's special, inter-organisational corporation, the supportive R&D mechanisms in this team are not

obvious. This means that the project does not gain much support from the host organisation or the universities involved. A senior team member indicated,

> *'We do not gain support from them (host organisation), but a little support from other teams in our university through my supervisor's connection.'*

Thus, the specific supports are tied to the leader group. The professional technical mechanisms in this team are distinguished as technical decision, facility and knowledge inputs. In this case, these three elements are completely controlled by the leader group without their organisations' involvement. A senior team member said,

> *'They make final decision and we just follow.'*

This means this project team has much more autonomy to conduct the project. However, it also appears that these three groups' organisations and the host organisation are unable to gain sufficient support. For example, these three groups are not permitted to access the host organisation's sources relating to the project. Meanwhile, they do not open their own project related sources to each other. This may have resulted from security concerns. A senior member indicated,

> *'We are not allowed to access their knowledge management system, but we also do not talk much about our ideas in team meetings because my supervisor has security considerations.'*

This also shows that in an inter-organisational project; the different project teams' support function is isolated from their mother organisations; therefore, the required R&D mechanisms need to be independently created according to the project needs.

6.2 A comparison between four teams' R&D contexts and processes

The four teams' R&D contexts and processes have been detailed in the above section. This section will further discuss their similarity, differences, and influence on knowledge exchange activity. The R&D contexts within a team, in fact, are restricted by organisational R&D contexts and procedures. Therefore, it is partially based on organisational R&D contexts and a team's permitted autonomy which can be complementary of organisational R&D contexts and allow a team to develop its specific R&D mechanisms according to project needs. The R&D processes are

affected by a team's experiences, customs, and project needs. A senior member of Team D indicated,

> *'...from the last a few projects, I recognised that a team's experiences and customs influenced how it manages and processes the projects...there is a inertia which directs R&D processes...if there is any change, it must suffer some pressure or environmental change...'*

This statement seems to highlight that a R&D team usually has its way to process the project, which is stable and followed by the team members. In the situation when newcomers appear in the team, this informal regulation will be transmitted by the senior members as they hold and follow this regulation within the team. This can be seen as a core process (Eppler and Sukowski, 2000) of the team, which relates to a team's knowledge which accumulated over time.

In these four teams, the data shows that each team has its own core processes and features to operate the team and projects, as was highlighted in their individual models. These core processes and features may be the significant factors that distinguish their success from each other. For example, spontaneous discussion and coordination of tasks are important factors in Team A and Team B (4/6 (Team A) and 3/4 (Team B) from interviews, Appendix 3, item 18, see also section 7.2.6), which facilitates knowledge sharing and problem solving. In those two teams, spontaneous actions between senior and junior team member is a core process. In contrast, in Team C, frequent interaction with external experts and the team leader's involvement are the core processes that facilitate the project (2/5 (Team C) from interviews, Appendix 3, item 18, see also section 7.2.6). In Team D, the leader group and frequent interactions within each task group are the core processes that achieve the team project (3/3 (Team D) from interviews, Appendix 3, item 18, see also section 7.2.6). This represents that each team has its core processes which are valuable and can be turned into team routines. This supports Tidd et al. (2001) suggestion that managing innovation is about seeking effective routines and turning it into team procedures.

However, these four teams respectively possess projects with different characteristics and rely on different knowledge sources as outlined in section 5.3; this causes a situation in which Team A and B emphasise more internal interactions than Team C and Team D. This implies that firstly, knowledge sources determine whether a team's interaction is to be of an internal or external orientation. Secondly, how long a team's members have been working together influence the team's routines and internal

interaction. In this case study, Team A and B mostly rely on internal knowledge sources (senior team members' technological knowledge and experiences), and their team members have been working together for a long period of time. In contrast, Team C and Team D rely on external knowledge sources and they have only been working together for a short period of time. This makes the differences in what knowledge the teams possess, how the teams manage and process their project, and how their core processes are formed. This seems to correspond to Senker (1998) and Cardinal (2001) that different types of R&D are associated with different knowledge inputs in which the teams need to build close relationship with knowledge sources. Also, effective R&D processes and contexts' design is situational according to the circumstances that teams face and a project needs.

In order to highlight and summarise these four teams' similarity and difference, this research compares their R&D contexts and processes in Table 6.1.

Table 6.1 Comparison between R&D context and processes of four teams

	Team A	Team B	Team C	Team D
R&D contexts:				
■ Professional Technical mechanism				
1. Technical decision	Team leader	Team leader	Team	Leader group
2. Facility investment	Team/centre leader	Team/centre leader	Team/division leader	Leader group
3. Team composition	Team/centre leader	Team/centre leader	Team/division leader	Leaders group
4. Knowledge inputs	Team leader and senior team members	Team leader and team members	Team leader and external experts	Leaders and external experts
■ Support function				
1. Knowledge management system	KM system	KM system	KM system	FTP Website
2. Intranet facility	Public files (centre wide)	Public files (centre wide)	Public files (division wide)	None
3. Cross-unit	Team leader	Team leader	Team leader	Team leaders

communication mechanism	and official path (centre and lab)	and official path (centre and lab)	and official path (division)	
R&D process:				
1. Model	Improved Waterfall	Improved Waterfall	Partial outsourcing	Improved Waterfall
2. Project initiator	Team leader or senior members	Team leader	Head of division	Team leader group
3. Progress check	Team meeting, a month	Non, report to team leader at anytime	Task group meeting, season	Team meeting, two weeks
4. Quality control	Task review (senior engineer to junior engineers)	Engineers inter-review	Report and discussion	Project review
5. Task coordination	Team leader and senior team members	Engineers themselves	Team leader	Team leader group
6. Problem solving	Task group's discussion	Team discussion	Task group's discussion	Task group's discussion and team leaders' supervision

Source: interviews and team observations

This table is base don the collation of material from the interviews and observations and it shows that the R&D contexts in Team A, B and C have similar R&D contexts. The R&D mechanisms that the teams can completely control are only technical decision and knowledge inputs. The rest of the mechanisms are within higher managers' authority and part of organisational procedures. However, the data also shows that technical decision and knowledge inputs are the most important mechanisms at the team level (Table 6, R&D contexts, professional technical mechanism, item 1 and 4), because the teams have to make decisions regarding the adoption of new technology and management of knowledge sources. The leader of Team A indicated, for these four teams, due to their projects' speciality, organisational R&D mechanisms do not provide sufficient support. Therefore,

empowerment is very important to allow them to obtain what they need. For example, Team B relies on interaction with suppliers to solve hardware system's problems and Team C and Team D rely on external knowledge sources. This implies that it is difficult for organisational R&D mechanisms to cover all the needs. Therefore, organisational empowerment and team autonomy are required to enable R&D teams to deal with their specific situations. This drives the teams to develop their own knowledge management practice to cope with the gap between project needs and what they can obtain from the organisation. This refers to Cardinal (2001) that a team's R&D context is associated with the situation and project needs by which team autonomy enables the teams to react to situations and satisfy project needs. In these teams, access to external knowledge sources relies heavily on the team leaders. Here team leaders play a significant role with associated external sources by using their personal social networks. In Team C and Team D, the leaders' social networks are an important asset to the team to connect with external agencies. A further discussion of the role of team leaders will be presented in chapter 7, 7.1.

Moreover, Team A is the only team within the organisation that possesses the mobile testing technology. This makes the team to rely on some senior team members who have engaged the similar projects in an international cooperation project. This causes a situation in which senior team members' supervision for the junior team members becomes important because it is a way to transfer and sustain technological knowledge within the team. Furthermore, this emphasis of internal interaction for sustaining knowledge also happens in Team B. The difference between these two teams is that Team B's members have been working together for more than four years. In contrast, Team A's members contain newcomers, junior members and senior members. Thus, team members of Team B have already formed a close working relationship. This facilitates them to coordinate tasks and solve problems, as well as sustain technological knowledge. Tuckman's (1965) model of team working would support this observation in that the team has already arrived at the performing stage of its development cycle.

In terms of R&D process, Table 6.1 shows, even though Team A, B, and D adopt the same R&D process model, they apply the model in different ways which are based on team situations and project needs. For example, in Team A, senior team members review junior members' work in each stage when one task is completed. Therefore, many reviews take place during the development stage. In this team, R&D processes provide junior engineers with a chance to learn and practise new knowledge along the project time. In this process, senior engineers and junior engineers interact as master

and apprentice but this relationship is informal and flexible. This enables junior engineers to learn experiences from senior engineers (a discussion that will be presented in more detail in section 8.3) and also integrate into the team. This strengthens a senior engineer's role within the team in terms of handling the project, solving problems and transferring knowledge.

In Team B, the team members' self-management and coordination are emphasised. R&D processes in this team are based on team members' experiences of how tasks should be carried out most effectively. Therefore, there is a clear task distribution. However, how work is carried out is dependent upon individual team members' knowledge and experiences, as well as interpersonal coordination. Therefore, as evidence above, there are no team meetings held by the team leaders to control the progress. The coordination within this team is supposed to be a spontaneous behaviour. This influences problem solving and knowledge management related activities in the team as it is dependent upon the situations and needs. If there is no situation coming up, individual engineers will continuously carry on their tasks and the progress is transmitted through their daily interactions without specific formation. This automatic process or team routine is based on two factors: a leader (further discussed in 7.1) and team cohesiveness (further discussed in 7.2.1). In this team, team cohesiveness is highly emphasised by the team leader. Therefore, the team members can automatically coordinate with each other and help each other. However, a small sized team may be an advantage to enable the team leader to adopt flexible ways in which to manage the team (7.2.3). This refers back to the discussion in team cohesiveness (2.4.3) that in high team cohesiveness groups, the members communicate more frequently for a longer period and display more openness to each other, which facilitates coordination (Holtz, 2004; Kirmeyer and Lin, 1987).

It was shown for Team C that some tasks are outsourced because the team and organisation are not able to support the required knowledge inputs. Therefore, the team members have a closer relationship with an outsourced firm (consultancy). In this team, the team leader and a few senior team members are the core members who conduct the external knowledge resources and social networks. Therefore, the working process is centred on the team leader in which individual team members work independently and report to the team leader. This causes formalised team interaction and coordination, as well as knowledge related activities namely through team meetings. This refers back to Damanpour (1991) that incremental innovation requires lower involvement of top management and radical innovation requires higher

involvement of top management. In Team C's case, team leader's social connection is an important input to the project.

In Team D, the leader group reviews the project every two weeks during the team meeting. It was evidenced above that team meetings are also a significant occasion to solve problems. In this team, independent task design leads each group to work separately until the phase of system integration comes up. Then three groups start to have closer interaction outside the meetings. In this team, the leader group has the power to decide on research direction and make decisions. In the team meetings, each group presents their progress and points out the problems that need to be solved. Once the leader group makes decision, each group will follow the decision. Therefore, R&D processes in this team are highly constructed and centred on the leader group. This reminds again of Damanpour (1991) that radical innovation requires higher involvement of top management because this type of innovation requires more support. In Team D's case, the leader group's support is important to project implementation.

6.3 Summary

A team's R&D contexts are associated with an organisation's R&D contexts which can be a supporting factor and also a restricting factor. In terms of support, the organisational R&D contexts may provide useful mechanisms for access to internal and external knowledge sources and cross-function or cross-team communication. This facilitates the R&D teams to obtain essential knowledge support. In terms of restriction, centralised and decentralised R&D structures influence R&D teams to initiate projects, arrange resources and make professional decisions. The data of this research shows that the R&D teams in this organisation are empowered to initiate projects and make professional decisions but have limited power to arrange resources in terms of expertise and investment. This may be restricted by considerations of cost and organisational resources arrangement at top management.

A team's R&D contexts and processes are determined by the team leaders and some senior team members according to their experiences. Moreover, they are also the significant knowledge sources and nodes of social connection. This facilitates a team to connect to specific knowledge sources when the organisational R&D contexts cannot support the team's R&D activity.

A team's R&D processes are considered highly associated with its team members' experiences and team routines which show the ways the team handle the projects.

However, the data shows that there are no fixed R&D processes practiced by a team year by year, or project by project. A team will develop and modify the processes according to its project needs and past experiences. This leads teams to practise knowledge management activities in different ways based on the teams' actual situations and project features. Based on the above discussion, it is suggested that in an incremental type of innovation (Team A and Team B), spontaneous interaction and the manner to facilitate problem solving and task coordination are important. This originates from internal knowledge source oriented circumstances and flexible management. Within this interaction, the senior team members' experiences and knowledge can be exchanged and shared with junior team members. Also, this kind of interaction takes place over the project period. In contrast, in radical type of innovation (Team C and D), formalised interaction is associated with problem solving and task coordination. This stems from external knowledge source dependent circumstances in which the team leader controls the connections with knowledge sources and decision-making power.

These two themes illustrate how knowledge management related activities take place alongside innovation activities. R&D processes are associated with when and what knowledge management related activities are required. R&D contexts relate to the input of knowledge. This influences the scope of interaction with internal and external agencies. These findings are able to answer research question 2: 'how are knowledge management activities integrated with innovation processes?' by showing this relationship between knowledge related activities and R&D process and context. Furthermore, these two themes (R&D processes and R&D contexts) are also considered the contextual factors which influence knowledge management related activities in this specific innovation context. This provides the insights for answering Research Question 3. The above discussion also shows that knowledge management related activities within the teams centres on knowledge acquisition and knowledge sharing. The requirements for these activities are associated with whether or not their R&D contexts can cover their needs for performing the project and their experience of how the project can be effectively performed. In this thesis, this means that both R&D contexts and R&D processes are important factors to influence a team's knowledge management practice and to enable knowledge management to be integrated with innovation activities. However, the above discussion also shows that this integration process involves effective team operation to manage knowledge inputs and solve problems to move the projects forwards. Therefore, the next chapter will discuss team operation in detail to show how the teams operate to obtain and share knowledge to carry out the projects.

Chapter 7 Team operation

7.0 Introduction

The previous two chapters have outlined the influence of the R&D processes and R&D contexts on team knowledge management. This chapter will discuss further how the teams operate in order to carry out knowledge management and innovation. This chapter relates to the theme 'team operation', which comprises team experiences and team interaction. Team experiences are a team's routines which entail team knowledge base and the ways of handling projects. Team interaction in this model underpins three elements: the role of team leader, team cohesiveness and team members' attitude. These factors further lead to team interaction and a supportive team atmosphere. However, this supportive team atmosphere is also influenced by team structure and team size.

The research finding suggests that a team leader has a significant influence on the other factors. A team leader is not only an R&D leader who is responsible for achieving projects but also responsible for creating a supportive atmosphere to enable team interaction and knowledge management related activities to take place. The team leader influences the team through adopting different roles.

Furthermore, the relationship between team interaction and team atmosphere is likely to be circular as frequent interaction enables a supportive team atmosphere to be fostered. Appropriate team atmosphere further improves the quality of team interaction. Thus, this research assumes that a better quality of interaction among team members facilitates knowledge-related activities to take place within a team. Also, better quality of interaction among team members is derived from a specific team atmosphere which is associated with the team leader, team cohesiveness, and team members' attitude are mediated by team structure and team size.

This chapter is divided into three parts. The first part discusses the role of team leaders in team knowledge management, which influences forming a supportive team atmosphere to facilitate knowledge management related activities to take place. The second part addresses how team atmosphere is developed through forming team cohesiveness and changing personal attitude. In order to illustrate these four teams' interaction, the latter section shows four team's interaction paradigms based on

interview and team observation results. The final section summarises the above discussion.

7.1 The role of leaders in knowledge-related and innovation activities

The role of a leader has been proven to have strong influences on projects and a team's work (Cleland, 1995; Kangis and Liz, 2000). How a leader influences the effectiveness of innovation and knowledge management is of interest, but little research is evident. Some empirical investigations (Cleland, 1995; Eppler and Sukowski, 2000; Kodama, 2004; Krause, 2004; Kangis and Liz, 2000; Politis, 2001) show that leaders play various roles in knowledge management activities as well as in team innovation. However, what role a leader plays in this particular context remains unclear. This thesis' research identifies some of the roles leaders may hold within teams, such as connector, distributor, coordinator, decision maker, supervisor, a friend and old brother (summarised in Appendix 3, item 14). However, as will be shown, in different teams, team members and team leaders have different recognition of the leaders' roles. Moreover, the leaders' roles are not only associated with leading work but also associated with the leaders' roles within the social contexts (such as a friend or old brother). This social position influences forming team cohesiveness and supportive team atmosphere. This research suggests that this supportive atmosphere facilitates teamwork and knowledge management related activities. The team leaders' social position and its influence in this research context respond to Ahmed et al. (2002), who suggested that leadership's role in knowledge management is to install a culture and climate for undertaking knowledge management. Therefore, the following sections will start with this point and then discuss a leader's social position which is associated with forming team culture. Hence, the following sections discuss the other roles supervisor, connector, distributor and coordinator. Decision maker in this case study is related to the above roles when a leader has to make decision; therefore, this role is not discussed separately.

7.1.1 Forming a culture – initiator

In the researched teams, knowledge sharing activities are triggered by the needs for solving problems as discussed previously. When the organisation lacks a clear policy to guide and support knowledge management activities, the data of this research

shows that the climate for sharing knowledge is a prerequisite for successful knowledge sharing in the teams. With this, a team leader plays a crucial role to establish a supportive team environment and initiate knowledge sharing activities within the team.

To highlight the significance of the findings presented below, this thesis adopts the following definition of organisational culture: '*the interdependent set of values and ways of behaving that are common to the organisation and that tend to perpetuate themselves, sometimes over long period of time*' (Dessler, 1995, pp. 364). Culture forming is a long term effort for any organisation or group. It requires a concrete vision, a procedure and frequent interaction and communication within a team/organisation. Culture also relates to the cohesion of a group; their behaviour in specific events and the sharing of values. Organisational culture and shared values are highly influenced by the founders (Schein, 1992). However, at team or division level, the team leaders replace the status of founders to influence the formation of the culture. In this particular organisation, a team is a basic unit which can initially be created for specific projects and sustained as a permanent team afterward. Therefore, in some of the teams, team culture can be formed and sustained by the team leaders and senior team members. Team B is an example of this. The leader of Team B indicated,

> *'There are some traditions in this team that are inherited from the past. For example, we had quite close working relationships between team members during developing ATE technology (before current project). So, I learned and recognised from that period of time that team cohesiveness is important to the team. Therefore, when I took over this team, I have been trying to keep this. That is why I emphasises that (team cohesiveness) on late coming team members...'*

In this case study, knowledge management activities are in their infancy. There is not a strong organisational culture to support such activities. However, the cases show that most of the team leaders have recognised the importance of knowledge management. With this recognition, they have gradually made efforts promoting the sharing of knowledge. However, initiation of knowledge sharing is difficult and also

needs some catalyst and incentive to evoke team members' attention and gain support. As the leader of Team A said,

> *'I think it is a mutual recognition, if someone obtains knowledge from the team, he or she would like to offer his or her (knowledge). So, it is mutual and interactive. To begin with, the team requires an atmosphere which is sharing knowledge. Once, the atmosphere is formed, everybody would like to put something on (the folder)...I think the atmosphere and habit should be fostered...We start to do this is because I learned it from Germany...'*

In this team, some of the team members' experiences from a previous collaboration project are a catalyst triggering knowledge related activities in the current team. For this reason, the team leader starts with creating a public folder in the server and putting all project related documents and information in this folder that is open to all team members and the whole laboratory. The leader said,

> *'...the whole process of developing the project, now, has been recorded and opened through the public server during the project time. Individual engineers did not keep any documents and records. If any of them needs data and information, they can find out from the server. This makes a difference from before. We used to produce final results and deliver results without making efforts to put related data and documents in order in the project time.'*

Central filing is also applied in the other teams. However, some of the team leaders further consider that educating (i.e. Team B) and communicating with (i.e. Team C) team members are more important when a team wants to form a sharing culture. The leader of Team B said,

> *'It takes time. You need to educate them and make them understand that it benefits all of us and the team...'*

The leader of Team C concurred,

'They would not take it serious if you try to lecture them. I think communication is more important in my team.'

The data shows that in practical situations, the sharing of knowledge between team members would not take place spontaneously; '*someone needs to ask*', a member of Team B put it. Thus, to form such a team culture the leaders have to address some potential inhibitors, such as '*individual performance differences*' and '*rewards*', the leader of Team B said. Also, team cohesiveness and harmony are considered factors which influence knowledge sharing within a team, which are discussed below. One may agree that knowledge-related activities are underpinned by a supportive environment with regards to team culture, team cohesiveness, and harmonious atmosphere, but in order to develop such an environment, team leaders have to influence and guide team members through the use of informal power. As a junior member of Team A said,

'...he (the team leader) acts like friend, so I do not feel pressure working or talking to him, or ask for help.'

A member of Team B confirmed,

'...he (the team leader) is like our old brother, help us a lot...'

This was emerged in the context of forming team cohesiveness and a supportive atmosphere. This will be further discussed in detail in 7.2.1. Based on the above discussion, this thesis suggests that one role of leaders is as an initiator in teams.

7.1.2 Supervisor – Consultant, master, and tutor

Knowledge related activities are often associated with problem solving in which a team leader usually plays a consultant to give ideas or provide possible solutions based on his or her experiences and knowledge. A leader plays a significant role in guiding the team members to access certain sources to solve specific problems. For example, the leader of Team B indicated,

'...any hardware problem which they cannot solve, they will pass to me or another very senior engineer...I have been involved with this system for a very long time, I can handle most situations...I can give some advice...'

Moreover, the leader of Team B said,

'...I may not be able to tell you what exactly you should do, but I can give you some advice...'

A senior member of Team D revealed,

'...they (leader group) will give advices but we also give our opinions on what we have found...'

This suggests that a team leader plays a significant role as a consultant to the team members to guide their work and help them solve problems. In addition to a consultant role, Team D appears to be special. This team is composed of postgraduate students and scholars of the university. The postgraduate students are supervised by two scholars. Thus, the relationship between them is different from other R&D teams. The team leaders have much more power to influence their students. Thus, they normally play a supervisory role as well as a consultant role. In this team, the leaders generally provide ideas, direction, and make decisions for the team members. Team members mostly accept the suggestions without question. In this case, the difference in status between the team leader and the team members causes the team leaders to possess more authority. This situation reflects an existing phenomenon which is traditionally seen as a master-student relationship in Chinese society. In this society, masters have a higher status which enables them to conduct students when they work together. Moreover, in this case, the role of the masters is not only influenced by the masters' recognition of the role, but it is also reflected in the followers' expectation that they wish to gain help from the masters, especially when followers perceive a big knowledge gap between them and the master. Masters own a dominating power to influence followers. In this case, a team member said,

'...supervisors own the power to decide whether you are qualified or not to own the degree. Therefore, it somehow affects us as the students but it is a personal perception. It is actually not a serious problem nowadays, especially with my supervisor...'

In addition, a team leader has a responsibility to know individual team members' needs and facilitate work by providing an appropriate environment. In this scenario, a team leader may play a tutor role in which he/she has to look after team members, and be concerned with their career planning and organisational vision and also align them with the team's mission. The leader of Team B indicated,

'... my team, so far, is in a good situation because my team members are satisfied with what they are doing and this facilitates their future career development...for example, our most senior engineer he enjoys playing with technology, this team can provide such an environment to let him try...'

This role has also been recognised by other team leaders. For example, the leader of Team A encourages team members to join inter-organisational projects to learn new things from different organisations. He said,

'We (centre) have many projects cooperate with Sony Ericsson and other companies. I always encourage them to take these chances. They can learn something from them...'

In Team C, the leader spends time with individual team members to discuss their individual works:

'I prefer to talk to individuals, on one hand, I would like to know their progress. On the other hand, I like to know if they have any problem.'

In Team D, team leaders are also the supervisors of the team members. '*He takes time to talk to us one to one every two weeks,*' a senior member of Team D said.

7.1.3 Connector

A significant role of the leader which emerged in the case studies is team leaders as connectors. This stems from team leaders having more work experience and, at times, having worked for the organisation for a longer time. Therefore, they know the organisation and expertise within the organisation. However, when a team leader is new to the organisation, this advantage may not benefit his/her team, but the experiences in the specific area of expertise may make him or her available to connect to external organisations and experts. This means that the team leader's social network and professional network is a significant asset in the shape of a connector. For example, a senior member of Team B said,

> *'Our leader, Mr. X, has worked in this institute for a long time. He has general ideas about each lab and its significant project and technology domain. So, when we encounter the problems and need other labs' help, our leader can provide useful information where we can probably obtain the sources.'*

This quotation shows that the team leader is an important person to connect with internal teams as the leader has worked for the organisation for a long time. However, a team leader's role is not only internal but also to extend reach externally. A member of Team B said,

> *'...last time I encountered a problem which resulted from an IC chip. Because we do not know this IC chip's feature very well, so the problem cannot be solved. I told our team leader this situation. He had no idea either. So he took me to see his friend who is a sales manager of the IC agent who sells this IC chip. From that meeting, I obtained a lot of information and data about this IC chip. Therefore, the problem was solved quickly.'*

In some teams, this is expected because the team leaders have extensive experience in a specific technological area. For example, a senior member of Team A indicated,

> *'...because our boss has been here for very long, he knows a lot of people and what they are doing.'*

This enables them to build social connections within particular areas no matter whether they are internal or external.

A particular reason that this role is emphasised in Team C is that the team leader has an equal amount of working years with his team members. Also, the team incorporates diversity, having members with varying backgrounds. The team leader in Team C recognised that he did not have much more knowledge and experience than his team members. Thus, he considers his influence stemmed from the sources he had access to. He said,

> *'...because I am slightly young to be a team leader, I need some achievements to convince my team members. Of course, I think I have some special experiences which I am proud of, such as the relationship with official sections, and also I know the industry environment quite well, which my team members have a lack of...my connections facilitate them to handle difficult situations when they service customers.'*

In this team, the role of the team leader is defined as a connector by himself. Achievements and self-confidence are becoming the strong traits of the team leader. These traits reflect a phenomenon where the leader is highly involved in the problem solving and intends to show his external connections. Moreover, in order to sustain this advantage, the team leader engages in nearly every aspect of the project. The leader of Team C said,

> *'I intend to attend my team members' meetings with external agencies or have words with external agencies before or after their meetings. So, external agencies would know that I am in charge.'*

The reason he is involved to such an extent is that team members flow in and out randomly. Therefore, he needs to control the progress of each case. However, as he said, these external connections depend on him and he would not like to see those connections being exploited for other irrelevant affairs. This implies that mutual trust within a team is an important issue because it does not only impact on how those connections are used, but also how those resources are deployed efficiently.

Moreover, team leaders may not be the only individuals to hold resources. Senior team members may have similar resources which have been accumulated over time.

Cross et al. (2001) investigate the knowledge flow in social networks. They suggest that the position and information held by particular personnel are not necessarily equal. Even more, the division leader may be a person who holds the least information within a division. This argument seems to go against the common image that a team leader would be the person who holds the most information within a team and this research seems to confirm that other team members, besides the team leader, can hold such information. This leads to the belief that a *node person* is a valuable asset of an organisation who should be located in the right position. However, the right person is not necessarily located in the right position in the organisations. The reason for this is affected by many factors such as political issues, personality and so on. No doubt it provides an issue of how to arrange a 'node person' to contribute to the team if they are not in a position of hierarchical authority. The data of this research shows that the interaction between a team leader and a node person is an important issue. The team leader of Team A said,

> *'...sometimes the talented person cannot be put in the right position...so, the talented person would leave...a good interaction (with the team leader), they would contribute to the team. Conversely, a bad interaction, they will seek other opportunities from external organisations.'*

In this team, talented people are given great autonomy to handle their tasks or their own small project. They are assigned specific tasks to help other team members as a supervisor or consultant.

A team leader's connector role is mostly associated with his/her personal social networks and relationships. In order to access knowledge or information, a team leader needs to negotiate with other teams to develop co-operative relationships for exchanging knowledge or information.

However, any cross-divisional or inter-organisational communication is underpinned by top/senior management's commitment and support. Without that support, cross-divisional knowledge exchange is difficult. Consistent support from top/senior

management, middle management, and project/team are also very important. The leader of Team A said,

> *'...cross-divisional interaction needs senior management's support to create a mechanism, otherwise, at the end even we both agree, it still needs to go through the organisational hierarchy to complete the procedures. For example, cross-team engineer exchange involves complicated procedures. It also needs to be approved by divisional manager, VP...'*

The leader of Team C said,

> *'...my boss (head of centre) lest me to organise all external connections, actually, they put me in this position because I can handle it...'*

This reveals that organisational structure and procedures are the factors that block cross-divisional communication and knowledge exchange.

7.1.4 A distributor

Davenport and Prusak (1998) indicate that knowledge management activities are about transmitting knowledge to people in which a team leader acts as a distributor of the information and knowledge.

Information overload has been a problem for many people in the workplace. Thus, selecting information or pointing out knowledge sources can be a matter in which a team leader can make a contribution to the team through distributing essential information or knowledge sources to his or her team members. In a large group, research shows that there are some people who are partly or fully responsible for information and knowledge collection and distribution; the position of a librarian, editor, or reporter (Davenport and Prusak, 1998). However, in small groups, there is probably no one team member who can take this job. Also, experience may be a problem in which not all team members are qualified to distinguish useful information from a complex and fully tumultuous environment. In this circumstance, the team leader can play the role of librarian, editor and reporter to select and distribute essential information and knowledge. The data of this research shows that some of the team leaders are willing to adopt this role. The leader of Team B said,

'...all documents including e-mail and Q&A which are produced in the life cycle of the project, I used to collect and manage them. So, when colleagues need these sources, they usually come to ask...here I am like a librarian...'

Moreover, the role of a reporter within the team is also taken by the leader of Team C. He said,

'...some articles propose great perspectives, for example, there is an article just published on the Business Weekly, it said if you want to obtain resources, you firstly have to manage your boss...something like this, I would like to forward it to my team members...'

In these two teams, the team leaders play different roles respectively. However, it indicates that the role a leader plays in the knowledge selection is influenced by a leader's subjective perception about the work environment and the individual aspect of working knowledge. The leader of Team C indicates,

'...working skills are easier to obtain by training or practising but individual's attitude of the work is difficult to change by training. So, I try to communicate and influence their attitude through delivering some useful articles...'

This recognition is reflected in the leader's attention and selection of the information and knowledge by which he wants to influence his team members. In Team B, the team leader recognises team member fluctuation can cause knowledge to disappear. He is struggling to collect technical documents as completely as possible. Thus, the role he plays is a librarian, as outlined above. In Team A, the team leader does not act as a distributor. The role of distributor is shared by senior team members based on their expertise as the leader of Team A said,

'I let senior engineers take responsibility of organising and performing their tasks, they all have experience.'

In Team D, three senior team members share this role. One of them said,

'...if we found useful sources, we pass them to other team members. We are kind of in charge of performing the project, especially one of the most senior fellows.'

7.1.5 Coordinator and mediator

In order to integrate people, a team leader can be coordinator or mediator to sustain team members' interaction and communication. An effective integration is based on a certain direction (Grant, 1996b) which integrates team members' thinking and action to move in the same direction. In project based teams, the members could change frequently. This evokes difficulty in making a vision or long term goal for a team. Thus, the team leader must be able to create a clear goal and make individual tasks clear to align team members' thinking and action toward the same direction during a project. This makes the coordinator role very important for a team leader.

The integration of people can be supported by organisational procedures and informal activities to enhance understanding and communication. The data of this research shows that informal activities have a great influence on knowledge sharing as it is based on spontaneous behaviours. Conversely, formal activities and occasions are considered an unfavourable factor to knowledge related activities as it may cause pressure to participate. A senior member of Team C indicated,

'...you do not say the details in formal meetings or other occasions because firstly it takes time and secondly you want to protect some sources.'

Moreover, the data also shows that task distribution, understanding between team members, and team leaders' coordination ability are considered significant factors in knowledge related activities. For example, a senior member of Team C indicated,

'...a team leader's attitude, if he/she likes to keep harmony, many creative sparks may be disappearing, if argument is welcome, it probably brings the team a great idea afterwards. However, he must have an ability to control either situation...'

If a team leader encourages different perspectives and also knows how to define and solve the argument, appropriate controversies facilitate the team to integrate differences and enhance innovation. However, if a team leader is concerned with team harmony, he or she may try to minimize argument or adopt an inactive attitude towards conflict. This may reduce creative ideas to be generated and lose the chance to integrate different opinions. Therefore, a leaders' attitude towards conflict and the way he or she addresses conflict is a crucial factor to the integration of knowledge and innovation in teamwork. This refers back to Damanpour (1996) that managerial attitude towards change influence a project team's engagement in radical innovation. However, in this case study, there is no further evidence to justify how the team leaders deal with conflict under an emphasis of team harmony and how they keep their team's creativity.

Moreover, the data of this research shows that a team leader's coordinator role in solving controversies is also affected by team members' participation and a team leader's personality. If the team members have higher participation, the team leader's involvement facilitates conflict to be solved by the members themselves through constant discussion and communication. The leader's coordinator and mediator positions are strengthened. Conversely, when the team members' participation declines, conflict relies on the team leader's involvement to make decisions. In this situation, the team leader's coordinator role is weakened. In terms of a team leader's personality, some leaders like to be involved in every detail. This style tends to lead to solutions whatever the conflict is, such as the leader of Team C. He said,

'*I like things to be done as soon as possible as I tend to control the progress.*'

If leaders are less involved, they tend to select problems which they think they can contribute to. For example, the leader of Team B said,

'*...if they cannot solve the problem and it is related to hardware problem, I would get involved, otherwise I find someone who knows how to solve that problem for them.*'

This justifies that a team leader's personality could influence how they much they get involved in solving conflict and coordinating people.

The above discussion shows that a team leader plays multi roles within these teams which are associated with obtaining knowledge sources, initiating knowledge management, guiding team members and developing a supportive atmosphere. A team leader's role within a team not only involves formal roles but also involves informal roles to align team actions. This influences a team's teamwork, learning and participation on either knowledge management and innovation activities. The roles of a team leader discussed in this section remind of Mintzberg's (1973) ten managerial roles in which his so called interpersonal group's figurehead, leader and liaison roles are particular important in the R&D teams. On this basis, the next section will discuss how these teams develop a supportive atmosphere for knowledge management and knowledge related interaction to take place.

7.2 Towards supportive team atmosphere

The sharing of knowledge and experience is considered very important in these teams, which is associated with their team's the development of capability and team performance. However, Clegg and Palmer (1996) indicate that sharing individual knowledge and experiences within organisation may not be easy because it is also a political issue. Knowledge may be considered associated with an individual's value in the organisation as well as power. Thus, the sharing of knowledge and experiences within a team or an organisation not only involves the development of routines or procedures but also involves a knowledge holder's political consideration. Therefore, rewards may need to be offered by the team or organisation to encourage team members to share or exchange knowledge with others.

However, in this research, the data reports that a reward system for supporting knowledge sharing is not an important consideration (11 out of 18 interviewees mention this, summarised in Appendix 3, item 5). In fact, most team leaders and senior members are concerned with team atmosphere as reported by 3 of the four team leaders (summarised in Appendix 3, item 11 and 12). Once, an appropriate team atmosphere is formed; it stimulates team interaction and supports knowledge related activities. In this case study, such atmosphere is considered to be associated with team

cohesiveness (summarised in Appendix 3, item 12) and also related to team members' personality. However, the data also shows that team size (summarised in Appendix 3, item 17: team interaction; item 11: Team B) and structure are an important factor which allows teams to form a supportive atmosphere. Based on the above evidence, the following sections will discuss these factors in detail.

7.2.1 Team cohesiveness and team knowledge management activities

The literature suggests that team cohesiveness is associated with team performance (Evans and Dion, 1991; Gully et al., 1995; Mullen and Copper, 1994). This thesis argues that team cohesiveness is the foundation influencing a team's knowledge management activities. The data of this research shows that without emphasising team cohesiveness, individual knowledge and experiences is rarely shared within a team because team members would not spontaneously share their individual knowledge with others. For example, a member of Team B indicated,

> *'I don't share my stuff (e.g., information and documents) automatically because it is a bit strange.'*

This shows that the sharing of knowledge and experiences within the teams is not an energetic action. The leader of Team A said,

> *'...most of us have the willingness to share, just need to ask...if anyone knows the subject, most of us are willing to release his/her knowledge. But, if nobody asks, we wouldn't leave knowledge somewhere that people can see it.'*

A member of Team B indicated a similar situation,

> *'...usually people come to ask a question, then I will tell him/her..., if no questions, I don't know how to tell him/her. So when people asks question, sharing knowledge/experience does occur...'*

A senior member of Team C revealed that if any team member needs his knowledge and experience, he likes to help:

'...my background is related to banking and finance, some colleagues they don't have similar experiences, so when they need, I give a presentation..., or they can come to ask me directly...'

In addition to face-to-face interaction to share knowledge and experiences, Intranet (e.g. server, KM system, and intra-Website) is also an important medium for sharing information in the teams and the organisation. However, most of the team members do not share individual documents online (intranet). They would do so when the team leaders or top/senior management ask them to do. The leader of Team A said,

'...unless senior management makes a strong statement (for supporting KM system), they (team members) will carry out that order, otherwise they don't do it... we need a rule to follow basically...'

One of his team members indicated,

'...sometimes I do documentation, but I don't feel like sharing it with others, or putting it on the server...one of the reasons is those documents are not ready for public use because they need to be tidied up. Unfortunately, we don't have time for it.'

However, the data also shows that the problem of lack of use of the organisational KM system is not a result of people's willingness to share documents and information. Work load, system design problems and organisational support are associated with such problems as s senior member of Team A indicated,

'To much work to do so we do not really have time to make effort on this particular event issue...'

The above data shows that the nature of sharing knowledge and experiences in the organisation is not an automatic behaviour for most of the interviewees. For the team leaders, sharing knowledge within teams is related to team cohesiveness and personal attitude. The leader of Team B indicated,

'...in the process of managing a team, you have to let your team members understand that we are in the same boat, if one of the team members cannot achieve his/her task, the whole team cannot achieve the stated goals, meanwhile we have to spend more efforts to solve the problems due to ineffective coordination. In other words, one's better performance cannot differ from other members' poor performances...I used to tell my members, a team as a whole, so, only one situation, high performance (whole team) and poor performance (whole team). Although you do not encounter any problems, you still need to help other members to seek probable solutions. This facilitates the problems to be solved easily. Hence, the sharing and sustaining of knowledge would take place without barriers within our team so far...'

The leader of Team A indicated a different aspect,

'...I think it is about 'mutual support'...the team members' consensus...that knowledge has to be shared, if this is formed within the team, all the team members will spontaneously release (knowledge or information), from time to time, when you recognize that it actually benefits not only the team but also yourself...'

This sort of consensus is formed by the team members. It takes longer to achieve. However, the leader of Team B emphasises that he used to educate his team members to understand the importance of team consensus and cohesiveness in teamwork. In this team, the team leader has successfully influenced the team members. However, for a younger team, to form team consensus and cohesiveness to smooth out team operation seems to be difficult for the leader, especially for a heterogeneous team with a young team leader. The data of this research shows that continual communication between team leader and team members to exchange different opinions seems to be very important for forming team consensus and cohesiveness. The leader of Team C said,

'...I like to emphasise some senses to my team members, because I think in the workplace, personal attitude and sense are the most important things...

moreover, I am still young...so I lead by personal example...also when I read a good article that I agree with, I will forward to my team members...Through an indirect way to influence them, rather than directly advise, that sounds like preaching, especially when you want to transmit a sense of value or belief.'

For Team C, team consensus and cohesiveness are still developing, as well as a sense of knowledge sharing and exchanging. As the team leader indicated,

'...we are progressing gradually, a few team members feel uncomfortable here, they may leave...We are adjusting, so far, I feel, our team's atmosphere is ok, I will try to create a more cheerful environment...'

However, in contrast to Team A, B and C, Team D does not emphasise team consensus and cohesiveness. One of the reasons may be attributed to the specific group characteristics, i.e. being an inter-organisational team. Within the previously described set-up, individuals' goals and the project goals are integrated together. Moreover, a classmate relationship is also a feature which differs from the relationship between members in the other teams. This seems to be a factor enabling the group to form a consensus within the team. As a senior member of Team D said,

'...because we are all senior/junior classmates, if someone needs help...I would be very happy to discuss with them and help them. Also, they (team members) sometimes automatically arrange meetings and discuss together.'

However, in terms of the whole team's interaction, some barriers between the three groups seem to exist. The senior PhD student said,

'...the interdependence between three groups' tasks is not very high; thus, if another two groups encounter an insolvable situation...we can drop their part off and keep going...'

He added,

'...we don't show important ideas in the fixed meeting, we need to protect our idea not being adopted, so, we sometimes just give some ideas..., because there is one group that we don't know very well.'

This may indicate that the team, NU, has quite a strong in-group identity which implicitly influences the co-operation among those three groups. This supports Brewer and Harasty (1996) in that team cohesiveness distinguishes between team members and non team members in sharing knowledge.

The above discussion and evidence show that team cohesiveness and consensus generate a mutually supportive behaviour which facilitates knowledge sharing and contributes to problem solving within the teams. This support Holtz (2004) and Kirmeyer and Lin (1987) that high cohesiveness facilitates team interaction and team members' openness, which further enhance knowledge sharing and teamwork. The ways to achieve such cohesiveness are different in the four teams. Team leader, team experience, and team context are important elements. In this particular case, the recognition of belonging to a team is adopted in these four teams. This responds to Hoegl and Gemueden's (2001) suggestion that quality teamwork partially underpins team cohesiveness. Moreover, cohesiveness is particularly emphasised in Team A and B by the team leader. This indicates that permanent teams (Team A, B, and C) focus more on team interaction and team cohesiveness. In contrast, in temporary teams (Team D), it may not be an issue. This may relate to Shapiro, Sheppard and Cheraskin's (1992) suggestion that when a team's trustworthiness stays at calculus-based trust, its knowledge sharing behaviour is determined by the familiarity with others within the group.

7.2.2 Personal attitude and knowledge management activities

The literature shows that attitude is significant in regards to team cohesiveness (e.g., Harrison, Price, and Bell, 1998; Terborg, Castore, and Deninno, 1976). In these cases, personal attitude in general is considered an individual's feeling about his/her work, and the willingness of contribution to the work. The data of this research also indicates similar contentions of three team leaders, Team A, B, and C. For those team leaders, a team member's attitude is a determinant of whether or not one can actively take part in teamwork and achieve the tasks. The leader of Team C said,

'...I think attitude and sense are the most important points in the workplace, personal expertise/skills are secondary.'

One of his senior team members also indicated that,

'...personal attitude problem, if one's attitude is not to care what is happening to his/her work, and does not even think about where the problems could be, and then he/she just comes to people to say please give me a help or a answer. I don't think it is a positive attitude to what he/she wants to ask for help, and I would have no inclination to give help.'

This indicates that personal attitude to work does not only influence an individual's achievement but also influences other people's recognition of co-operation and his/her participation in teamwork.

Moreover, for the leader of Team B, to educate his team members to respect each other is changing team members' attitude. He tells his team members, a team is a body of common fate,

'...we are in the same boat. Although sometimes the problems are not yours, you have to involve yourself and help others to solve their problems...be more open to others...'

In team A, the members' attitude with regards to sharing and exchanging knowledge amongst team members is influenced by previous experiences in an international co-operation project. Thus, the members have had a sense and a positive attitude towards sharing knowledge in which most of the team members employ public servers as a medium to open individually collected information and documents and share with others in the team. The team leader said,

'...our knowledge sharing was learning from (a previous project in) Germany, so, in our team, the team members have higher willingness to share experiences and information with others, because in that team (in Germany), they are very

open, you can acquire a large amount of documents and information, we learnt from what they did.'

In addition, he also indicated,

'...we are very open, we put all the related documents in the server, nobody hides documents and information...'

'...knowledge sharing within our team takes place in a very informal way, and at any time, if someone needs help, just ask...'

This seems to correspond to one of the senior team members of Team B, as presented above, who indicated that knowledge sharing is determined by team members' attitude. When all team members have this attitude, knowledge related activities automatically take place within the team.

However, the data also showed above that within Team D, team members' attitude is consistent among group members but is not shared towards other groups. In fact, it is determined by the leaders' attitude. There is a concern for protecting ideas.

The above discussion and evidence show that changing team members' attitude is part of the process of building team cohesiveness. In this process, changing individuals' attitude towards teamwork and fostering the recognition of belonging to the team is a way to develop team cohesiveness. With team cohesiveness as a basis, a team can further form a supportive atmosphere which maintains knowledge related interaction continuously taking place. This supports von Krogh (1998) and Zárraga and Bonache (2005) that within a supportive atmosphere better knowledge outcomes are generated. Thus, the next section will discuss team atmosphere in the teams' knowledge management activities.

7.2.3 The influence of team atmosphere/climate

The above sections has outlined that a team's cohesiveness influences team members' participation and teamwork. Team cohesiveness aligns team members and generates mutual support between team members. However, to keep team members to

frequently interact and further share their knowledge is not easy, as the leader of Team A above indicates that it needs an atmosphere to drive team members to carry on.

The data shows that even the organisation has recognised that knowledge is a significant property and it needs to be shared and made available for use by its members[6]. However, if there is no atmosphere to support knowledge sharing, it cannot take place regularly as a routine. The leader of Team A considers an atmosphere for sharing knowledge within a team. He said,

> *'...that is team members' consensus...they understand that knowledge has to be shared, if this atmosphere is formed within a team, all the team members will spontaneously release (knowledge or information), from time to time, when you recognise that it actually benefits not only the team but also yourself, and you like to continue it...'*

However, the leader of Team B suggested an atmosphere of harmony to facilitate team members to share knowledge and experiences. Furthermore, he also indicated that it may be associated with sharing honour and reward. He suggests people,

> *'...have to create a harmonious atmosphere between them. Because I am an engineer, to make knowledge shared between engineers, a priority is to keep a harmonious atmosphere between them, then they wouldn't hide their individual knowledge...'*

He also mentioned,

> *'...when you release your knowledge to others, the creativity does not only belong to one person; the way I used to do it, is to share team honour, empower people who share reward equally...'*

In Team C, a senior member, who is also concerned with a team's environment and atmosphere, considered that the atmosphere should be created by team leaders. He said,

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[6] 'Knowledge management has become an important issue in our organisation since 2000. We are still working on this direction...' the leader of Team C said.

'...I think a leader's leadership and his recognition of doing tasks are very important. A team leader, if he can create a nice environment and atmosphere, I think it (knowledge related activities) will naturally work out within the team.'

All three teams suggest that team atmosphere has an influence on a team's knowledge sharing activities. However, they are thinking in different ways with regards to what kind of team atmosphere is needed. This seems to indicate that a team's atmosphere for supporting knowledge management activities is actually associated with a team's context, such as a team's culture, distribution of power, and social norms, habits, practices, expectations, and preferences. This finding seems to respond to Zack and Mckenney's (1995) work about the importance of situating atmosphere within team contexts. Each team notes different norms, beliefs, values, etc. For example, some members of Team A have had experiences of knowledge sharing in an international project. Therefore, a team norm has been formed among those team members. Once, they work on a new project, this norm will be continued and also influence the newcomers. Thus, an atmosphere for sharing is recognised as important to support knowledge-related activities in a team.

However, in Team B, the team leader and team members commonly recognise that most team members are likely to help each other no matter what type of help is required. They recognise that a team's harmonious atmosphere is important to them.

Furthermore, in Team C, most team members have never worked together; thus, the team has not formed strong team norms, beliefs, and values; this is consistent with traditional models of team development such as Tuckman (1965). Also, individuals' tasks are rather independent. Therefore, they recognised that the team leader plays a significant role to create an appropriate team atmosphere to facilitate knowledge sharing.

In contrast, this issue was not actually recognised in Team D because of its composition and supervisor-student relationships. Each group's atmosphere/climate is influenced by its supervisor. For example, in the NU group, the interviewees frequently mentioned the phrase '*see how our supervisor think*' or '*our supervisor makes decisions*'. Thus, their team atmosphere tends to be '*complying with the supervisor's advice*'. Moreover, a classmate relationship between team members seems to be an advantage to facilitate them to help each other without asking for reward. A senior member of Team D indicated that it is based on a fair distribution of work. He indicated,

'It may be associated with matching of progress and job distribution. You have to assign job carefully and fairly in order to avoiding an unfair situation in terms of individuals' load.'

This research also shows that team atmosphere is more and less influenced by local culture and societal norm. The leader of Team B suggested this:

'...in Chinese society, whatever it is, a technical unit or an administration unit, "jiao qing (interpersonal relationship)" is very important. "jiao qing" with customers is a kind of "guanxi (relationship)"; within a team, this is 'harmony' which is like family relationship...'

This reflects that in a Chinese society, a team atmosphere is somehow built upon personal relationships, rather than tasks. Within a team, whether or not an individual makes extra effort is not only associated with one's commitment to task but also the relationships with other team members (Wang et al. 2006). This is an interesting finding in light of the continuous discussion on the influence of national culture on organisational cultures.

In this context, to keep a harmonious atmosphere between team members is considered a key to further develop mutual support and a knowledge sharing atmosphere between team members. Thus, in some of these cases, for example, Team C, the interaction being centred on the team leader more and less means the team leader is leading the team by using his personal relationship to connect with individual team members rather than using his authority power. The leader of Team C indicated,

'...I rarely gave orders to my team members. I have never pointed out anyone's wrong in front of team members...I gave them flexibility to arrange their time and decide how to do their work.'

This shows that the team leader tries to make efforts to build personal relationships with team members. Therefore, authority is avoided. Similarly, in Team A and B, a member of Team A said,

'...our boss plays with us, has lunch with us, and makes fun with us. We have never seen him as a boss; that may be why we have quite a relaxed relationship and workplace...'

And a member of team B concurred,

'...our boss is like an old brother, he really takes care about us....'

In Team D, a traditional master-student relationship exists. Therefore, interaction between team leaders and team members tends to be formal, and masters conduct the way they interact. In this case, the interaction between team members and leaders is built upon this traditional ethic.

The discussion shows that an appropriate team atmosphere triggers spontaneous behaviours and facilitates to turn knowledge related activities into team routines. However, such atmosphere has different meanings to the teams, this is associated with team context and project features. For example, Team A and B have the features of engaging in incremental innovation, consisting of homogeneous expertise, and are classified as permanent teams. The ways in which both teams work are based on tasks to arrange team members. There is no manager between team leader and team members, and senior team members only play an assisting role to junior team members. Therefore, team atmosphere is emphasised in these two teams.

In contrast, Team C and D engage in radical innovation, consisting of heterogeneous expertise and have a shorter team experience. The teams have different functional groups and team hierarchy exists. In this situation, team atmosphere is not a strong component of working or is still developing.

The above discussion shows that these teams respectively have their own aspects about team atmosphere. It relates to each team's context and is developed in different ways in the teams. However, as the leader of team B indicates that in a small team, the emphasis of team cohesiveness is able to enhance team members' participation and further develop a supportive atmosphere for undertaking knowledge management. The following section will discuss the influence of team size and team structure on team interaction.

7.2.4 The influence of team size and team structure on team interaction

The literature has suggested that team size is an important factor influencing team members' interaction, outcomes/performance (Revans, 1958; Cunningham and Chelladurai, 2004), and team cohesiveness (Manners, 1975). This is also supported by the data of this research. The leader of Team B indicated,

> *'I can manage a small team like this, but I am not sure whether or not it is the same way to manage a big sized team.'*

And a member of Team A concurred,

> *'Our team (at the moment) is quite small and all members are in the same office, any problem, just stand up and ask.'*

This shows that a small team may have an advantage which facilitates team members to improve the quality of team interaction and further develop consensus and cohesiveness, as well as a supportive team atmosphere. In a small team, team members seem to know each other better. A member of Team A said,

> *'...when I was in the other lab, the feeling about the team was quite different from here. Its team size is quite big, all the team members were working on their own, even lunch time...everybody is alone...Here is quite different, we are chatting, discussing together. It is different from there, maybe there are more team members, and has high flow in/out, so...I cannot remember who was sitting next to me when I worked there...'*

This shows that through frequent interaction team members can know each other's expertise, experience, and/or personality. This facilitates team members to map each other's expertise and know whom to talk to when they encounter problems. A member of Team B revealed,

> *'...when I encountered problems, first of all, I am going to ask team manager or another senior colleague, if this is a hardware problem. If encounter software*

problems, I am going to ask another colleague...Because we only have five team members, we know each other.'

However, when the team size increases, team hierarchy usually forms. This causes interaction and communication between team members to become difficult. In other words, team hierarchy will influence horizontal interaction and communication, and turn horizontal interaction into vertical interaction and communication. For example, in Team C, an early team structure was team leader (C1) and team members (C2-6). At that time, the interaction between team leader and team members was horizontal. However, in a short time, the team added two members (C8 and C7) who were subordinate to C6. Therefore, the team structure took different shape (Figure 7.1). The hierarchy had three levels, team leader (C1), managers (C2, C3, C4, C5, and C6), and team members (C8 and C7). This change increased vertical interaction and communication as C8 and C7 have to go through C6 to connect with the team leader, as evidenced by the quote below. If more members are added, the hierarchy structure becomes more complete. Hence, interaction and communication within the team will be more vertical rather than horizontal.

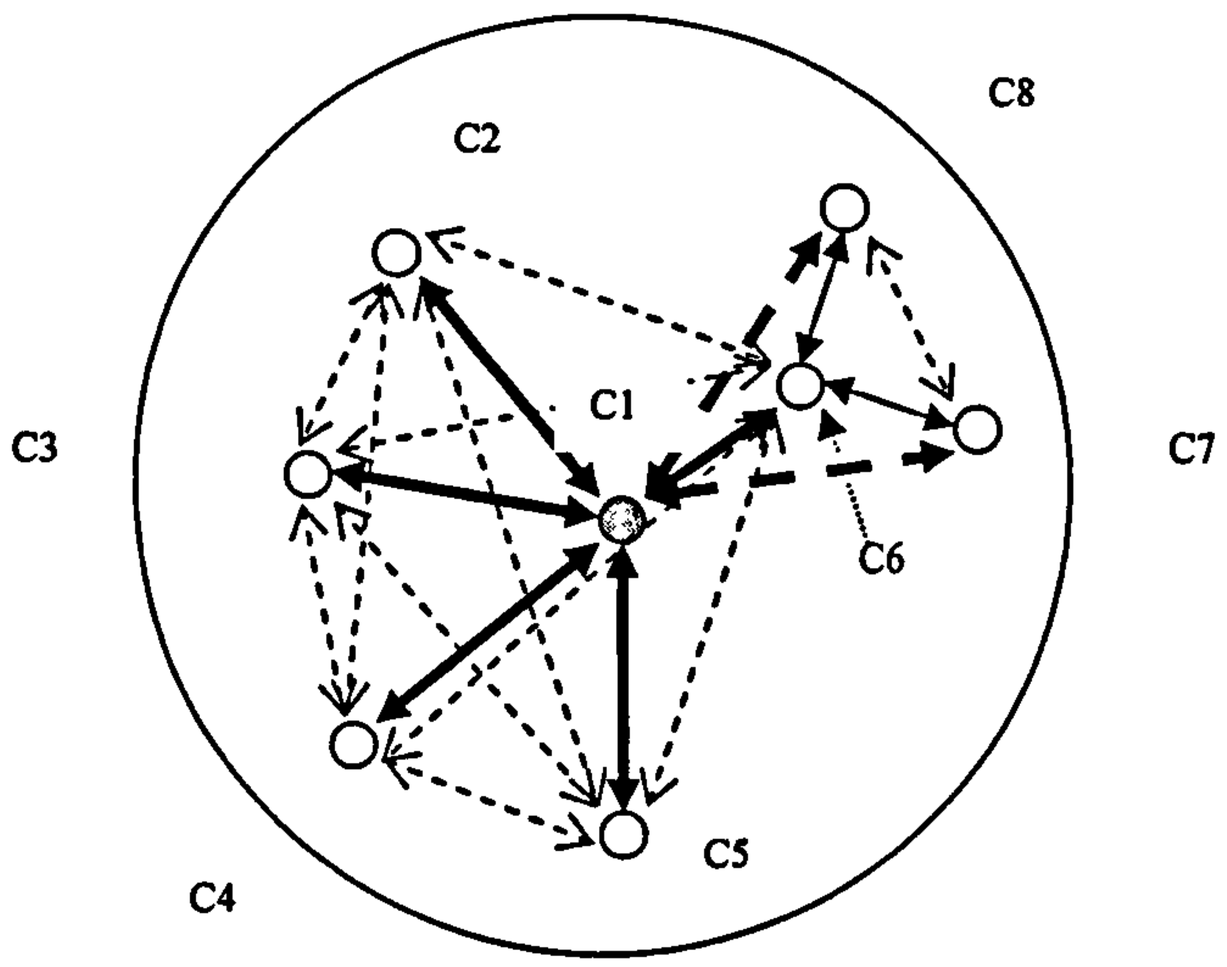


Figure 7.1 Team Interaction Team C

This verticalised interaction creates a difficulty in developing team consensus because different task groups would not really communicate with each other. A member of Team C said,

> *'I think our team's interaction and communication tend to be verticalised. It is tied with our team leader. He used to interact with us separately. We seem to lack horizontal interaction and communication...'*

In this case, team size is a factor that causes a lack of horizontal interaction. The data also shows that with increasing team size, team hierarchy evolves. This causes task groups to emerge. The data suggests that team members in the same task group have much more frequent interaction than with different task groups. For example, in Team A, the team size is small (6 people); interaction amongst team members seems well-distributed when looking at their interaction matrix (Figure 7.2).

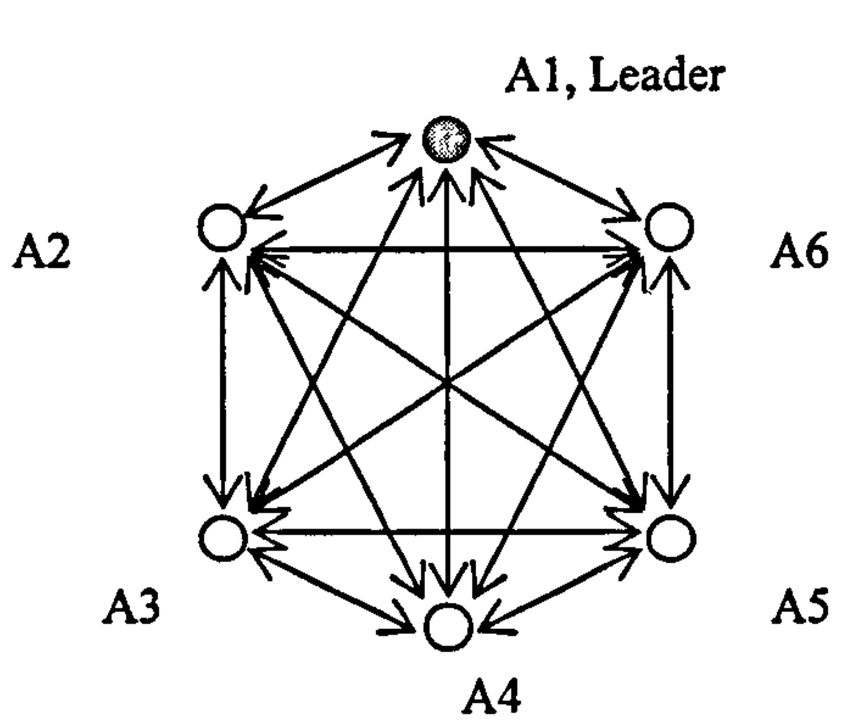


Figure 7.2 Team Interaction Team A

However, when Team A's size increased 11 (see Table 7.1 and Figure 7.5), team interaction is less well distributed and frequent interaction appears only in the two task groups, Aa-Ae-Ac and Aa-Ab-Ad. Moreover, in Team C, within the same task groups, Ca-Cb-Cd and Cb-Cc, team members have more frequent interaction and communication than with others (Table 7.2 and Figure 7.8). This is further discussed in section 7.2.6.

Team D (Figure 7.3), due to its specific team composition, is slightly larger and it adopts a team hierarchy. Within the NU group, members have frequent horizontal interactions through either meetings or informal discussions However, in this group, the project related interaction and communication between the team members and the leader group is moderated by a senior PhD student (D1). As a member of Team D (D2) said,

> *'...our senior PhD colleague interacts with his supervisor very frequently, and we mainly interact with him and supervisors have their interactions. We do not interact with supervisors about this project directly...'*

This shows that in the NU group, team hierarchy (leader, D1, and members) determines team interaction and communication flow. However, when the situation is focused on NU's member group, the interaction between team members is quite energetic and open. Meanwhile, when all groups are involved, the interaction tends to decrease. The different identities within this team cause the interaction and communication to become more formalised.

The above discussion and evidence show that team size influence the frequency of interaction and communication, as well as team structure. However, team size and team structure are also associated with project characteristics. For example, Team A and B (incremental innovation teams) have quite different project characteristics from Team C and D (radical innovation teams). In Team A and B, team structure tends to be flat (team leader and engineer) and have small team size. In Team C and D, team structure tends to be hierarchical in order to deal with different functional expertise and increased team size. The interaction within the teams is further explored in section 7.2.6.

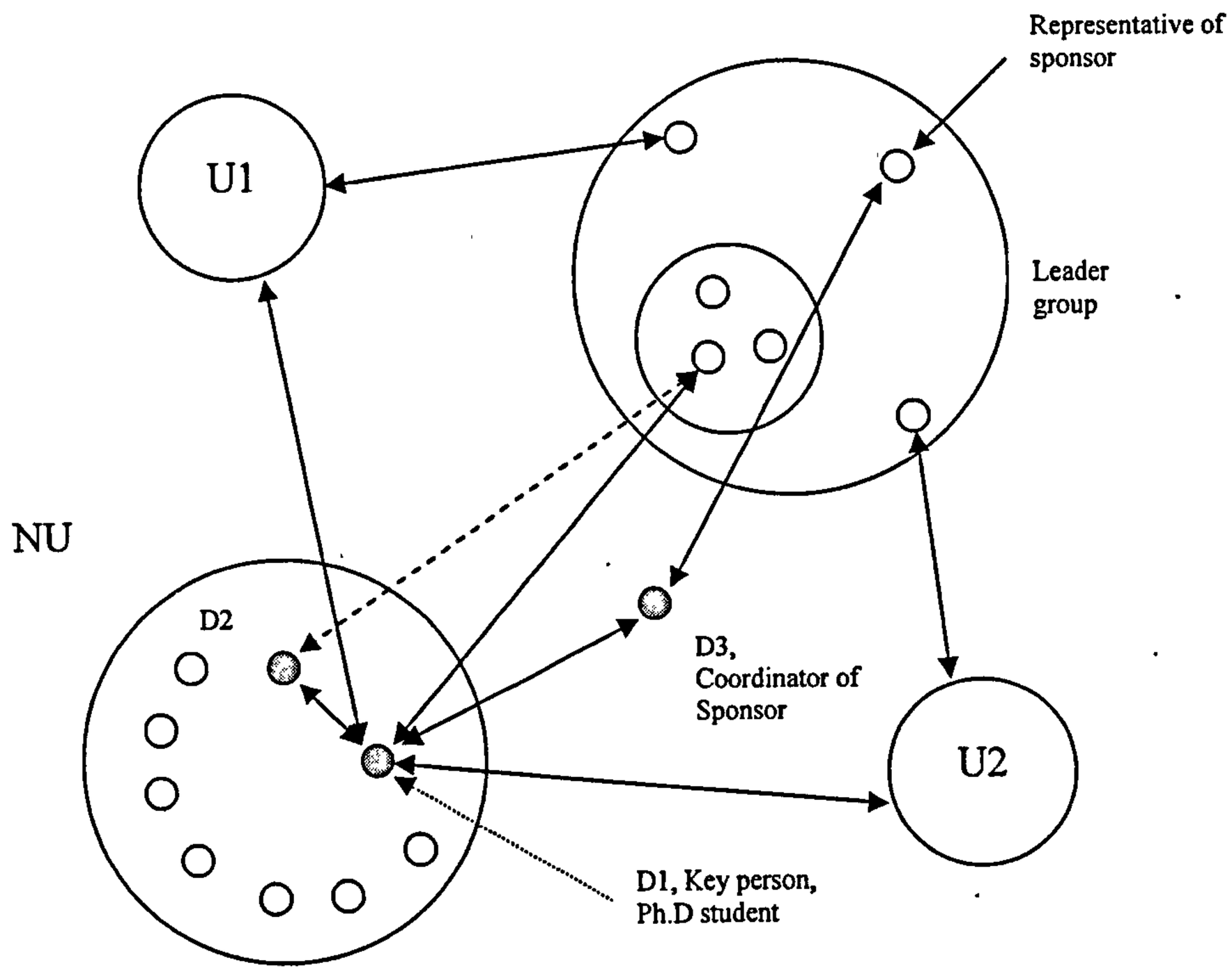


Figure 7.3 Team Interaction Team D

In summary, the above discussion shows that team cohesiveness increases mutual help and spontaneous communication within the teams. On this basis, a supportive atmosphere enables the team members to keep their spontaneous interaction. This further influences team members' knowledge related interaction. In this case study, this continuous and spontaneous interaction facilitates problem solving and knowledge sharing to take place between team members. This influences R&D activities in terms of integration of team members with different expertise and coordination of tasks. Thus, in this thesis, team operation is considered an important factor which facilitates knowledge management activities to be integrated into innovation processes through solving problem at different stages. This responds to Leonard and Sensiper (1998) that team interaction and interpersonal interaction at the conscious level enhance creativity; interplay among team members facilitates exchange of knowledge and generation of new knowledge which is essential to innovation processes.

With the above understanding of how these four teams foster their team interaction, the following sections will discuss how team interaction takes place. Interview and team observation data report that there are various types of interaction within the teams with regards to sharing knowledge and acquiring knowledge for solving

problems. Thus, the following sections firstly discuss different types of interaction and then portray each tea, individually. This will help to understand how the team members interact, share knowledge and coordinate tasks within the four teams.

7.2.5 Modes of interaction

Knowledge related interactions within a team are underpinned by team atmosphere. With a supportive atmosphere, knowledge related interactions can be more spontaneous and turn into routines, according to the findings so far. This section explores the types of interaction that team members use

Interaction within a team can be various. In this case study, it entails face-to-face interaction, on-line interaction, and social network. Face-to-face interaction can be formal or informal. On-line interaction can be the use of e-mail or on-line chat. Social networks can be internal or external. These different types of interaction are related to the efficiency and effectiveness of knowledge related activities, problem solving, and coordination.

7.2.5.1 Formal and informal face-to-face interaction

The data of this research shows that most knowledge and individual experiences are shared through informal face-to-face conversation and during informal occasion (see data summary sheet Appendix 3, term 2 and 15). This implies that this kind of interaction is personal and based on an individual's willingness. It cannot be forced by others because it involves an individual's mental models and intellectual property. Therefore, formalised interaction or occasion are not considered an appropriate way to show one's insight to other people, especially within a software engineering context in which creativity, skills and experiences are the significant individual asset, and show an individual's value to the organisation. Therefore, informal interaction is preferred. A senior member of Team C indicated,

> *'...from a view of problem solving, informal interaction offers an efficient and accurate advantage to the problem solving. Also, you can obtain much more precise information...The formal interaction usually causes stress to the people which may decrease his/her willingness to provide the useful contents...'*

Also, a senior member of Team B, he revealed a similar perspective,

'...if it is formal, the interaction is likely to be restricted, whatever it is team or individual interaction, because we normally tend to be spontaneous. For example, when we encounter a problem, we do not always post the question on the KM system and wait for someone to answer the question through the system, ...face-to-face interaction is more real...'

A senior member of Team A also concurred,

'...informal is better, no stress, you don't need to show them all, within an informal schedule, you can really discuss, and you have interaction...'

These statements show that face-to-face informal interaction is believed to be a better way to share knowledge and information. This responds to a high-context culture in which knowledge is shared and exchanged through interpersonal interaction (Dulek et al., 1991; Kim et al., 1998). Moreover, a reason, beyond these statements, is that finding sources to solve problems is usually based on individuals' social networks and use of social relationships which are difficult to formalise.

However, in some circumstances a formal meeting is considered necessary, such as reviewing project progress, when new members enter the team or when the tasks tend to be more independent. As a senior member of Team C indicated,

'I think a fixed formal meeting is necessary for the entry of a new member to understand this team...it is also important for team members to report their progresses and coordinate tasks.'

In these circumstances, meetings are considered necessary because they provide the opportunity for all team members to communicate and exchange experiences and information face-to-face. For example, in Team C, they used to hold informal meetings, so-called strategic meeting, including all team members. A member of Team C said,

'...this meeting used to take longer, so we could share some experiences with each other...it usually took place in a situation which facilitates team members to talk and interact, such as afternoon tea meeting, it is a good opportunity for all of us to communicate...'

The idea of fixed meetings is applied in Team D. In this team, fixed meetings take place frequently (see data sheet Appendix 3, term 2 and 15, Team D). Due to its specific feature, the fixed meetings are the main occasion for team members' interaction and sharing knowledge. However, a special phenomenon appears in this team where each group has its own informal meetings prior to this formal occasion. A senior member of Team D said,

> *'We have informal meetings, just our group, before a team meeting to discuss the contents that we want to present in the team meeting.'*

In this team, the meetings tend to be run in a hierarchical format, which reflects the interaction patterns within the team and its hierarchical team structure (Figure 7.3).

7.2.5.2 On-line interaction

The data shows that the Internet and its virtual communities are increasingly playing a significant medium for the interaction between people and for diffusing and exchanging information. The data shows that most interviewees are heavy users of the Internet, as a member of Team A said,

> *'We work on computers and search information or data from the Internet. We are kind of living on it.'*

Most of their information and knowledge are updated through exploring specific internet websites. This provides day-to-day information to update their specific or general knowledge. However, some of the interviewees also doubt the effectiveness of using Information Technology (IT) as a tool for knowledge sharing. A senior member of Team C indicated,

> *'...IT tools have their own advantages, it can be a good tool for documentation or recording ideas, but if you want to use it to share knowledge, I think it is very difficult...'*

This statement implicitly indicates that knowledge sharing and exchanging actually relies on people's face-to-face interaction and the Internet/Intranet is just a medium for facilitating people in accessing sources. This is because sharing and exchanging knowledge between people is associated with not only knowledge itself, but also situational factors, such as individuals' social connection, trust between people, the way people express their knowledge or experience, the context of a specific event,

and the situation where they talk. Therefore, the situations where people share knowledge are significant. This perspective is also supported by some of the other teams. For example, a member of Team D revealed,

> *'...when I find a useful document from the Internet, I used to check the source and if possible I would try to contact the author. If the author works for this organisation, I usually make an appointment and go to visit him/her. If this document is very important to me, I would like to know more details.'*

This highlights the importance of face-to-face interaction for sharing knowledge. As he said,

> *'...it makes things clearer, and you may get extended information about what you are looking for during the interviews.'*

The above evidence supports other research that compares the use of different modes of interaction to conduct meetings. Lantz (2001) research outcomes also suggested that face-to-face meetings are still the most effective way to interact.

No doubt, the Internet has a great impact on their action and work. One of the significant functions is the improvement of the interaction between people. Some interviewees indicated that although sometimes they do not talk much to each other, they use e-mail to communicate or forward related information to each other frequently when they find interesting content on the Internet. A member of Team A said,

> *'I spend time on the Internet to search what I need. Sometimes I find something that is relevant to my colleagues' works. I just forward them. They do the same thing as well.'*

This situation is where people know each other well and the Internet becomes an appropriate channel to keep in touch and share information.

The data suggests that interaction through the Internet occurs in interest groups or peer groups within the organisation and the teams. Within those groups, people have close interaction based on their common interests. This normally enables people to develop and extend their social networks and relationships. Such social networks and relationships facilitate people to access different information and knowledge sources

when they need. A member of Team B explained why peer groups are developed within the organisation, and a member of Team A explains why they work. They said,

> *'...basically, here, I feel like in the university with my friends. We sometimes do exercises or play games together. Because most of us are taking National Compulsory Service (NCS), four years later we are probably staying or leaving. So, our relationship during these four years is something between colleague and classmate relationship.'* [A member of Team B]

> *'...one reason, because half of the team members entered (this organisation) at the same year (at the same time), this make us closer. We usually have lunch together and also talk about the work during lunch time. Implicitly, discussion groups or interest groups are developed over time among us.'* [A member of Team A]

This kind of group not only appears within a team but also emerges across teams when their offices are located nearby. In this case, face-to-face interaction takes place during a specific occasion or break time and the Internet provides a channel that allows them to interact during office time through on-line chatting and e-mail. For example, a member of Team A indicated,

> *'Sometimes have a chat with colleagues, sometimes through on-line or e-mail, it depends on how busy I am and time. It is quite flexible...'*

The interactions facilitated through IT are similar chats during break time in the corridor – spontaneous and convenient. It is a short-lived, but it sometimes delivers useful information, ideas, or clues.

7.2.5.3 Social networks

A team's structure reflects its team members' interactions with regards to task performance and task coordination, but it does not completely reflect the interaction pattern among team members as team members' interaction is also influenced by many factors, such as individuals' social network. This research shows that knowledge related interactions rely on team members' personal social networks. Social networks include team colleagues, interest group, peer group, friends, and external agencies. In this case study, similarity in background, interest and work experience, are often used as a catalyst to bring people together within the workplaces. Some of the interviewees indicated that they normally have much more

interaction with people who have similar interests or work experiences than with people who have task similarities within the teams. For example, a member of Team C said,

> *'...for me, I usually interact with some colleagues who are my previous colleagues in the bank because we have known each other for a bit longer. Of course, I do interact with other colleagues when our tasks overlap with each other, but the relationship between me and co-workers is dependent upon people's personality and interest which we may match, maybe not...'*

Also, some statements presented in the previous section, indicate that formal relationships in the task or team structure may not encourage team members to interact frequently or share knowledge and information automatically. However, it does not mean that individual social networks and relationships can replace a formal relationship at work. Indeed, it shows that social networks and relationships appear more positive in facilitating people's interaction.

Although a formal relationship between team members does not motivate interaction, it is still an important relationship to converge team members' efforts to the tasks. In this situation, the interaction may focus on task coordination, rather than sharing knowledge or exchanging information.

In contrast to interest and peer groups, interpersonal social networks can also be extended through team leader's or other people's networks, especially external social relationships. The data of this research show, in Team A, B, and C, the interactions with external organisations or experts are centred on the team leaders. The team members rely on team leaders' social connections and relationships to access external knowledge sources. The reasons for forming this pattern are indicated by the leader of Team B, he said,

> *'...they don't like to face outside, because they like to do things relevant to their expertise, they don't like to interact with external people or be an interface.'*

Also, some interviewees revealed that less work experiences causes them to rely on team leaders' social connection. A senior member of Team A said,

'...our team leader, Mr. Y, he has had a long term working experience in this organisation and in different labs. He knows many people and what they are doing and who has skills. He often keeps in touch with them...'

A similar situation also occurs in Team C. The team leader has worked on the main project for many years, so he knows many external agencies, '*external networks are my advantage, they need my sources*'.

External social networks are associated with a person's work experience and it is often connected to introduction by others. It is different from an interest or peer group which is formed in a situation where people may have known each other for a long time, have colleague relationships and have similar interests, age, or background. However, these two relationships have different influences and functions on teams' knowledge related activities. Internal social networks facilitate knowledge to be shared or diffused within a team which enhances a team's capability for problem analysing and solving and innovation. External social networks facilitate a team to access knowledge sources and introduce new knowledge which enables the team to learn and generate new ideas. A senior member of Team B revealed,

'...some new ideas are often generated from our customers, because their backgrounds sometimes are different from that what we have; they sometimes indicate some ideas which are attractive but some of them we think are impossible...It is very important to interact with external experts or organisations. This facilitates us to get away the rigidity of thinking...'

The data shows most teams interact with external experts or organisations to seek solutions for problems. They also believe that solving problems and practising are the best ways to learn new knowledge and share knowledge with other team members. For example, a senior member of Team B showed his experience about training customers' technical staff,

'...to supervise a person, the most important thing is that he/she has to practise by him/herself, and then he/she can find out the problems from the practicing, then he/she can come to me to discuss the problems, this makes them going into more details...'

This statement indicates that to share knowledge, experiences and skills does not simply rely on knowledge holders' willingness to share with others, but also relies on

learners' practicing and questioning. This may justify why the interaction between team members influences knowledge management activities within the teams because it not only involves the sharing of knowledge but also involves the learning and practising of knowledge. This responds to Ahmed et al. (2002) that knowledge is also learning because it involves the action of the use of existing knowledge to produce new knowledge.

This section has outlined various types of interaction which constitute the teams' interaction patterns and is associated with knowledge management activities. The next section will discuss further these four teams' interaction patterns.

7.2.6 Interaction patterns in the four teams

This section will discuss how the team members within the four teams interact to coordinate tasks and share knowledge. In the two teams that were observed, these patterns were informed by the observation and informal interviews. As was discussed previously, in the teams that could not be observed, additional conversations with team leaders were conducted, which provided the basis for these models.

Team A

The interaction in this team is classified into two phases: the beginning stage and the progress stage of the project. At different stages, the team has different interaction patterns (see Figure 7.4). Figure 7.4 (left) shows that at the beginning stage, team members interacted with each other in order to map the project. At this stage, there was no distinction between team leader (A1), senior team members (A2, A3, and A6), and junior team members (A4 and A5). However, when the project moved to the implementation stage, individuals adopted different responsibilities. The interaction centred on the team leader (see Figure 7.4, right). The research suggests that the change derived from the need of progress control and decision-making. At this stage, team members still frequently interacted with each other in order to solve the problems, coordinate tasks and review projects between senior team members (A2, A3, and A6) and junior team members (A4 and A5). Knowledge related interactions between senior and junior team members take place spontaneously through problem solving and project reviews. Moreover, there are some team meetings held for reviewing the project and solving serious problems.

However, the observations of this team provided different team interaction patterns (see table 7.1 and Figure 7.5). During the observation period, team size increased, which was the result of organisational restructuring and team members' return from other projects. In this period, team members still had interactions but the most frequent interaction appeared within two task groups. Team member Ab and Ad worked with the team leader (Aa); thus, the interaction between Aa, Ab, and Ad was much higher than interaction with other team members. Moreover, team member Ac worked with team member Ae, so the interactions between them were higher than their interactions with others. In this team, Aa and Ae held different project accounts and Aa was a team leader. Therefore, communication between Aa and Ae was necessary. Moreover, this interaction pattern shows that the senior team members in team A play a significant role to supervise or help junior team members with their work (see, interaction between Ab, Ac, Ad and Af, Ag, Ah, Aj, Ak). The author suggests this enables knowledge to be shared between them through discussions and imitations. In this team, knowledge related activities focus on transferring knowledge from senior team members and sustaining team knowledge. The returned team members (Af to Ak) concentrated on their work (supporting specific tasks from the centre) and had only some interactions with other team members.

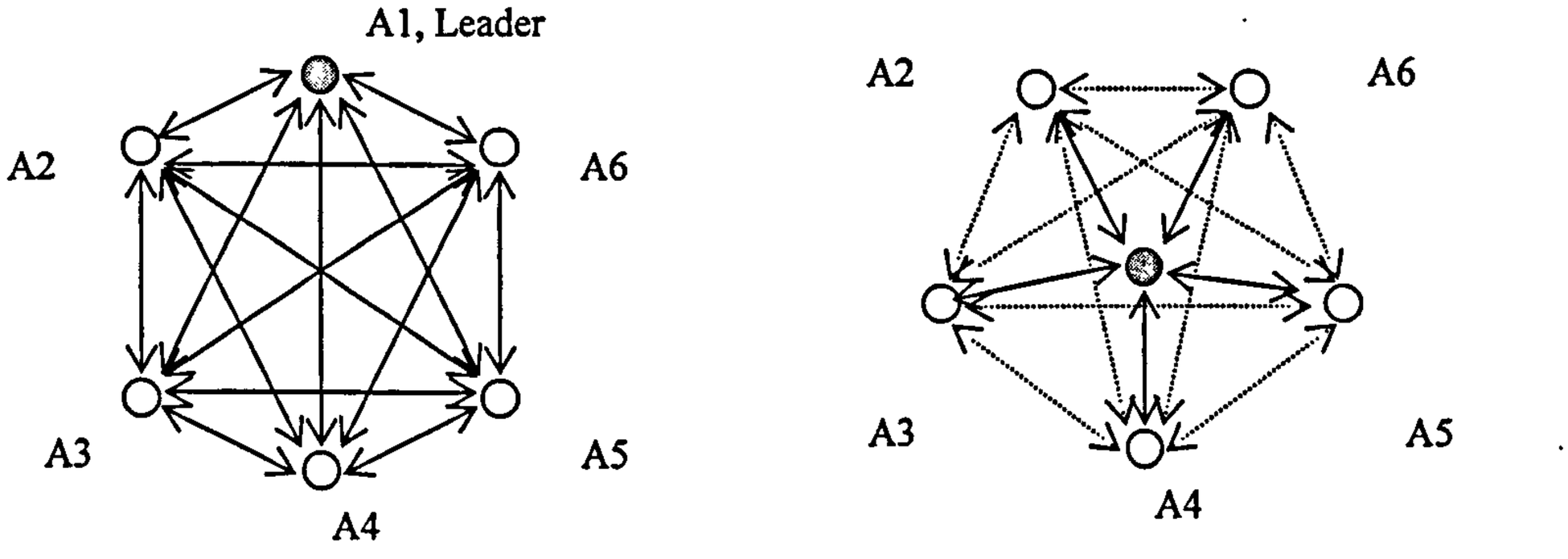


Figure 7.4 Team Interaction – beginning project (left) & during progress of project (right)

Table 7.1 Frequency of team interaction team A (related to Figure 7.5)

Team A										Time span: one week		
	Aa	Ab	Ac	Ad	Ae	Af	Ag	Ah	Ai	Aj	Ak	Footnote
Aa		13	5	9	11	2	1					
Ab			5	19	4	1	1			1		
Ac				5	7	2	1	1		1		
Ad					4	1		1			1	
Ae						2	1			1	1	
Af										1		
Ag												
Ah												
Ai												
Aj												
Ak												

1. Aa: team leader, Ab: junior engineer, Ac: junior engineer, Ad: assistant, Ae: most senior engineer and project manager, Af, Ag, Ai, Aj: senior engineers, Ah, Ak: junior engineer

2. Aa,Ab,Af,Ag,Ai,Aj have experiences of international co-operation projects

3. Ab and Ad work with Aa

4. Ac works with Ae

5. Af own few patents

6. Ab, Ac, Af, Ag, Ah, Ai, Aj, and Ak are taking NCS

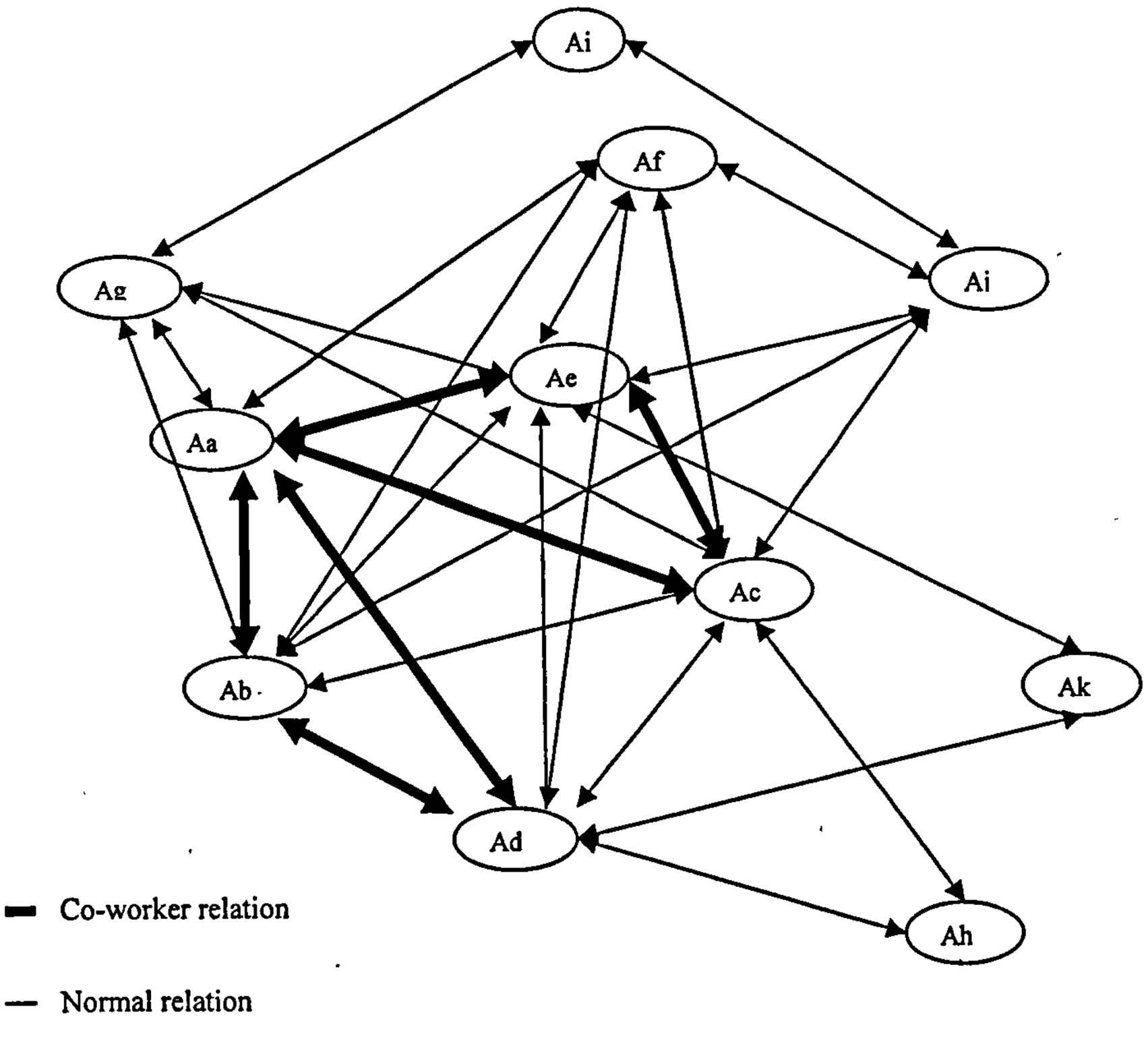


Figure 7.5 Team Interaction (observation) Team A

Team B

All team members agree with the team leader as he said, *'our interaction is very informal'*, and '*we do not have any meeting in this team.*' In this team, the four original team members (B1, B2, B3, and B4) had very frequent interaction and a newcomer (B5) at the time was looked after by the team leader himself (Figure 7.6). The leader was placed as a node to interact with external agencies. Most team members only interact with work related people, such as officemates, sponsors and suppliers as the team leader said that they do not like to face external agencies. Team members B2, B3 and B4 worked closely. B2 is the most senior hardware engineer; he often helped B4 to solve hardware problems. Moreover, the team leader said that these three engineers would help each other to solve problems and sometimes share work. Interaction between them relied on face-to-face interaction. On-line interaction

in this team was not really important; at least none of the interview data suggest IT as a major influence on their interaction pattern.

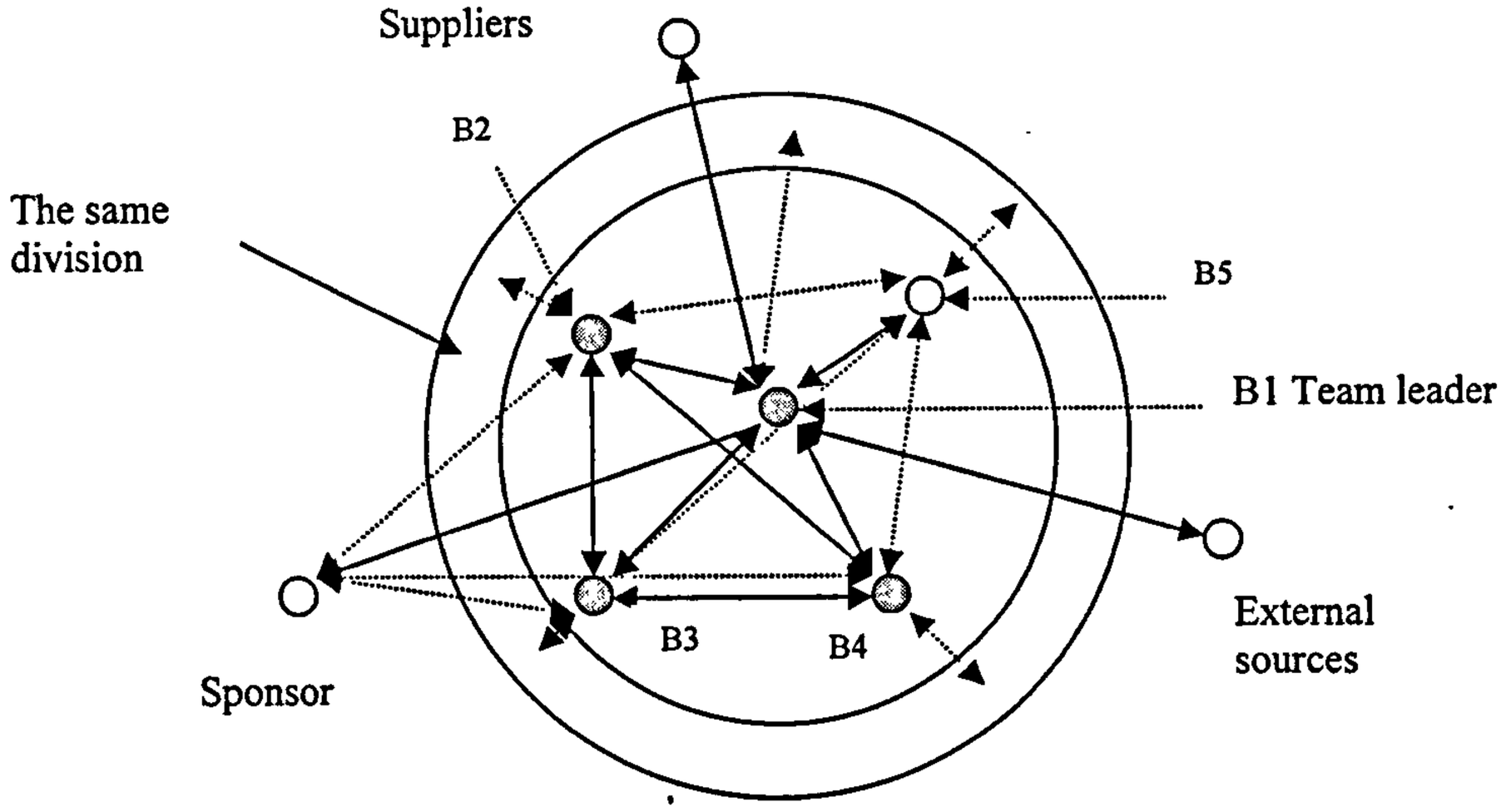


Figure 7.6 Team Interaction Team B

Team C

Interaction in this team was centred on the team leader (C1) (Figure 7.7). Some team members (C2, C3, C4, and C5) had their independent responsibilities. There was no particular need to coordinate each other's task in this team. The progress was reported to the team leader. Moreover, there was a task group with a hierarchy in which there is a manager (C6) between the team leader (C1) and two team members (C7 and C8). This research suggests that the team leader was a connector. Moreover, some meetings were held in order to discuss specific cases and announce important information.

In addition, according to the observation data (Table 7.2 and Figure 7.8), interactions between team members were more social in nature and procedural coordination. In Figure 7.8, Ca (the team leader) had many interactions with Cb and Cc because Cb was Ca's assistant team leader, and Cd was Ca's secretary. This research suggests that both Cb and Cd were the gate keepers of Ca, who were the bridges of transmitting information between Ca and team members. Moreover, team member Ch was an

assistant. who was in charge of assisting all team members. Therefore, Ch had frequent interactions with all team members; thus, the author proposes that this person took the role of an information node within the team. In this team, Ca, Cb, and Cd worked as a group, and they had more interactions and more chances to share knowledge and information. However, accounts of tasks (Cc, Ce, and Cg) and project managers (Cf and Ci) were working independently. Most of their interactions tended to be of a social nature, such as general chats. In this situation it seems that the interaction between team members tends to stem from social needs. It means that there are no particular issues and work-related items in their conversations and interactions, at least none that the researcher was aware of. The interesting point is that this social interaction can be seen as facilitating them to develop social networks within the workplace.

Moreover, in this team, senior team members work independently without much overlap; thus, they are not assigned the role of supervising junior team members. This decreases the interaction between team members. Also, this team's knowledge related activities in the development phase mainly consisted of obtaining external knowledge through interacting with external experts and consultants. Therefore, there are not many interactions between them to share knowledge and information.

Furthermore, the Internet in this team was relied on to access information sources and data bases. Most team members use MSN as a communication facility instead of visible face-to-face interaction. A team member (Cg) said,

> *'...we cannot work without MSN, it is so convenient. You can chat and forward information at the same time...'*

This was concurred by others. One team member (Ch) said,

> *'It is useful to keep in touch with your social circle (within the organisation) because it makes it easy to get information... '.*

This indicates that social networks in this team are emphasised and on-line interaction is one important channel for them to keep connected.

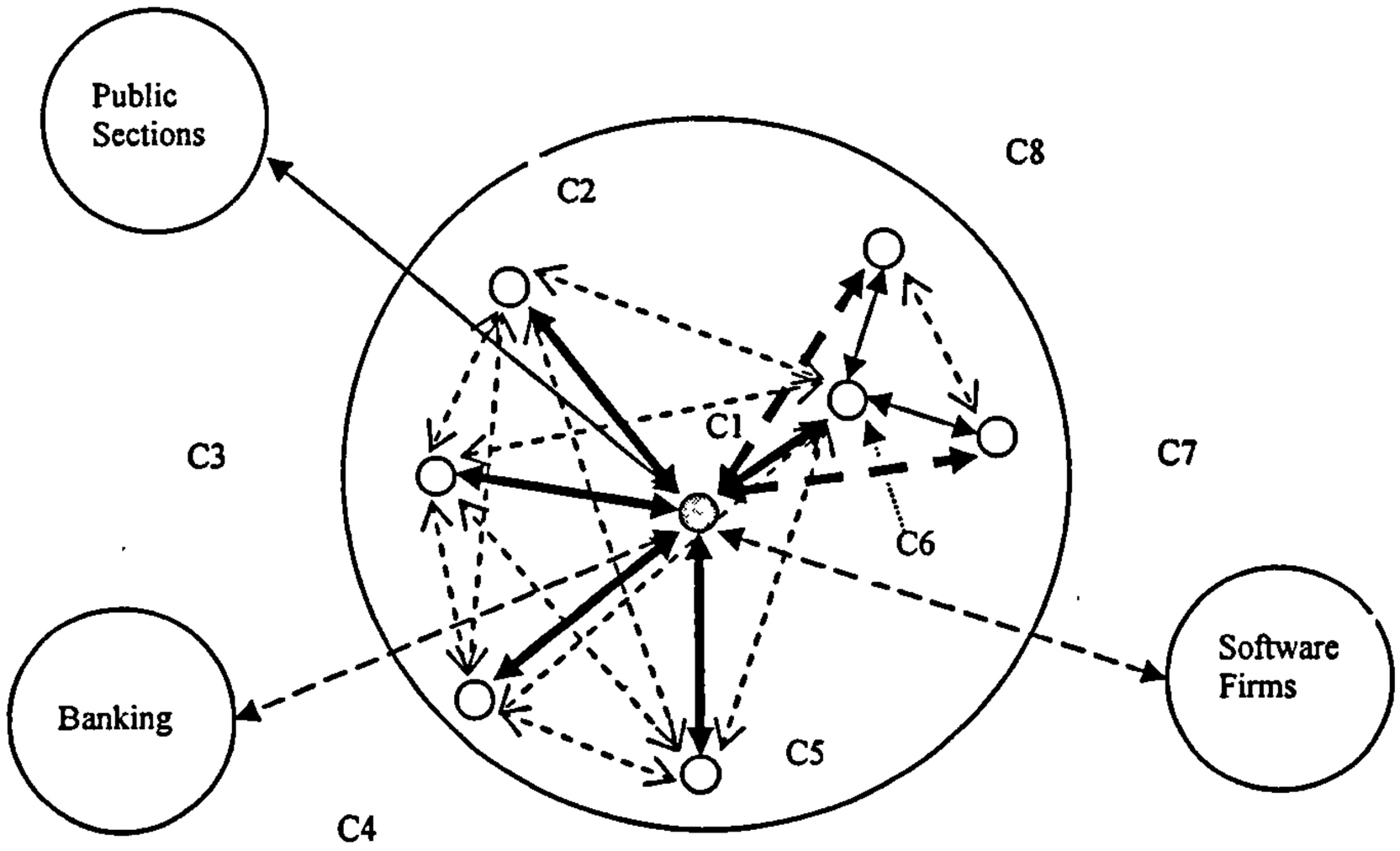


Figure 7.7 Team Interaction Team C

Table 7.2 Frequency of team interaction Team C (related to Figure 7.8)

Team C									Time span: one week		
	Ca	Cb	Cc	Cd	Ce	Cf	Cg	Ch	Ci	Cj	Foot note
Ca		17	1	22	13	7	8		8	8	
Cb			10	23	23	8	22	8	4	3	
Cc				6	3	6	13	15	7		
Cd					11	13	11	9	8	7	
Ce						4	31	18	11	4	
Cf							13	5	24	3	
Cg								41	14	1	
Ch									11	8	
Ci											
Cj											

Ca: team leader, Cb: assistant team leader and manager (load), Cc: account of load, Cd: secretary, Ce: account of assessment, Cf: manager (investment), Cg: account of investment, Ch: assistant, Ci and Cj: managers (investment)

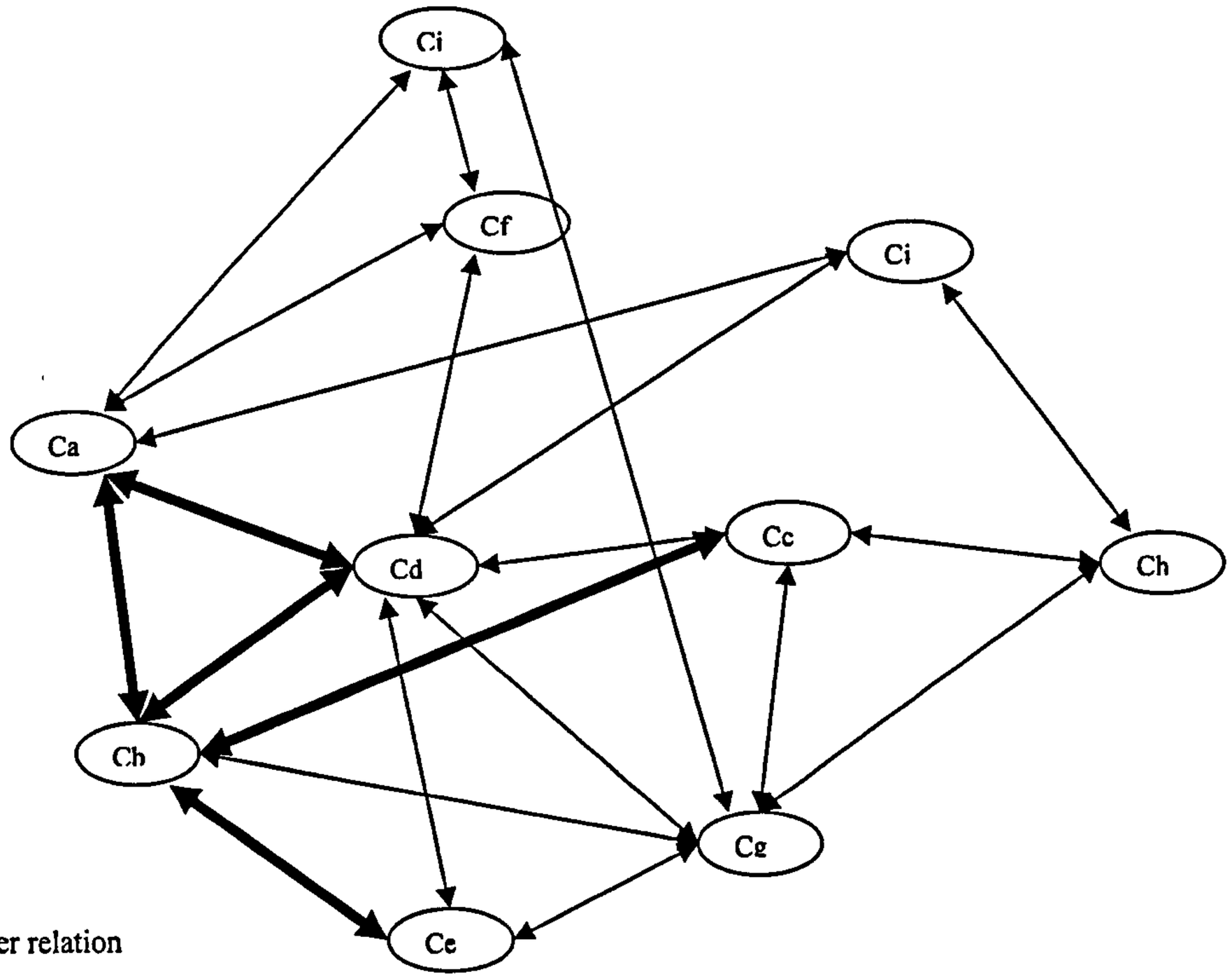


Figure 7.8 Team Interaction (observation) Team C

Team D

The interaction in this inter-organisational team was divided into two groups: leader group and member group. The interaction between leader group and member group was mediated by a senior PhD student (D1) (Figure 7.9).

There was a fixed meeting which was held every two weeks. This fixed meeting brought all the team members together to present the progress and discuss problems. This was the main opportunity for the team to communicate. One team member (D2) said,

> *'In our lab, we are quite close and have very frequent interactions. They are very spontaneous and flexible.'*

This group also held informal meetings every week to discuss each member's problems and possible solutions. The results were presented in the fixed meeting to the leader group who decided what solutions were going to be taken. In addition to team meetings, there was not much interaction within the team. The senior PhD student was the only person who interacted with all team members and controlled the progress, thus, he can be seen as a key (node) person in this team. The leader group in

this team was placed as the node to connect with external agencies through leaders' personal social networks. The on-line interaction was not emphasised in this team even within the different groups.

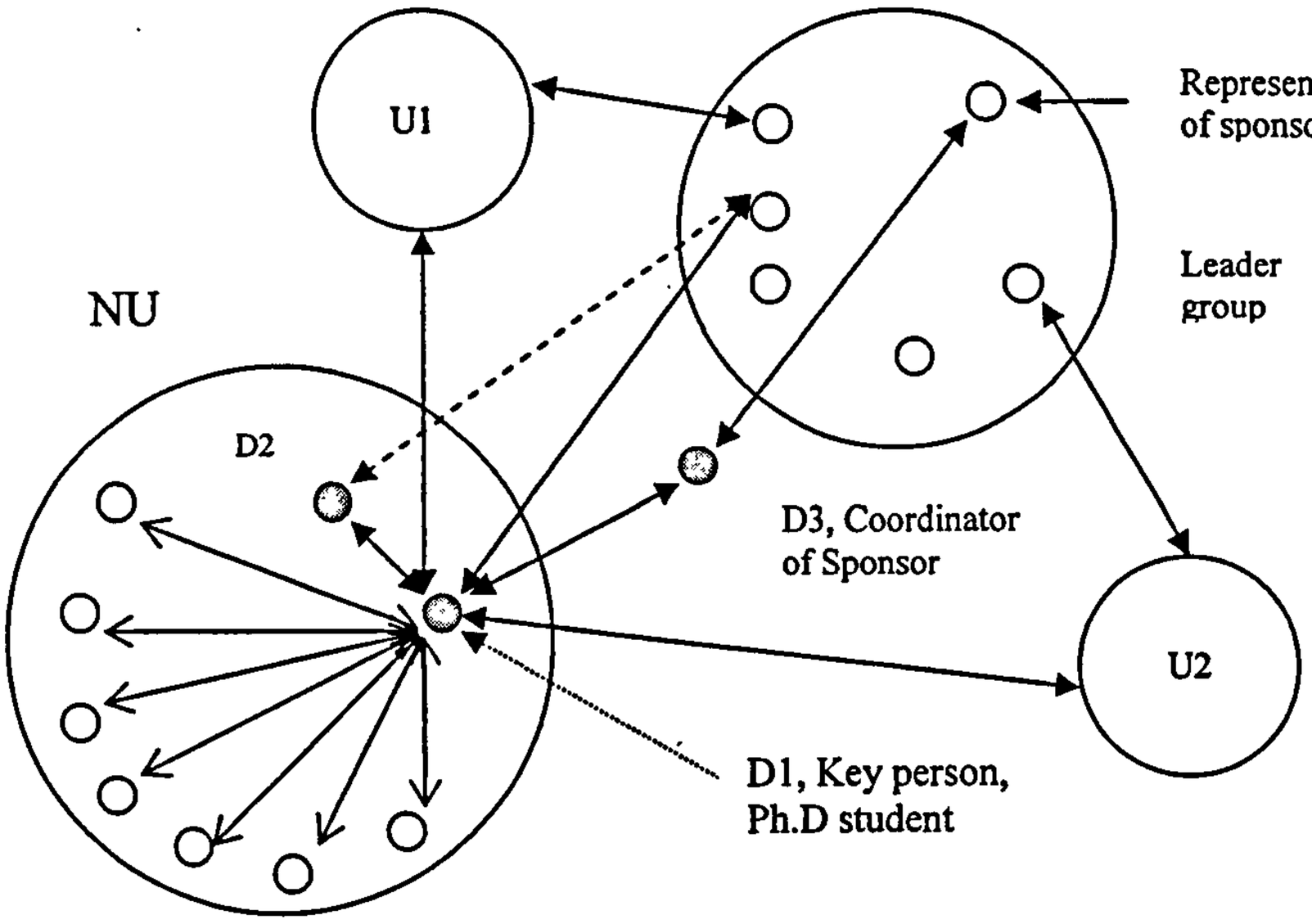


Figure 7.9 Team Interaction Team D

The above four teams have different interaction patterns, Team A and Team B tend to have more frequent internal interaction. This corresponds to what they indicated with regards to spontaneous interaction happening any time without a formal structure. In contrast, Team C and D are slightly more hierarchical, and interactions are centred on the leader or leader group. The interaction within these two teams tends to be formal. However, what this research suggests is that the team leaders in those four teams have the same role which is a connector. They are in charge of linking with external knowledge sources.

7.3 Summary

This chapter firstly summarises the factors which influence team operation and secondly point out team atmosphere as an important factor influencing team interaction with regards to situations of problem solving, knowledge acquisition and knowledge sharing. However, each team has different experiences of working

together and different ways of performing projects. This influences how teams practise knowledge management and integrate it with R&D activities. This research has found that a supportive atmosphere drives mutual help and spontaneous interaction. This facilitates knowledge management related activities to be undertaken through solving problems that emerge during R&D in progress. This result enables this thesis to respond to Research Question 2 on how knowledge management activities are integrated with the innovation process. This chapter points out that knowledge management is a practice involving many interactions within the teams. The findings suggest that these reflect the reality and the situations the team face and how the teams react to the situation to carry out their tasks. Therefore, it enables knowledge management to be carried out and integrated into innovation activities. However, how a team operates relates to its experience and knowledge. Thus, team operation is an important contextual factor in this thesis which is able to provide additional evidence to answer research question 3.

In summary, this research suggests that the role of the leader in teams and in knowledge management activities is diverse dependent upon the situations and needs. Each role is taken in different situations. Connector seems to be the most important role and is generally adopted across all teams. No doubt, whatever role a leader plays, the roles would facilitate them to initiate and sustain those activities. When the organisational environment is not ready for performing knowledge management, team leaders have great responsibility initiating various activities and responding to individual team members' needs. Once the environment has been developed, the role of the leader reverts to sustaining activities and proceduralise the activities into routines.

Team cohesiveness, personal attitude and team atmosphere are considered the fundamental factors in influencing team members' participation and team interaction, as three team leaders emphasised. This can be seen as a particular trait to Chinese culture as team cohesiveness is recognised as relevant to develop family like relationships, rather than just a working relationship. By emphasising this relationship, mutual support can be generated and inter-personal barriers can be removed. Meanwhile, team members' attitude to teamwork is also important. The data suggests that team leaders have great influence on changing team members' attitude

to become more participative, as well as lead a team to foster cohesiveness and develop supportive team atmosphere. An appropriate team atmosphere can sustain team members' interaction, communication and task coordination to continue, and further enhance team members' participation to engage in the sharing of information and knowledge. Moreover, team size and team structure are considered influencing team members' interaction and communication. Small teams normally have simple team structures, whereas large teams tend to have more hierarchical structures that inhibit horizontal interaction and communication.

There are three important types of interaction that emerge from the data: face-to-face interaction, online interaction and social networks. These three types of interaction are associated with sharing knowledge, acquiring knowledge and coordinating tasks. In this case study, an informal interaction is emphasised as it provide a flexible and less pressure environment for communication and discussion, which is considered important in knowledge management activities.

Team interaction in these four teams is influenced by each team's situations. The differences among the four teams are derived from their different R&D processes, team size, task division, and team composition. This implies that team situation influences a team's interaction pattern and further influences a team's knowledge-related interaction.

The following chapter will further discuss the undertaking of knowledge management within the team contexts, which is related to different aspects of undertaking knowledge management within teams, application of information technology in knowledge manaġement and the role of leaning in team knowledge management activities. This discussion will provide further evidence for the factors that influence knowledge management and the processes that enable effective knowledge management.

Chapter 8 Knowledge management in practice

8.0 Introduction

Based on the discussion in previous chapters, project characteristics, R&D processes and R&D contexts are important contextual elements which distinguish the situations and needs that the teams face. The above discussion on team operation relates to team dynamics which outlined team interaction in order to acquire knowledge and solve problem. This chapter focuses on how knowledge management related activities are undertaken within specific team contexts. This chapter explores the themes of knowledge management in practice, information technology, and individual and team learning.

Previous chapters have shown that different project teams have different contexts and needs which lead teams to practise knowledge management in different ways in order to respond to their situations. However, this chapter will show that the teams pointed out that different knowledge management foci in the organisation and the priority between R&D and knowledge management activities seems to be influencing knowledge management activities. Moreover, the use of information technology seems to change the way people interact and connect, which is likely to influence teams knowledge management activities. Furthermore, the following discussion will indicated that the teams feel that knowledge sharing is just transmitting messages. In order to make sense of messages, learning is required. The data of the teams will show how the teams perceive individual learning to be more important than team learning. However, an earlier discussion concerning team cohesiveness associated knowledge related activities with team learning.

In order to discuss the above issues in detail, the first section of this chapter starts with looking at different aspects of knowledge management across organisational hierarchy and the priority of knowledge management in the teams. This is followed by a discussion of knowledge management related activities. The second section discusses the influence of information systems on knowledge management activities and knowledge related interaction within the teams. The third section will discuss individual and team learning in the four teams. Moreover, earlier chapters have outlined that knowledge management within the teams involves many social networks. This is related to the knowledge-communities within the organisation. Thus, section four will further evidence this. The final section will summarise the discussions in this chapter.

8.1 Knowledge management within the teams

The purpose of team knowledge management may not be the same as organisational knowledge management because a team has limited functions and resources. A team relies on its organisation to give support to complete its tasks. However, in some circumstances, the organisation may not be able to provide all the support needed – especially knowledge resources. In this case study, this insufficient supply of knowledge or expertise from the organisation drives teams to focus their knowledge management activities on establishing knowledge accesses in order to obtain needed knowledge. In this thesis, the data indicates that this insufficiency of knowledge and expertise is mostly derived from the multi-faceted characteristics of projects that the organisation engages in. Moreover, although a knowledge management system has been established in this organisation, it focuses on collecting information and knowledge across the whole organisation for further use. However, the interview data shows that the system solves the problems of collecting documents about project outcomes but it fails to connect to how the outcomes are produced. A gap seems apparent between the way knowledge management is undertaken at an organisational level and team level. The interview data suggests that knowledge management in the teams is activities and interactions embedded in a team's action towards achieving projects or tasks. Therefore, knowledge management in teams is associated more with what they are doing and the social nature of interactions in order to obtain essential knowledge. The following sections will discuss the evidence and its implications.

8.1.1 Different aspects of undertaking knowledge management in organisational hierarchy

Even though there is a range of literature that discusses the value of knowledge in innovation and organisational practice and provides theoretical frameworks for managing knowledge, most of these frameworks are focused on the process itself (e.g. Nonaka, 1994; Wiig, 1993; Leonard-Barton, 1995). There is little literature that examines in depth the circumstance of team knowledge management activities in organisations (e.g. Eppler and Sukowski, 2000; Gray, 2000). By investigating four teams in a professional IT research institute, the data suggests that knowledge management activities within organisations are associated with organisational hierarchy where different levels of the hierarchy have different goals and operation scopes which may lead to different focuses and ways of undertaking knowledge management related activities. Organisational members may have different perceptions of the knowledge management activities, which relates to how they position knowledge management and how knowledge management relates to their work. This may lead them to form different knowledge management practices.

For example, the team leader of Team A indicated,

> *'At our centre level, knowledge management activities are aimed at generating technical synergy through sharing information and rotating engineers between teams. That is why we have a public server because it enables all technical documents to be stored and referenced.'*

The leader of team C also concurred, he said,

> *'Our centre is working on that (a public server), our director (centre) is making efforts on developing a system which is hopefully suitable for our work.'*

However, the data reports that at R&D team level, solving problems and making progress according to schedules is emphasised. The leader of Team B indicated,

> *'It is important to complete a project on time. During this time period, a lot of problems need to be overcome. The point is, how a problem is solved and the experience and technology generated from that situation can be used on others are important.'*

Therefore, problem solving becomes a very important initiator to trigger knowledge related interaction within teams and between team members. This causes knowledge management activities within the teams to be centred on solving problems in order to meet progress and project goals. The problem solving here is recognised not only as technical problems and know-how, but also where and how to access knowledge sources. This suggests that knowledge management activities at R&D team level tend to be associated with practical needs as presented above. In fact, it denotes that acquisition and sharing of knowledge/information can be the most important activities within the project teams. In contrast, storing of knowledge/information and diffusion of knowledge/information seem not to be considered very important issues within the project teams because they are associated with extra efforts, storing systems, and perhaps cross-team/unit barriers. A junior member of Team B indicated,

> *'I am the only one in charge of uploading all the documents to our KM system in our team. No one wants to do that because it is a lot of effort. I do not think others have time to do that.'*

This shows that it may be in excess of a team's needs and capability. In order to make the system a success, the leader of Team A indicated,

> *'It needs a strong support and pressure from top management (e.g. VP) or a routine to follow...'*

Furthermore, the data also shows that knowledge creation actually occurs in an implicit process which is part of problem solving processes. It is based on team members' experiences, discussions or brainstorming. In this circumstance, team leaders or senior team members may play a significant role in providing their experience and knowledge. For example, the leader of Team B revealed,

> *'I would not necessarily know how to solve the problem, but I can tell my team members my stories or what I thought from my experience. This may give them some clues for solving the problem, or may lead them to create new knowledge for particular problems. That is what I do.'*

The above shows that there is a gap between a centre and its teams in undertaking knowledge management. For the teams, knowledge management is more problem solving oriented which leads to interaction. In contrast, for the centre, it is more about collection and storing information and knowledge for use. In this case study, the use of a public server for storing documents is an example. Thus, in the teams, knowledge management is perceived as an activity which facilitates a team to enhance problem solving capabilities.

8.1.2 The value of knowledge management in the teams

Nonaka's (1994) model is aimed at sustaining organisational competitive advantage through knowledge creation. The data shows, as 8.1.1 presented, that R&D teams' knowledge management activities mostly focus on solving problems and achieving projects in which new knowledge is created through solving problems. Thus, its knowledge management activity may differ from what Nonaka's model aims at. The data shows that knowledge sharing (socialisation) and learning (internalisation) are the major activities within the teams. A senior member of Team C said,

> *'...to solve a problem...I can tell you my experience or how to do it, but it is not enough, you need to do it to get a sense...'*

A senior member of Team B concurred,

'It is not about what I tell you, it is about to try different ways and find out what works in your case.'

In this case study, externalisation and combination processes seem not to be particularly explicit or they are embedded in practising. In practice, knowledge sharing and learning are directly associated with individuals' tasks and project achievements (learning on job/learning-by-doing, see 8.3). In contrast, externalisation and combination processes are embedded in the processes of R&D through problem solving, and it is not essentially relevant to individuals' performance and project achievements. Therefore, it seems to be less emphasised by teams and their team members if there is no specific emphasis or organisational routine to promote it. This corresponds to Davies and Mabin (2001) and Hoegl and Schulze (2005) that successful knowledge management is about processes of how knowledge is shared and created.

The data from interviews shows when a team aims to accomplish a project with less cost, existing solutions and techniques will be adopted. For example, the internet is a main channel for teams to seek existing solutions (see Appendix 3, item 1). If there is not any available technological solution that can be adopted, the team may be forced to create its own solution. A senior member of Team B indicated,

'The problems we have, they need to be discussed with someone who has experience or knows this area very well. For our project, we mostly create our own solutions for solving problems.'

In this case, team members' experiences and connections with knowledge sources become important. This may explain why knowledge sharing and learning are the major activities within the teams because experience is an important asset for the team and it needs to be passed from one to another in order to sustain that knowledge within the team. Moreover, it also explains why the data shows that the team members rather rely on the internet and informal social networks (see Appendix 3, item 1) because both channels enable them to rapidly access knowledge sources for solving problems. A senior member of Team A said,

'The Internet and asking colleagues or friends are the quick ways to obtain information that you may need...'

The value of knowledge management and how it is positioned within a team/organisation tends to be associated with team leaders and top management's intention (Davenport and Prusak, 1998). The data of this research shows that knowledge management is commonly recognised as a significant activity to the teams and the whole organisation, as 8.1.1 presented. However, the consistency of promoting the activity seems to be insufficient, and does not fit the situation of the teams. For example, the documentary data indicates that since 1994, the organisation has performed several organisation-wide projects to enhance organisational R&D capability. The first project was adopting ISO 9001 in 1994, which was expected to develop systematised operation procedures to improve the quality of R&D. The second project was a knowledge management system that was launched in 1999. Through this system, the organisation wished to integrate organisational knowledge resources to sustain a leading position of R&D in the industry. The recent project in 2004 was to adopt the Capability Maturity Model Integration (CMMI) by which the organisation wished to improve its software development processes. Although every project had different focuses, it somehow interrupted the procedures that were developed by the earlier projects. In fact, when a new management project was launched, the whole organisation put all attention and efforts onto applying the new system. This caused the earlier system to be neglected or abandoned by the teams. This case shows that frequently applying new systems within the organisation causes unnecessary disruption and also confuses organisational members. For example, the leader of Team A said,

> *'Our focus now is CMMI, everything we have done is required to meet its standard procedure...we still make efforts on knowledge management but CMMI dominates our work at the moment.'*

In this situation, team leaders play a determined role to discuss with team members what they want to achieve and how they are going to apply the new system. The leader of team A said,

> *'It is confusing to the team members. For my self, I feel I have to give them a focus or priority which they can work on.'*

This may determine how much effort a team will spend on each system. This may relate to an earlier discussion in this chapter that the role of knowledge management within a team needs to be clearly defined because it facilitates a team to decide how much effort they are willing to spend and also what the emphasised activities will be.

For instance, the documents that they produce need to meet the particular system's requirement or they need to produce separate documents for a different system. A senior member indicated,

> *'ISO, knowledge management and CMMI for an engineer is all about paper work, you need to decide which one has priority within limited time.'*

8.1.3 Team knowledge management: knowledge acquisition and problem solving

The discussion in section 8.1.1 has shown that there is a different view between organisational knowledge management and team knowledge management. In team knowledge management, acquisition of knowledge and problem solving are focused. A team is a small unit with limited types of expertise and resources. To overcome this disadvantage teams need to build connections with different teams through communication or rotation of members. Therefore, cross-team communication and information sharing become very important to a team to obtain resources and access essential knowledge sources. However, the data from interviews shows that in practice, cross-team communication and sharing resources are difficult because of project differentiation and team competition. For example, a senior team member of Team A indicated,

> *'...cross-team or unit communication and coordination are quite difficult. It is sometimes more difficult than cross-organisational communication...'*

This causes knowledge acquisition and related interaction to be limited within team boundaries, and forces teams to rely on private social relationships to connect with knowledge sources and share knowledge. There are some features related to team knowledge management activities that are distinguishably different in the four teams, such as private connections with knowledge sources, informalised intra-team and inter-team interaction, composition of expertise and specific team learning process (which will be discussed in 8.3).

The data shows that the four teams in this research have their own knowledge sources for access. Most knowledge sources in these four teams are associated with team leaders or team members' private social networks. However, access to the organisational cross-unit knowledge sources is rarely mentioned. The leader of Team A indicated,

'...if you know someone in the other teams, otherwise, you have to ask a favour from someone to connect to these people. It sometimes works, sometimes doesn't. Therefore, mostly, we try as much as possible to solve problems by ourselves. If it doesn't work, we would try to contact someone we know...'

This quotation shows that the connections with knowledge sources are mostly developed by team members themselves through their past/current colleagues and friends. Therefore, these knowledge sources tend to be unique and personalised. In Team A, knowledge sources for this particular project are based on its senior team members. In Team B, knowledge sources are associated with its suppliers and previous team members for this particular project. Team C's knowledge sources are built upon a contract with consultancy and senior team members' social relationships with banks and the pubic sector. In Team D, knowledge sources are based on the Internet, three group leaders, and some specific external agencies in that particular subject. In these four teams, organisational internal knowledge sources are not considered important. This means that each team has its specific needs. Such needs can be satisfied by either the teams themselves or building connections with particular sources.

This also causes a phenomenon of informal intra-team and inter-team interaction because access to knowledge sources is mostly based on individual social relationships. Even in the same team, team members' interaction and the sharing of information is influenced by private relationship. For example, the leader of Team B indicated,

'...within a Chinese society, relationship between people is very important when it comes to sharing something with people...'

This personalised connection between team members or with external people facilitates knowledge sharing. The data (11 out of 18 interviewees mentioned this, see Appendix 3, item 1) shows that friends are the significant sources to ask for help and obtain knowledge because it makes them feel comfortable and eases communication. This is consistent with the literature (e.g. Nonaka and Takeuchi, 1995, Panteli, and Sockalingam, 2005) that mutual trust influences the quality of sharing of knowledge between people, and different levels of trust are associated with how much knowledge can be shared amongst people. In this case, social relationships and personalised connections are the significant factors that impact on how knowledge sources are accessed and how knowledge is shared in this particular context.

In addition, team composition is considered influencing a team's knowledge-base. At a team level, they seem to have limited or homogenous expertise composition. This affects a team's knowledge related and innovation related activities. For example, the data shows that, except for Team C, Team A, B, and D have quite homogenous expertise composition (Team A: information engineering; Team B: electronic engineering; Team D: information engineering). Most team members have similar backgrounds and expertise. This has disadvantages and advantages. For instance, a senior member of Team B indicated,

> *'...we are too similar in background and expertise. This doesn't seem good for the team, creativity is insufficient. Our views are too narrow and rigid on where we are familiar...'*

However, an advantage is, *'it makes communication easier between us'*, he also said. This relates back to an earlier discussion (2.2.1.2) that knowledge sharing is not only about transmitting messages but also about shared mental models and the use of common language. In addition, homogeneous composition may restrict a team's creativity. On the other hand, it may enable a team to focus on certain subjects and accumulate related knowledge in depth. This facilitates the team to develop its core capability over time. Meanwhile, this also denotes that such teams may need the connections with outside the team to obtain knowledge resources to complement their insufficiency in the expertise when different expertise and knowledge are needed.

The above three features (private connections, informalised interaction, and team composition) denote that in team knowledge management practice, the integration of functional units or project teams within the organisation is an important issue as a senior member of Team a said,

> *'We have difficulty in cross-team communication because of project difference, organisational procedures...'*

Meanwhile, current organisational structure and procedures may not necessarily initiate cross-unit or cross-team interaction and communication (further discussion in 8.4). This indicates that official connections within the organisations seem to be substituted by organisational members' personal social networks when the teams need access to external knowledge sources. Also, based on these social networks, the teams and team members may have a broad connection with either organisationally internal

knowledge sources or outside organisation's knowledge sources. This corresponds to Rulke and Galaskiewiez (2000) that social networks are more important than formal structure to exchange and diffuse knowledge.

8.1.4 Organisational context and social context influenced team knowledge management and knowledge related interaction

Each organisation has its own history, value, belief, and vision. These factors interact to form an organisation's specific context. This organisational context influences its climate, operation, performance, etc. For example, the organisation that this research investigated is a public sector organisation. Its vision is to assist the Information and Communication Technology (ICT) industry development in Taiwan by enhancing Taiwan's ICT R&D capability. This leads the organisation to be involved not only in developing ICT but also playing a role as a technical source to the whole industry in Taiwan. With this specific vision, the organisation formed a specific context interacting with different sectors. The organisation has developed specific features, such as developing a technology stream based organisational structure and project based management, playing an industrial technology provider, supporting government policy, and running different types of projects (e.g. different sponsors, technologies, and types of innovation) that help defining its context.

These characteristics construct the organisation and make the organisation different to other organisations. For example, project based management facilitates self-managing teams to be created and teams have rather high autonomy in organising resources and making professional decisions (6.2). This specific organisational context allows teams to undertake projects in different ways according to team situations and project. However, it also indirectly prohibits the interaction and communication between labs or between teams. This disadvantages the flow of information and knowledge within the organisation.

Within an organisation, each division or team has its own divisional/ team context based on their experiences, subjects and team composition. For example, the data shows that the four teams in this research have different team contexts which are associated with each team's project experiences and team composition (4.5). This difference between teams can be perceived and distinguished by the team members. An example is given by a member of Team A. He reveals the differences between two teams that he has experienced,

'...I worked for the other lab before I came here; people there have a very different working style. They do not interact and communicate with each other, they are very serious, they seem to work on their own. So, I cannot remember colleagues who were next to me after I left that lab. In this team, we actually talk and work together.... The team leader, he is friendly to us. So when I had a problem, I went to him directly, he always gave help...'

This statement portrays that within the same organisation, different team climates result in different patterns of team interaction and communication. This further influences their knowledge related interactions between team members. The data shows that these four teams have rather different team situations which have been highlighted in chapter 4. Based on the teams' contexts, knowledge sharing and exchanging in Team A and Team B tend to be performed as routine and intra-team interaction is emphasised (7.2.6). In Team C and D, due to their needs of external knowledge to support the project (6.2, Table 6.1), knowledge sharing and exchanging tend to emphasise the use of social relationships (7.2.6). These two different situations result in two different perceptions of mutual trust. In these four teams, mutual trust between the knowledge holder and receiver is not recognised as very significant, but it is noticed when faced with external agencies in Team C and D (Appendix 3, item 6). However, it is also recognised differently between the team members and the team leaders. The following quote highlights this difference:

'...for them (team members), they just need to concentrate on their work, I give them my sources; therefore, they do not need to negotiate with outsiders. They do not have pressure to deal with maintaining these sources and building connections...' [The leader of Team C]

Some team members indicated that they are in general concerned with professional interaction, rather than personal relationships or familiarity in the office (11 out of 18 mentioned no influence, Appendix 3, item 6). However, some leaders have different opinions. From the team leaders' point of view, the sharing of knowledge seems to be associated with individual social relationship, especially when knowledge is shared with external agencies. For example, the leader of Team B emphasises the importance of '*jiao qing*' and '*guanxi*' which mean interpersonal relationship with someone especially outside the team, and the leader of team C emphasises social networks (7.2.5.3). This difference seems to be influenced by the position that team members and team leaders have in the team or organisation. Therefore, they generate different perceptions of why they share knowledge. In fact, in this case, the team members

often focus on their task and rely on the team leader as a connector (7.1.3). Therefore, within the office they do not really recognise the importance of social relationships. However, it is different for the team leaders as they play the connector. This use of social relationships in this research context is considered associated with local social context (Kim et al, 1998; Wang et al., 2006).

In a Chinese social context, social relationships are recognised as having great impact on individuals needing to be connected to external agencies. Social relationships make it easier to access different groups of people or knowledge sources (Wang et al., 2006). However, for the team members, they may not have to face external partners (7.1.3). Therefore, it is not recognised as significant. Moreover, for most team members, they have different perceptions and manners to deal with social interactions in the office.

This indicates a special situation in which the members who take NCS may have a specific connection and subculture which distinguishes them from other organisational members. This also facilitates them to create extended social networks within the organisation. These specific social networks enable them to interact and exchange information with externals. Therefore, there is not a strong distinction between inter-team and intra-team based on their specific social networks. A member of Team D (who is a coordinator in Team D coordinating three groups) indicated,

> *'It is quite obvious during our lunch break that you sit with your friends from the university who work for different labs or office. So, you can know a lot of people from the organisation. It is sometimes useful to know someone and build connections.'*

Another example is also given by him:

> *'Once, I was discussing a problem with my friend on the phone, we spent a lot time trying to figure out but we did not come to any conclusion. At that time, my friend's friend was on the other line talking to my friend; he told his friend what problem we encountered. Fortunately, his friend knew the area very well. Then, I discussed with his friend my problem on the phone; we got to the point very quickly and found a solution...'*

Moreover, considering the above discussion of the evidence presented so far, the thesis suggests that the mutual trust between two people can be substituted by social

relationships (Wang et al., 2006). This is based on both knowledge receiver and knowledge sender knowing the same person and having a clear purpose for engaging in the sharing of knowledge. This also means that the holder of this connection acts as a node person in which trust is rooted on both sides. Underpinning this connection and understanding, the data suggests that the quality of sharing information and knowledge can be better than in a non-connection situation. For example, the leader of Team B noticed that he was willing to support this research because of a friend of his, who asked him to do a favour to support this research,

> *'...here, I am willing to support your research that is because T asked me. We have been colleagues for quite a long time and we are quite close friends, so I am glad to do this...I will provide you essential information and details as much as I can do...'*

This indicates to this research that this connection is important for access to external groups and knowledge sources and it also facilitates the quality of accessed sources. In addition, this connection is not only considered useful to access external groups but also facilitates building new social networks. In this context, access to knowledge sources in most situations is secured by using social relationships or connections in which the team leader and senior team members usually play a significant role to mediate this kind of connection. The literature to date lacks a clear discussion of the potential to substitute social relationships through mediation. A forthcoming paper by the author adds significantly to the discussion of the role of trust in knowledge management (Wang et al., 2006)

In this context, group distinction (e.g. NCS versus non NCS, intra-team versus inter-team, and interest group) and mediation of social relationship may be the significant factors of the social context beyond the team members' recognition of how they judge the issue of familiarity and its influence on the sharing of information and knowledge. This is because they work in a specific social context in which the sharing of information actually takes place in a developed social network. Therefore, the issue of trust and familiarity may not be taken as seriously by some team members.

However, for some non NCS members, different aspects seem to define trust. For them, trust in someone and sharing of information is by knowing people's background and experience of previous interactions. As they indicate it is a mechanism to screen or evaluate other people by which they can decide whether or not they are willing to ask questions or share knowledge. However, this would not be recognised as mutual

trust but it is working all the time in their mind to find appropriate people to talk to within teams or organisations. A member of Team C said,

> *'...if I need help from someone else, I must know him/her, and I am sure that they can contribute an idea. Otherwise, I would not ask...'*

A member of Team B concurred,

> *'...to ask who you know in this place, or ask colleagues who can help...'*

This seems to underlie the pattern in the workplace that people mostly interact with someone they know in terms of background and expertise. Therefore, trust is actually embedded in knowing people. Also, the use of social relationships may be greatly influenced by social context in this case. This implicates that social context has an influence on knowledge management activities in which knowledge and information are travelling through social networks. To access knowledge sources somehow requires the use of social relationships to connect with particular agencies or sources.

The above discussion shows that team knowledge management within an organisation is a set of context-influenced activities which are associated with different views of undertaking knowledge management at different hierarchical levels. Also, an insufficiency in knowledge support drives team knowledge management to focus on acquisition of knowledge and sharing knowledge in order to solve the problems that teams encounter. In order to access knowledge sources, the data also suggests that social networks and social relationship are important factors which influence knowledge access and knowledge sharing. This relates back to the previous discussion in chapter 6 that R&D contexts influence a team's knowledge management activities and also in chapter 7 that discussed how a team operates and interacts is associated with access to knowledge sources and knowledge sharing to enable problem solving. The above discussion is able to answer research question 1 in that problem solving is an important initiator and purpose in team knowledge management.

As this section discussed, interaction with people is an important channel to access knowledge sources, the data from interviews also reports that the internet is an important channel to access knowledge sources (Appendix 3, item 1) and information system is important facility to store knowledge. Therefore, the following section will discuss the influence of information technology on team knowledge management.

8.2 The influence of information technology on knowledge management activities

8.2.1 The influence of computer-based information system

Computer-based information systems are widely employed in organisational management, they are not only employed to improve organisational efficiency, but they are also considered to be a crucial facilitator for knowledge related activities. It provides the most efficient function to rapidly transmit large amounts of information in real time. Nonaka et al. (1996) investigated the impact of information technology (IT) on the knowledge creation model and suggested that: 1.) IT tools are not only facilitating explicit knowledge exchange but also facilitate tacit knowledge exchange by using video technology, 2.) through electronic tools (e.g. e-mail and intranet) to reach information redundancy which facilitates organisational members to know what others are trying to articulate, 3.) IT facilitates R&D teams to undertake virtual prototyping to implement and test new ideas by using simulation technology.

The first suggestion indicates how IT plays a significant role in terms of information and knowledge sharing and exchanging in an organisation or a knowledge community. For example, in this thesis, most interviewees are heavily relying on the Internet (10 out of 18 interviewees mentioned this, Appendix 3, item 1) as a tool to explore, search, and acquire related information and knowledge for solving problem (Appendix 3, item 1). Even searching for internal information, most interviewees would prefer using internet search engines because it makes searching easier as one member of Team A indicated, '*via Google to search and connect internal web pages is much quicker than using our intranet*'. The reason for using the Internet is that engineers consider the Internet to be able to link a large amount of information and data which helps them to obtain a wide-range of general information and clues. Through the Internet they can know what people are doing in the world-wide community, rather than only know what internal teams or individuals are trying to articulate. This seems to partially concur with the second suggestion, information redundancy. The difference is that informational redundancy is world-wide rather than organisation-wide. This indicates a significant and specific characteristic in the IT industry in which competition in business and technology is global. This makes the Internet very important to people who work in this industry. A senior engineer of Team A mentioned,

> *'...you would want to know other teams not only in Taiwan but also in the U.S., Europe, or Japan, what are they doing right now. In this industry, technology is changing too fast...'*

However, the use of the internet to access external knowledge sources also encounters problems of validity and reliability of the data and information. A member of Team D said,

> *'...there is a large amount of information, but you cannot really identify its reliability in the sense of how one comes out with this idea. Has it been tested before? Therefore, you might just have a look at other people's efforts. I don't really take it directly...if I want to use them. I will try to get in contact with the authors (engineers) to get more details...I don't usually believe it all...'*

A member of Team A agreed,

> *'...information or data from the internet is inaccurate and fragmented, you need to know exactly where it is from, if it is necessary, you should contact them and ask for details.... It is always an idea to get clues from internet...'*

Heavy use of the Internet can also be explained by several factors that emerged from the data. First of all, organisational knowledge management systems, intranets, and project teams' public servers provide a limited amount of information and data bases. These do not necessarily support current and future needs, as '*information technology is developed and update so fast, different generations of technology cannot necessarily be compared*', one of the interviewees concurred. In Team D, the project team (NU) originally adopted KERNEL as a system platform for the project. However, when the new teams joined the project, they suggested using a new version of KERNEL as a system platform. This caused the previous efforts to be abandoned, and the NU team had to go through the whole process to re-test all cases. This seems to point out a crucial issue that knowledge management systems and its activities in the IT industry have specific requirements. This supports the author's claim that knowledge management is a context-specific activity that needs to consider context and needs for each situation. In this case it implies that a knowledge management system should address global range and rapid change.

Moreover, the question as to whether previous knowledge and experiences can be employed in newly created projects which are based on new generation technology is debated. During the interviews, some of the engineers indicated that in their experiences, previous knowledge and experiences in a particular project seems unhelpful on this kind of new project. The tool software is upgraded or renewed very

quickly so they always need to learn and familiarise themselves quickly to this new tool and its programmes. This kind of discontinuity and rapid development often appears in the computer software domain. Namely, upgraded versions of software may not only add new functions and change the interfaces, but can also change the original design of the systems structure to enhance operational efficiency. This usually means that the engineers need to put in more effort to learn and adapt to the new versions of that software. Therefore, the effectiveness of sharing specific techniques and experiences with regards to a specific software programme between engineers or within the team is sometimes doubted by engineers: '*you hardly look back at what you have done as you always face new and challenge,*' a senior member of Team A said. However, some interviewees agree that previous experiences may facilitate them to shorten the learning curve, as well as improve their ability to solve design and operation problems. A member of Team B indicated,

> *'...you may not be familiar with new software or a technology but experience helps you to figure out the logic that it is based on. Then you can learn quick...'*

This expresses a truth in the IT software industry; rapidly upgrading operating systems and application software may cause compatibility problems. It also reveals a specific phenomenon that R&D teams in IT software domains may need a wide-range of information access to update new technological and industrial information. In other words, it requires a world wide informational redundancy, rather than internal informational redundancy. Also, this rapid progress feature leads to a requirement of intensive learning for engineers in order to adapt to upgraded software systems.

The adoption of simulation technology could renew an organisation's R&D processes (George and Williams, 2004) and shorten development schedule (Nonaka et al., 1996). Through simulation, a prototype can be built, implemented and tested on the computer. This facilitates R&D teams to integrate knowledge, and also to create new knowledge through solving problems. The data of this research shows that this technology is commonly adopted by Team A, B and D. For example, in Team A, the test of logical computing was applied in programmes to detect the errors of logic structure before they began to develop functional modules.

8.2.2 Computer-based virtual knowledge communities

Nonaka et al. (1996) indicate that computer-based information systems greatly influence organisational knowledge management activity. This research finds that it also influences people's behaviours in terms of sharing information, communication

and interaction, and managing data. For example, the data shows that other than e-mail and intranet, instant chat facilities are commonly used in the four teams. All engineers in the four teams used instant chat during office time as a member of Team A said, '*it is a convenient communication tool for us, it is very efficient for communication...*' A member of Team C also added, '... *I cannot work without this (MSN).*' This seems to indicate that most of them are relying on instant chat facilities as a communication tool.

> '*...we used it for online meetings in a co-operating project with a team in Hong Kong. It is actually very convenient, and you can also send the data online during the meeting, so we can discuss and check documents at the same time...*'
> [A senior member of Team A]

Except for convenience, the data shows that each team member has his/her own communication group on the instant chat facility in which friends, colleagues and co-workers are included. This enables them to contact and communicate with each other anytime when they are online. This is considered facilitating information exchange in real time. However, the data also shows that communication on this platform does not only involve business but also involves social interaction. This makes people interact more frequently. For example, the data from interviews shows that in Team C, communication through instant chat is approximately equal to that of telephone, especially at non manager level. A member of Team C revealed, '*we use a lot MSN to communicate or chat or message, except our boss...not only business but also private...*' In most situations, this tool is employed to communicate with friends/colleagues (social interaction) and coordinate tasks with co-workers who may be in the same team and same office. The contribution of this tool is '*you do not need to waste time or put things away to ring someone particularly, just message someone, and have a quick chat, and then things are done...*' a member of Team A said. This seems to point out their work style which is computer-based work. Moreover, information exchange through MSN is brief but random and frequent. The details are normally shown in the attached files or discussed through telephone or face-to-face, which is dependent upon situations. Since instant chat facilities came out and were applied by a large number of people, it has been considered to have a great influence on sharing and exchanging information between people and within a team because it copes with distance and time (Driskell et al., 2003). However, as the data shows, face-to-face discussion and interaction are considered as important for sharing knowledge and details (9 out of 18 interviewees mentioned this, Appendix 3, item 3).

This seems to confirm Lucas and Baroudi (1994) that the Internet not only influences access to knowledge and information sources, but also impacts on people's interaction and communication models. Namely, in some circumstances, the Internet provides many alternatives which can be used for interaction and communication. Within certain situations, it can be further developed as a virtual community in which information can be shared and exchanged rapidly and it may provide a diversified environment for people with various information and perspectives. This facilitates teams and team members to advance in knowledge acquisition and learning in knowledge management and innovation activities.

This section shows that information technology, especially the Internet, is an important facility to teams and individuals for access to knowledge sources as well as interaction on-line. This indicates to this thesis that a team's knowledge sources are from a variety of communities from physical communities to virtual communities. It facilitates teams and individuals to update information and learn new knowledge. This further influences a team's decision-making in terms of creating projects, adopting new technologies and seeking solutions. With these influences, this thesis considers that information technology has an influence on the whole process of team knowledge management as well as innovation activities.

Although information technology is an important facility in knowledge management, the data from interviews shows that it cannot deal with sharing knowledge in depth. As a senior member of Team C said,

> *'It is an e-version documents that you obtain from the Internet. The problem is if you cannot understand what it means you cannot really talk to the author or someone. So for important things, you still need to talk to someone face-to-face.'*

Moreover, the use of on-line interaction within the four teams is because the team members already know each other. On-line interaction provides a convenience. Indeed, an earlier discussion (8.1.2) indicates that experience and knowledge is an important asset for the teams. A team expects that important experience can be sustained within the team through undertaking knowledge management. The data from interviews shows that in order to perform knowledge management effectively within the teams, to develop a common understanding and align team action (7.2) are important. This builds on the notion of mental models outlined within the literature review and its relevance highlighted in regards to successful knowledge exchange.

Understanding the process of developing shared mental models relates to how a team undertakes team learning; therefore, the following section will discuss team learning.

8.3 Team learning

This research argues that knowledge management processes should be undertaken with consideration of learning processes. Hence this research outlined learning in the literature review (2.2.3) to explain why it is important in knowledge management activities. However, during the interviews, it transpired that the teams see individual learning as more important. However, the data also showed that team learning takes place associated with how a team leader brings the team members together. Hence, issues are raised which are related to different managerial aspects and their influence on learning, development of a common understanding, a practice-based view of socialisation and different ways towards team learning. The following sections will discuss this in detail.

8.3.1 Learning within the teams

The data shows that within the organisation or teams, learning systems are focused on supporting individual professional learning rather than collective learning. A member of Team C said,

> *'The organisation provides many training opportunities and courses, you can apply for it...most courses are professional but they also offer something like language courses...'*

A member of Team A concurred,

> *'You can choose, for example, if you are interested in something new you can start from basic courses to very advanced courses.'*

This leads to a situation where the organisation intends to offer a diversity of constructed training courses or on-the-job-training. This leaves a gap in collective learning. Although, there are plenty of professional training courses provided by the organisation, there is not any course that is related to collective learning. Therefore, the improvement of teamwork and team learning is imposed on the team leaders according to their rationale in which they may educate, communicate, and encourage team members in order to enhance teamwork (also see 8.2.4, team atmosphere) or achieve certain purposes. The collective learning here seems to depend upon a team

leader's rationale with regards to development of team cohesiveness and creation of a supportive team atmosphere (7.2). The leader of Team C indicated,

> *'...the learning of professional knowledge and skills is not difficult for team members as they all have the basic qualification in professional skills. The most difficult thing is to change their personal attitude toward their jobs, to learn new knowledge and to take part in teamwork.... The only thing I can do is to communicate with them, sometimes educate them...'*

The leader of Team C concurred,

> *'Team learning is able to share and have similar thoughts. From my opinion, as I said, team cohesiveness is important, and I always emphasise this to my team members...'*

This evidences that a team leader's intention and attitude are important to develop collective learning within the team. In this case study, collective learning seems to build upon a team's consensus in which team leaders seems important to align team members.

8.3.2 Similarity in background and communication during team learning

It was highlighted already previously that for the leader of Team C frequent communication with the team members is very important. This facilitates team members to form similar values and beliefs as he said,

> *'I try to deliver something which is important to teamwork.'*

Moreover, in Team C, lectures and seminars are frequently held. This is considered a way of enabling team members to build an essential knowledge base in this specific project, considering their diverse expertise. Such lectures and seminars enable them to understand different areas and further reduce the gap between them. However, this team did not seem to hold any training course to improve team members' non-professional skills. Instead, the team leader adopts the way of communicating with individual team members and coordinating different tasks and people to work together. A similar situation also emerges in other teams as other team leaders said,

'...no need to call a meeting...waste their time...if I feel the need I come to see them...' [Team A], *'...if I have something to communicate with someone, I would find him...or he would come to see me...'* [Team B], *'...each team member has individual time to talk to a team leader (or supervisor)...'* [Team D].

Therefore, individual communication between a team leader and a team member is an important way to connect team members to undertake teamwork. Two reasons can be identified from the data that indicates why specific training in team working skill is seen as unnecessary. Firstly, this may result from team leaders' involvement as the leader of Team C indicates that *'I play a coordinator to integrate team members to work together.'* The leaders of Team A and B have similar opinions. The leader of Team A suggested that his role is *'to integrate them to enable communication.'* The leader of Team B saw himself *'to break down individuals and see the team as the whole...'* Secondly, a harmonious atmosphere and similar interests/habits provide facilitators to enable them to actually communicate with each other in terms of work related and non-work related issues.

Moreover, similar backgrounds or common experiences are also considered significant factors when it comes to enhancing team members' interaction, assistance and co-operation in formal and informal situations. For example, in Team A, team members help each other. This is because most of them have similar experiences which enable them to have an understanding of each other's job, build co-worker relationships and also have much more coherent mindsets. A member of Team A said,

'...we have worked together for an international co-operate project in Germany years ago. During this project, we lived together, spent much time together. It was not only working but also playing and travelling, so we got closer and know each other quite well. This makes it quite easy for us to ask for help, or share something in terms of work and life...this actually makes our interaction, communication, and coordination quite different from other teams in this office...much easier...'

Similar situations emerge in the other three teams. For example, in Team B, team members have worked more than five years together, and they have similar knowledge backgrounds. The team leader said,

'My current team members have worked together for at least five years, they chose to stay when they finished their NCS because they like to work together.'

In Team C, similar working experiences or expertise increases interaction between some team members because *'we have similar subjects to talk about and we can help each other,'* a senior member said. In Team D, the team members who are supervised by the same professor have closer interaction and tend to automatically help each other. A member said, '*working with the same supervisor makes us to become closer; therefore, we have more chance to communicate and also help each other.*' This seems to indicate that interaction and communication between team members are supported by an informal relationship. This relationship is built upon similarity in terms of experiences, interests, and backgrounds. A senior member of Team B revealed, *'similarity makes communication easier because you can understand each other's language. This perhaps facilitates to form what you called common understanding.'* This seems to relate to collective learning (Senge, 1993) in which a common understanding is suggested as an essential element. However, the data of this research shows that in these four teams, no specific way has been emphasised that outlines their team learning process. In fact, as above presented, team learning in each team is undertaken associated with different factors that they emphasise as above presented, namely team members' common experience, similar expertise and education background.

8.3.3 Practice-based learning and socialisation of new-comers

The data shows that most interviewees considered that learning by doing is the best way to learn and practice new knowledge. It is also an economic and convenient way to learn related skills and knowledge. With this view, in some of the teams, senior team members are assigned the task to supervise and guide junior team members and newcomers. In this circumstance, knowledge transmission between them is not only professional knowledge but also individual experiences in terms of project operations, social network building, and social skills. For example, on one occasion, the leader of Team C had a conversation with a new project manger,

Leader: *P! When are you going to hold the meeting in EA?*

P: *Two o'clock this afternoon.*

Leader: *I think I will go with you....*

Leader: *My job there is to understand what they want? These officers have never clearly said what they want to see. You need to listen to them carefully and know their language. Otherwise, you may just waste your time to prepare a lot documents and they may not be interesting to know.... What am I trying to tell you is, you need to know them.... Sometimes you need to guess but you cannot guess right without knowing them...I will help you till you can catch up...*

P: *I know...*

Leader: *You need to cultivate this sense gradually.....*

P: *I think I have got a little bit.....*

In this conversation the team leader tries to tell the new project manager what he should learn and pay attention to when he interacts with government officers. This social skill could be based on an experience of the team leader that he had during the last few projects. If the new project manger had not been told, he might have never known and never fitted in with government officers' requirements. This explains why practice-based learning and assigning supervisors are bounded as a common training model for newcomers within those teams. The team leaders in this research generally consider that learning professional knowledge is not difficult but practical/operational knowledge and skills are difficult to be learned and taught. It could take time for team members to adapt and learn. For example, case-by-case story telling and sharing experiences are considered good ways for sharing knowledge. A senior member of Team C indicated,

> *'Our project had many unpredicted situations occur; therefore, when you want to share your experience with others, you need to tell them your stories, otherwise they would not understand...'*

For newcomers, telling stories can make it easy for them to understand a new environment and further adapt to the environment if they are guided by senior peers. However, this model may not be a successful for team learning but it facilitates individual learning. The leader of Team C indicates that this model does not succeed in all cases. Some cases fail because of the dependence on the personality of the supervisor and supervisee. He said, *'it depends on people, sometimes it works sometimes not, because some people can learn very quick...'* In Team A and B, this

model is applied and the team leaders consider that this model works well at the initial stages of a project. When the newcomers are gradually familiar with the team environment the supervision is no longer functional. The leader of team B said, *'you need to guide them. Once they are familiar with environment and people. They can develop.'* At this stage, the newcomers' interactions with other team members become more important because it brings the newcomers into a deeper understanding of the team. It also causes the development of their social networks. This enables them to integrate with others and become part of a team's learning processes. This corresponds to Senge's (1993) collective learning process which is about alignment of a team's members actions.

8.3.4 Team learning

Team learning is also called collective learning. It is 'a process of developing team members' match and ability to achieve a common goal' (Senge, 1993). This indicates that collective learning aims to enhance the entire team's ability through matching team members and coordinating team members' roles and tasks, rather than focusing on individual professional skills' learning. In other words, team learning is a process to build shared team mental models by which the team members 'possess similar cognitive representation of specific situations and phenomena' (Cannon-Bowers et al., 1995).

Senge (1993) suggests three dimensions of team learning: firstly, extraction of team intelligence, secondly, innovativeness and consistent actions, and thirdly, the roles of individual team members and each team member's influences on other teams. Team intelligence is often empowered by individual intelligence within the team. Therefore, to extract team members' intelligence to be used relies on a clear assignment of role and task, and aligns the thoughts and actions toward the same direction. For example, a senior member of Team A indicated,

> *'...in general, as a senior team member when I am assigned a supervisor role, I will help my supervisees as much as I can because I am assigned this role. It means that I am in charge of supervisees' achievement as well as their tasks' achievement...but I always said to them, think about what you want to know before you come to me'* .

These quotations evidence that to clearly define the question enables knowledge to be shared between people. More so, to clearly define the role and task of a team member facilitates the team member to think how he or she can contribute intelligence to the

work and team. This provides a scenario in which every team member has a role to play.

In addition, every team member may have his/her thoughts or mindset to view the work according to his/her expertise and experiences. This may result in inconsistent actions to deal with the situations that they encounter. Therefore, to develop shared team mental models to enable them to generate similar cognitive representation of the situations is necessary as it relates to the basis of sharing tacit knowledge between team members. This facilitates a team to build its team knowledge (Ayas, 1996) where team knowledge may not be shown in an explicit way but shown implicitly by being embedded in how the team processes the project and solves the problems. The data of this research suggests that team learning can happen in many different ways which are associated with the team leaders and team contexts. For example, in Team B, team learning is underpinned by team values where members automatically help each other (also see 7.2.1 team cohesiveness). The relationship between them is a family like relationship. Therefore, a common thought exists in the team:

> *'...ask your team members when you encounter the problems...think of how your client likes it to be looked at when you encounter the conflict between different tasks...'* [A senior team member of Team B]

This common thought guides the team members to deal with their jobs and solve the problems.

In Team A, team learning is based on senior team members' common perceptions with regards to knowledge sharing and how the project is processed, a senior team member said, '*we learned a lot from previous projects, now we are applying that to our new project.*' On this basis, senior team members act as the tutors and knowledge sources to deliver their beliefs and knowledge to socialise junior team members by supervising and reviewing tasks. In this team, the formation of team mental models is through continuous discussion between senior team members and junior team members. This facilitates them to build common understanding relating to the team and this particular project. The leader of Team A said,

'If you cannot, just ask, if you can, just give a hand. This is what it is all about to teamwork. We found this is important value to the team.'

Team C has a different view to form a common understanding between team members. In this team, the team leader continuously communicates with individual team members to deliver his thoughts,

> *'...I behave as a leader ...I communicate with team members and deliver some of the values which I think are great to them... (I think) attitude and value are the most important issues (to teamwork), and then is expertise (that I am concerned with)...'*

In this team, although team learning was not particular mentioned, it is actually taking place implicitly embedded in the information that the team leader tries to deliver to the team members to create common team values.

In Team D, due to its specific features as a cross-organisational project, team learning is not an issue they would think of. In this team, a temporary professional relationship brings four groups to work together. This leads the four groups to work independently and to share information in a formal way. Moreover, a consideration of protection of intellectual property also leads them to keep this distance. Therefore, team learning in this team was not an issue.

Team learning is not based on what skills or knowledge have been learned but it is based on how team members reach consensus in actions and perspectives through effective coordination and matching people to tasks. In this organisational context, the team leader has a crucial influence on coordinating teamwork and initiating team learning. However, the differences in leaderships and team contexts also lead teams to approach team learning in different ways. In these four teams, forming common team values seems to be regarded as an important basis toward team learning. This confirms Espejo et al. suggestion (1996) that successful organisational learning is based on 'co-ordinated action' in which shared vision and values guide team members toward the same direction. With this common value and co-ordinated action, team members may find it easier to interpret other team members' behaviour and thinking. This may make Nonaka's externalisation and combination modes possible.

This section has shown how these four teams develop common understanding and reach consensus to enable knowledge management to take place. As a senior member of Team B indicates that a team's consensus not only influences knowledge management activities but also influences a team's teamwork:

'Team consensus is important to teamwork which enhances communication and mutual help, and also sharing knowledge...' a senior member of Team B

It enables a team to enhance its knowledge and R&D capability. Therefore, Team B takes challenge to move their research focus from ATE to RFID because the team leader said,' *I believe that we have successfully developed both our software and hardware R&D capability.*' This shows that learning processes influence a team's knowledge management and innovation activities. Moreover, it influences how a team selects its project and arrange its R&D processes and contexts to fit in with new project and also adjust its team operation to enable knowledge to be managed. Therefore, this thesis considers the influence of learning processes (individual and team learning) across the whole model as an important element.

8.4 Inter-team knowledge interaction – centre-based knowledge community

The earlier sections has pointed out that social network is an important factor in knowledge management. Therefore, this section will further discuss knowledge communities, as these are related to knowledge communities. The concept of knowledge community is considered a community in which diverse but related knowledge can be converged, exchanged, stored and applied through appropriately connecting and integrating people and databases, and effective communication. For example, an organisation can be seen as a knowledge pool consisting of a variety of knowledge and its divisions can also be seen as many sub-knowledge pools in which each knowledge pool may consist of knowledge converging at the same or related areas. It can also be further divided into smaller units along the organisational hierarchy. In this research, a team is the basic unit that is of interest with regard to knowledge pools, and a centre is a unit of gathering teams with similar technological focus. Therefore, the discussion here focuses on the team and the centre as within a centre the teams have similar characteristics in terms of technology focus and knowledge base.

Chapter four has shown that each centre has its own focus in a specific technology domain, and its teams have different foci and projects. This leads a centre to have heterogeneous features in terms of production and technology. It may be considered an advantage to have diverse knowledge sources. However, in this organisation, this is not an advantage because interaction and communication between teams is rare. Also, they do not particularly expect to find knowledge sources from other teams either within the centre or the lab. The leader of Team A indicated,

'Each team has its own expertise and project features, it might not be related...also, every project for us is new, it is a kind of exploration...thus, it is quite difficult to say that we can support each other. It is by chance...'

From this statement, the leader of Team A seems to suggest that knowledge sharing and experience exchange are important between teams. However, each project has its specific characteristics which are considered irrelevant to other projects in terms of product concept and technological focus. This differentiation in the projects seems to cause problems in a project-based institute to practise cross-team interaction and communication. In fact, most interactions between teams are constrained at individual level through personal social networks in the organisation, such as NCS, interest groups and past colleagueship. This facilitates individuals to obtain help for solving problems.

Although there is no strong connection between teams within a centre, there are three possible opportunities which may connect teams to form a knowledge community. The first one is information systems, the Intranet or public servers. The second one is the relationships between team leaders, and the third is the directors of centre's involvement or coordination between teams.

The influence of information systems has been discussed in section 8.2. The relationship between team leaders is an important connection which drives communication between teams as their relationship would encourage them to help each other and communicate with each other. This enables knowledge and information to flow through each team. The director of the centre's involvement and coordination can help teams to communicate with each other. However, it is usually ignored by the director of the centre. Therefore, some team leaders consider that creating an official procedure to guide teams to practise inter-team interaction for knowledge and information exchange is necessary. The leader of Team A said,

'Knowledge sharing is difficult to take place in a cross-team situation because there are no rules or procedures that we can follow, it is actually based on personal social networks and relationships...'

Inter-team communication and knowledge sharing is a good idea, but not embedded in practice. An alternative way to share or diffuse knowledge between teams is

seconding available engineers from other teams to support new projects. The leader of Team A indicated,

> *'...seconding someone from the same centre is easier, just go through the director of the centre and the other team leader... from other lab, you need to go through VP...it is difficult...'*

This may be an example that knowledge is shared and applied within a centre. The data shows that Team A has several engineers who are temporarily assigned to other teams to assist new projects. However, it also shows that this kind of secondment is sometimes used as a strategy to keep managing human resources flexible within the centre. This means it is not a deliberate part of inter-team knowledge interaction activities. Moreover, this situation only appeared in Team A and its centre. It did not appear in other teams. Thus, it may be a specific case in this centre but not a general case in other centres.

Moreover, the data also shows that inter-centres and inter-laboratory interactions in terms of knowledge sharing and engineer exchange are much more difficult to promote. It not only involves focusing on the technology differently but also involves unit strategy and advantages. Thus, it requires top/senior management's involvement to undertake inter-unit coordination and integration. The senior member of Team A said,

> *'The competition between teams sometimes causes a problem in exchange of engineers. No one wants to give a capable engineer away. So, higher management needs to get involved...'*

In this case, VP level's involvement is required, as was suggested above.

In the case study, knowledge communities at centre level are implicitly existing and based on the shared information systems and personal social networks. The evidence shows,

> *'...I know someone in our centre who has a specific skill that I need, I always went to him to ask questions...'* [A senior member of Team B], *'...if I know someone in this office who can help me, I would go to him/her...'* [A senior member of Team C]

This implies that forming a knowledge community within the centre or organisation is not only about creating procedures and information systems to bring teams together and encourage communication but also about knowing people in the organisation. As earlier discussions have shown, face-to-face interaction is the most popular channel for sharing knowledge. Therefore, an openness of information systems and a supportive environment for people's communication are important factors in forming knowledge communities in this specific organisational context.

8.5 Summary

Based on the above discussion, this research suggests that knowledge management activities at team level and organisational level have different foci. Team knowledge management activities are related to access to knowledge sources for satisfying emerging needs which may not be able to be obtained from the organisation. This leads knowledge acquisition and sharing to be prompted by problem solving. In the case studies, team knowledge management activities display features with regards to personal connections with knowledge sources, informalised intra-team and inter-team interaction, specific team learning processes, and homogeneous expertise. These features bring team knowledge management very close to social aspects of knowledge management rather than information system based knowledge management.

In addition, knowledge management are the activities associated with specific organisational contexts. The data suggests that it should be fostered by an organisation itself based on its history, beliefs, values and mission. Similarly, the teams within an organisation also have their own histories, experiences, beliefs and core values. These conduct a team's behaviour and the way of seeing and applying knowledge management. In these particular cases, social networks are a significant factor which influences interactions among team members as well as between teams, and further influence the access to knowledge sources and sharing of knowledge. This most significant finding is this thesis' suggestion that mutual trust in knowledge sharing situations can be substituted by the use of social relationships. This further strengthens the premise that knowledge-related interactions are part of social nature of interaction and local social contexts.

Computer-based information systems are a crucial facility to knowledge related activities in organisations. They facilitate information and knowledge to be stored, transmitted and diffused within the organisations, and also connect with world-wide organisations. However, in these particular cases, internal data bases may not be

adequate for the organisational members. In fact, they rely much more on external information and knowledge. Therefore, access to external knowledge and information sources through computer-base information system (e.g. Internet) is essential. Moreover, communication tools not only enable people to form a virtual community for exchanging and sharing information online but also change people's interaction models. This influences the way and frequency that people interact, and also influence the activities of knowledge acquisition and sharing within organisations and teams.

Learning is part of knowledge management activities. In this case study, individual learning is still highly emphasised within the four teams and team learning is addressed by forming a common value and reaching consensus in action. Team learning not only influences knowledge management activities but also influence a team's teamwork. It enables a team to form a common understanding which facilitates communication and knowledge sharing. This thesis considers that it is an important foundation to enable Nonaka's externalisation and combination modes to take place. This facilitates a team to enhance its capability for innovation and further build its core capability.

Knowledge community is a significant element of knowledge management which facilitates sharing and learning knowledge. In this case study, it entails inter-team communication, information systems and social networks. The data suggests that it implicitly exists within this organisation. However, different project characteristics and technology focus deter teams from communicating with other teams. Therefore, information systems and social networks are the significant factors that facilitate people in communicating and sharing information in this case study.

By outlining team knowledge management in the four teams, this chapter is able to answer all three research questions. Firstly, team knowledge management is found to be a needs-driven activity related to problem solving in the innovation process. This provides the answer for Research Question 1. Secondly, this driver leads knowledge acquisition and sharing to take place alongside the processes of R&D in order to solve emerging problems. This provides evidence responding to Research Question 2, which looks at the integration of knowledge management and innovation. However, such need-driven knowledge acquisition and sharing does not connect with regular knowledge sources. Therefore, social networks and a supportive atmosphere are required. Moreover, in order to effectively access and share knowledge, information systems and team learning are important factors with regards to accessible knowledge

sources and aligning team action. These influential factors of team knowledge management also provide the answer for Research Question 3.

The next chapter will build on this evidence and discuss further knowledge management activities in innovation process and its influence on the process and team performance.

Chapter 9 Innovation and knowledge management activities

9.0 Introduction

Chapters 5 to 8 have discussed the themes which influence team knowledge management. This chapter discusses how this team knowledge management process influences a team's innovation practice and performance.

If innovation is a strategic goal to sustain an organisation's leading position in the industry, knowledge management is the processes that facilitate the organisation to achieve this goal through sustaining and developing its knowledge and capability. This indicates to this thesis that successful innovation within an organisation is dependent upon knowledge and how well knowledge can be managed. As earlier discussed in chapter 5, innovation in the organisation is associated with factors that determine project selection and the specific characteristics of projects. However, project selection is influenced by several factors which stem from the organisation's specific contexts. Hence, the consistent technological focus may not essentially occur in the organisation's R&D teams. Indeed, the teams' R&D focus may move around different technology streams in IT area. This may cause problems in the accumulation and application of knowledge and expertise, because required knowledge and expertise between the projects may be rather different. This results in difficulties for teams or organisations to make a clear long-term plan giving guidance for their innovation movement and to develop their competencies. However, this inconsistent focus from one project to another may facilitate a team to have broad experiences and knowledge in the IT area which may enhance a team's capability in the application of technologies.

In addition, such inconsistent (or called shifted) focus can create a situation in which a knowledge gap and technological gap between different projects needs to be seriously considered and solved. In this research, the data shows that if organisational R&D contexts cannot cover such gap or there are no internal knowledge sources for support, the team autonomy and the team leader become important factors that influence the success of a project. In fact, team autonomy enables a team to seek specific knowledge sources for a project and also enables a team leader to organise his/her team and needed knowledge sources for the project.

Therefore, it was shown that project selection is associated with a team's knowledge and capability, and how it influences a team's development of capability.

In order to build on this understanding, the first section of this chapter will discuss a dynamic scenario of innovation and how it influences a team's knowledge management. The second section will investigate how knowledge management activities take place alongside innovation processes and how teams manage knowledge to respond to different situations. The performance evaluation highlights what the major concerns are for the organisation. It is a guideline which conducts organisational members' actions and attentions. Therefore, the third section will discuss how project performance is evaluated and how it is related to innovation and knowledge management activities.

9.1 Innovation – a dynamic scenario

9.1.1 Single focus or shifted focus in technological innovation—innovation strategy

In recent decades, innovation has been seen as a fundamental element of sustaining an organisation's competitive advantages (Tidd et al., 2001). However, it can be widely practiced in many different domains. Thus, setting innovation goals, scope, and the approach may need to be clearly defined. However, innovation may involve a large amount of investment and further relate to an organisation's development in the future. Therefore, any innovation strategy being made may need to consider organisational situations and short-term as well as long-term demands.

According to Teece (1996), technological development exhibits strong features in path dependency, cumulative nature, and irreversibilities. This causes technological innovation moving along certain technological paradigms. This indicates that the achievement of innovation in the short term is an important basis of ongoing innovation in the long term, because related knowledge and expertise can be developed and accumulated over time, which contributes to innovation activities.

However, in an environment where technology changes rapidly, the potential issues within a technological paradigm may be rapidly adopted by mass R&D teams around the world. This may cause difficulties for R&D teams to stay in the same technological paradigm for any extended period of time as related research efforts are launched very quickly. In such circumstances, R&D teams and organisations may have to develop a dynamic capability of managing knowledge assets (Teece, 2000) to select and handle new projects that may be rooted in technological paradigms different from their usual or preferred paradigm. In this highly competitive

environment, whether the short-term goals will essentially relate to the long-term goal is debated. In fact, this causes an ambiguity for organisations to position themselves and to systematically organise their knowledge and expertise.

Moreover, the projects accepted are not only determined by the factor of the technology domain that the organisation has addressed but are also influenced by other factors, such as political consideration, organisational performance (annual revenue and profit), and each unit's benefit and future planning. Therefore, the projects that are selected by a team may cross different technology streams in which the team or organisation may not have its major expertise. This relates back to the discussion in chapter six in which the projects are sponsored by different funds related to different purposes and types of innovation.

This research shows that a long-term innovation strategy is rarely seen in the organisation and its teams. In the short term, the types of projects are also inconsistent. For example, in Team A, the last project was involved in the development of mobile phone testing environment development. Its current project focuses on an application of a two-band mobile phone to develop a double loop presentation system. Contrary to the former project, the current project aims to develop a technology for a further development of an end user product and the project is involved in voice and data transmission technologies. The earlier project was an industrial product and involved communication testing technology. This change in the R&D focus was caused by a situational pressure, namely that there was no longer a similar project required in the near future. The team has to create new projects to survive and achieve financial performance. Therefore, the team widely explored the various trends of mobile technology for one year. They finally decided to engage in the development of the two-band mobile phone technology. This decision was considered to be contributing to the team's effort to create performance and R&D focus, but it is considered irrelevant to the previous R&D projects in terms of knowledge and expertise. As the team leader indicated,

> '*There is not an exact direction for them to predict what type of project will be the next.*'

The future direction depends on the organisational intention, commitment and technological development. In this case, it proves difficult to form a clear innovation strategy because teams may move their R&D focus over time according to the situations in the wider environment.

In Team B, the innovation strategy is also not clear. For example, its previous project addressed the development of ATE technology. The current project focuses on a development of RFID technology. Both technologies are rather different. The team leader indicated,

> '*This was a great change to the team. It was an opportunity. A few years ago, I met an internal expert who predicted that RFID would be the next wave of technology development, and it would be used in logistic management...*'

The team leader also said,

> '*After that meeting, I was thinking what would be the next topic for the team to focus on. Through several months of consideration, I decided to invest in RFID technology. The reason was that RFID technology is a new technology. It could be broadly applied in different areas. ATE technology in Taiwan would not have better development in the future. Therefore, I invested, and it seems to be a great decision so far. We have a lot of projects coming next year...*'

This case also indicated that innovation within a team is sometimes derived from an occasional event or specific chance. It is not imperatively happening along an expected path. This doubts the necessity of formulating an innovation strategy for either the short term or the long term. However, this case also shows that the team has built up its core capability in hardware systems over the last 10 years and that change is aimed at extending its existence through applying their knowledge and expertise to new projects. This can be seen as different from Team A. The leader of Team B commented on the current project in the following words:

> '*...we have accumulated a large amount of knowledge about hardware and software systems from previous projects (ATE technology). This is very useful to our new project because our engineers have fostered better techniques to deal with both hardware and software problems and system integration...*'

From these two teams, team (or department) performance and team existence are the most significant reasons for the teams to change and undertake innovation. Thus, innovation strategy is not necessarily made within teams. However, Team B showed that the team leader's intention was a significant decision towards the direction of the innovation. Moreover, the leader of Team A indicated that the vice president (VP) and

head of the centre are the two main people to conduct the direction of R&D and project selection. The VP usually indicates the goals and performance requirements for the labs and centres, and the head of centre is usually responsible for distributing resources which influence the team leaders to set the goals for the team, and select or create the projects. The leader of Team A said,

> '*The final decision is usually made by the team leader and the head of centre, VP usually respects our decision except extra-spending*...'

In this organisation, all new projects have to be sent to the expert board in which the experts examine the proposals and according to the results of this examination give advice in terms of technology and innovation focus. This is a significant mechanism to give ideas to teams to modify their projects or to make projects much more promising in terms of final production and technological focus. These seem to present a situation that innovation strategy is randomly coming up in the R&D teams according to a team's situation in the organisation and technology trends in the industry. In these cases, the trend of technology development and the expert board provide a direction for the teams to follow. In addition, a team leader's insights are the most significant factor to direct a team's innovation. This corresponds to Damanpour (1996) that managerial attitude towards change influences the adoption of innovation.

Furthermore, these two cases also show that project-based teams seem to have a difficulty in converging innovation focus, learning direction, and knowledge management into a structure for long-term practicing and developing their core capability in focused technological areas. A crucial problem here involves goal setting and time frequency: who sets the goal and over which time period should it be achieved? An R&D team's existence is usually for achieving a specified organisational purpose. If a team's goals conflict with the organisational goal, how is the team to obtain the necessary resources to continue its R&D? Also, if the conflict is recognised by top/senior management, how long is the team allowed to survive? For example, there was a conflict over performance between Team B and its centre during the current project (RFID technology). More specifically, Team B was asked to take on more projects to enhance its performance (the project was passed by the head of centre). However, the team leader considered that, since they were developing a new technology, they had to concentrate on this project without distractions. Therefore, he rejected the advice from the head of centre, he said,

'I would aim at new technology development, rather than split efforts to deal with irrelevant projects. I chose to lose one year's performance to accomplish new technology...'

This presents a situation where in practice, performance considerations or some other external reasons could affect a team's focus in innovation. In this case, the team leader seems to be a strong negotiator with top/senior management. Therefore, the new technology can be successfully developed in this team within eighteen months. During the new technology development, the team leader suffered strong pressure and warnings from top/senior management, but he said,

'I took this pressure and avoided to interrupt my team members' work.'

This portrays that a team's innovation strategy is also influenced by some organisational factors which may not be controlled by the team itself. For example, since Team B successfully developed RFID technology, top/senior management has tried to create another team to engage in the same technology in another laboratory. This means that the new team may obtain a commitment of investment from top/senior management, and Team B may have difficulty to obtain investment from the organisation to do further R&D in RFID technology. This leads Team B to face a dilemma. Either the team leader makes efforts in technology transfer projects, or he creates new projects by focusing on new technology. If the former scenario is adopted, technology transfer projects may be able to create income and enhance the team's financial performance. If the second suggestion is taken, the team leader may have to find the funds. In this case, the leader of Team B opted for the first scenario, namely, technology transfer. This indicates that forming an innovation strategy seems to be unnecessary for a team because it is mostly conducted by higher level or top/senior management. Also, a team's autonomy depends on the organisational structure and top/senior management's permission. This restricts the teams from moving away from the organisation's overall direction and keeps their attention on organisational requirements. This corresponds to Saleh and Wang (1993) that organisational strategy and structure influence entrepreneurial activities and innovation within the organisation.

However, the above situations seem not to happen in Team C and D. This is because Team C is a new sub project split from a long term project. Therefore, the team does not need to think about the future and re-focus of what they are engaged in, as the leader of Team C said,

'Our entire office (centre) is established for this long term project; therefore, it would not change as long as the main project is continuing...'

For Team D, the senior member (the project coordinator from sponsor) said,

'This is a temporary project, once the project is finished, the team would not exist. At the moment, we are thinking about how to apply the outcomes from this project.'

9.1.2 The influence of shifted innovation focus on knowledge management activities

Uncertainty in the future may cause teams to loose focus in the knowledge management activities and this could cause three great influences on teams. One influence lies in the individual team members' attitude on engaging in knowledge related activities. The second one relates to how the teams fill up the knowledge gap to carry on a new project. The third one concerns the building of the team knowledge base in depth or breadth. For example, what are the things worth learning and sustaining? Do they have to make efforts on unique cases which may never emerge again? For this reason, the team members may have to think about and decide what knowledge is useful and how they are going to learn and sustain this knowledge.

The data shows some of the team members considered that if they would never use the knowledge or expertise again, they would not make specific efforts to learn it, because they have time pressures from the project sponsors and industrial competition. For example, a senior engineer of Team A indicated,

'...it (technology) is developing so fast, I am not sure if they (project-specific technical documents and experiences) need to be sustained, you always learn new things, and you have no time to look back...'

On the other hand, for a knowledge holder, if he or she considers that some knowledge is not really necessary for the tasks, he or she might just give very brief notes that they considers being enough for others to carry on their tasks. In this situation, the sharing of knowledge between team members may just quickly pass over because they do not think that they need to go in depth.

> '*The point is what you need is to help you to solve the problems, I cannot give you everything. Therefore, you need to prepare yourself before raising your question,*' [a senior member of Team B suggested].

Moreover, the data also shows that sharing knowledge between team members is mostly focused on '*helping other people to solve the problems*'. In other words, to solve a problem or difficult situation that they face has a much higher priority than sharing knowledge itself in the work place, and to which depth the knowledge is going to be shared is dependent upon the problems that they try to solve. Therefore, with an unclearly defined innovation focus and limited project life cycle, knowledge management related activities in the teams are not structured. In fact, it is problem solving orientated and dependent upon a team leader's intention and the force from the organisation. The evidence from the leader of Team A and some interviewees,

> '*...if top(senior) management (VP) asks specifically or makes rule, I think most of us will do (documentation), otherwise, it is difficult to get engineers to do documentation properly...we are too busy...*' [The leader of Team A]

> '*...boss's attitude is an important factor, if he supports these activities...*' [A member of Team A]

> '*...a leader, if he can create a nice environment and climate, I think it would happen naturally...*' [A member of Team C]

The reason for this situation is that individual team members do not have a clear idea of where they are going to be in the future in terms of technological achievement. This may suggest that effective knowledge related activities are bound to a consistent direction in innovation activity because innovation goals are an important direction in which to guide knowledge related activities towards the accumulation and application of knowledge from undertaking projects.

In addition, shifted innovation focus also results in a knowledge gap between current focus and new focus when both are not in the same technological streams or areas. The data presented in previous chapters has shown that the team leaders are the key personnel to deal with the situations in which negotiation and use of social relationships to obtain essential resources are important, although the projects may have the budget to rearrange essential equipment and experts. However, due to some considerations the teams may not be able to obtain what they expect. For example,

recruiting new staff may be a consideration because the teams are concerned with their performance and team size. Therefore, secondment of staff from other teams may be a possible alternative to recruiting new staff from outside. Moreover, a team may not possess the necessary knowledge for the new project, in which case the team leader may need to use personal social relationships to connect with external experts or friends to bring in the new knowledge. This gives the team and the team leader autonomy to run the team. This seems to be an important factor which allows the team to have its own way of undertaking knowledge management activities by recruiting specific expertise to the project. This also relates back to the discussion in chapters 7 and 8, that each team has their own team interaction model and way of undertaking knowledge related activities.

As discussed above, innovation focus and shifted innovation focus are consistently associated with different results of accumulation of knowledge and capability. This may cause a cross influence in which the organisations or teams tend to pursue both advantages. For example, Figure 4.1 illustrates that a team may undertake a radical innovation project (advanced technology, government funded) first, and then move on to incremental innovation projects (technological application and technology transfer, private funded). For example, the data in this study shows that when a new technology has been mastered by a team, the organisation may ask the team to create application projects to apply this new technology, which means that application projects can create income for the organisation and also give the team opportunities to practise their technology. To some extend, this may *'enrich a teams' experiences in a particular subject and give a chance to search next target'* the leader of team B said. Although these three different situations (in Figure 4.1: advance technology, technological application, technology transfer) may not be related to this research's focus, however, the data shows that the four teams are respectively in different positions and have different emphasis on practising knowledge management to support their innovation activities. This will be discussed in the next section.

9.2 Knowledge management activities in innovation processes

Innovation can be seen as a combination of exploitation and exploration (March, 1991; Petersen et al., 2004). Exploitation uses existing knowledge or technology to create new or improve current objects. Exploration discovers or creates new knowledge or technologies from unknown areas. This presents the significance of

knowledge for innovation and also clarifies the relationship between innovation and knowledge. Namely, innovation is a knowledge-based activity in which different knowledge elements are applied to achieve certain goals. However, the way innovation is undertaken is very firm-specific (Tidd et al., 2001) and relates to an organisation's technical resources and organisational capabilities to manage it (Tidd et al., 2001).

'*Innovation is a process rather than a single event.*' (Tidd et al., 2001, pp. 50) Thus, from the highest level of abstraction, it can be seen as a linear process including a sequence of phases (Leonard and Sensiper, 1998), the first phase of which is idea generation, which is then followed by development, adoption and testing. The final phase is implementation. In this process, different phases are related to different knowledge inputs, and followed by different team dynamics. For example, an earlier discussion in chapter 6 indicates that different types of innovation are associated with different knowledge inputs which are either fostered by the project team itself or by external organisations. This leads to different team dynamics of acquiring and applying knowledge from different knowledge sources. It also influences the project teams to focus on different goals when they undertake knowledge management activity. For example, it was shown that knowledge management activity in the incremental innovation teams is more concerned with sustaining and diffusion of knowledge. On the other hand, it was evidenced that in the radical innovation teams, knowledge related activity is more focused on building connections with external agencies to obtain essential knowledge. This differentiation causes the teams to undertake the projects in different ways, which means different R&D processes, team dynamics, and addresses of knowledge management activities.

9.2.1 Idea generation and earlier development phases

In the idea generation phase, the ideas are generated by the observation of technology developments, market trends, and specific strategic insights. It starts with divergent thinking down to convergent thinking through continuous discussions and small decisions (Leonard and Sensiper, 1998). These ideas may be proposed by individuals or teams according to their positions and expertises. For example, the ideas from marketing teams may reflect the demands in the market. The R&D team may propose ideas based on technological trends and applications in the future. The ideas can also be generated through co-operation between different divisions or individuals. In teams, the ideas may be suggested by team leaders, individual team members, or their combined efforts. It may also be passed on from higher management levels. This means that idea generation could involve any participant within the organisation.

However, based on the case study in this research, ideas within teams are mostly generated by the team leaders or the senior team members because they are in charge of a team's performances and existence in the future. Individually, it also relates to the team leader's career life in the organisation. Therefore, it is a responsibility as well as a career pressure to the team leaders to search ideas for future projects or for solving problems. Ideas can be a new product concept or technology which can be further developed in the future, or a piece of advice based on individual experiences and skills which enable team members to solve technical and non technical problems.

The data shows that in these four teams, the team leaders usually play the role of idea generator or initiator in terms of creating a new project and the senior team members play the roles of developing ideas and solving problems. Generating ideas for new projects is associated with experiences and different views of seeing technology trend. Solving problems is associated with experiences and the capability of accessing to essential knowledge sources and use of knowledge. This respectively gives the team leader and the senior team member different roles within the teams. As the leader of Team A indicates,

> *'...this new project, I spent quite some time to doing research to see what will be needed in next few years. I got some ideas but I found that "two band mobile" would be very promising because its technology has not been successfully developed when I proposed this idea. I heard about that a few companies are engaging in this area but they haven't reached success. That is why this project came up...'*

This shows that the ideas are initially kept in the team leaders' mind based on their experiences and observations. The leader of Team B concurred,

> *'RFID project was initially stemmed from an expert's suggestion from a meeting. I spent a few months to reach my decision.'*

At this phase, the team members may not have the chance to be involved. Subsequently; the team leader proposes his/her ideas to some team members, usually senior team members or whom he/she trusts, and discusses these ideas with them. This allows the various ideas to be narrowed down to a few attractive or reachable ideas, after which they are further developed and one of them is selected to turn into the project. A senior member of Team A said,

'There are initially a few ideas that came out from our team leader, he will discuss with a few senior members and then he makes a decision, basically we all agree...'

During this process, the initial ideas are usually kept in secret; only a few senior team members know about them. Confidentiality is considered necessary for the protection of ideas. Firstly, team membership is dynamic and turnover within teams can be high. This makes it impossible to involve all team members in the whole process of idea generation and development. Secondly, it prevents ideas to be unwantedly adopted by others. Therefore, to keep new ideas restricted to a few participants is necessary. This is also partially a result of inter-team competition because in this field ideas are at the very heart of the R&D team. They are part of the performance of the teams. Therefore, the way to keep an idea confidential is to limit participants until it is turned into the project proposal.

In this phase, knowledge management related activities centre on acquiring essential information which enables the team leaders and senior team members to identify the promising ideas and also identify the problems that they may face in any of them. The leader of Team A indicated,

'When you got some ideas, you need to search related information and maybe discuss with some people to make sure that the ideas have potential or not and are possible to achieve or not...'

A further development of the idea enables them to outline the whole concept of the idea and decide the ways to achieve the idea. This is an initial stage before moving onto the development phase, and starting to write up the proposal to create the project. In this phase, the team leader and senior team members may have frequent interaction to search essential resources and possible solutions to respond to potential problems. Meanwhile, required knowledge inputs may differ depending on the innovation types and the team knowledge base. In incremental innovation teams, the team leader and senior team members may need to search information of new technologies and identify what are the options that can be adopted in the new project. In the radical innovation projects, on the other hand, the team leaders and senior team members may need to communicate with external experts or scientists to obtain related information and knowledge to support their perspectives. For example, in Team A and B, projects do not emphasis external knowledge because they have accumulated plenty of knowledge and experience from what they were doing. Therefore, in the

idea generation and initial development phases, they concentrate on identifying what functions or modules should be improved and what new technologies can be adopted to achieve their goals. A senior member of Team A said,

> *'Because we know what we are doing, so we start this project with specification that the sponsor requires and then transformation...'*

Conversely, in Team C and D, the technology that the team wants to develop is a leading technology in the industry. The team initially has no experience and core knowledge to support the project. Therefore, they have to visit external experts and keep communicating with them to bring in related knowledge and keep the project moving. In this stage, their knowledge related activities were focused on searching related information and communicating with experts to outline the project; '*we spent the first half of the year searching for related data and consulting experts,*' a senior member of Team D concurred. These four teams illustrate the differences between knowledge related activities in idea generation and initial development phases; they also show the influences of types of innovation on innovation practice and knowledge related activities.

9.2.2 Development, adoption and testing phases

Once the project is created, the innovation process moves on to the full development phase. In this phase, the project is officially performed and the technological know-how and prototype are developed, which requires knowledge integration and problem solving to be addressed. In this phase, individual skills and experiences become very important because they relate to how the projects are processed and how the problems are solved. This relates to a team's R&D processes which have been discussed in chapter 6, R&D context and process. In this phase, senior team members become very important as their tacit knowledge (e.g. experiences, technical skills and processing knowledge) facilitates the team to solve technical problems and connect with knowledge sources. The data presented showed that types of innovation influence the role of senior members within a team and further influence the focus of knowledge related activities. For example, in Team A and Team B, the incremental innovation teams, the senior team members are in charge of certain tasks for developing a certain function, a module, or a specific technique. Also, they are assigned the responsibilities of leading or supervising junior or inexperienced team members by working together. This triggers frequent interactions between them while they need to discuss their tasks and solve problems. The data from the team observation has shown that the team members who work on the same task have much closer and frequent interaction in

terms of sharing experiences and solving problems together (see section 7.2.5, Team A and Team C).

This is confirmed by a statement from the leaders of Team A and B, where they indicated that when they assign the team members into the same task group, they not only consider individual team members' expertise but also consider their personalities and characters:

> '*I would also consider their experience and personality before I assign them to work together,*' the leader of Team A said.

The leader of team B concurred,

> *'Personality is sometimes important when you put them to work together. My team so far is ok. They seem to like to work together.'*

This thesis suggests that this consideration is based on a working atmosphere in the task groups, and the impact this has on knowledge sharing between them. For both team leaders, knowledge sharing between team members is expected to be a spontaneous behaviour. This is facilitated by a harmonious atmosphere (Section 8.2.4) and team members with non-conflicting characters in personality. However, some of the team members in Team A, B, and C considered that there is an overemphasis on harmony and avoiding conflict within the teams, which seems to cause a negative result in creativity because different opinions may not be able to be proposed and discussed:

> 'W*e are too similar, sometimes this causes a lack in creativity,*' [a senior engineer of Team B]

> *'...background too similar may not be good, our team so far is ok, but seems too many team members having banking background...'* [A senior member of Team C]

This is also supported by the literature (De Dreu and Van de Vliert, 1997) which argues that certain amounts of conflict can be beneficial to triggering and maintaining creativity among team members. However, the type of conflict needed in teams has to be clarified. A senior member of Team C indicated that conflict in opinion should be allowed but inter-personal conflict should be avoided because it can destroy team

atmosphere and turn into political conflict which can cause a dilemma of making choice to team members between professional and private standpoints. He said,

> *'Conflict within a team sometimes turns into emotional and political which may create a battle.'*

Therefore, team leaders can be very important in trigger conflicts within teams to keep creativity under the control. However, in those teams, harmony is a priority to team leaders and conflict is somehow avoided if it is unnecessary.

In addition, in the development phase, the team members' individual sources for acquiring knowledge and accessing knowledge sources are important because they allow individual team members to solve problems. In fact, most problems that they encounter are related to individuals' lack of techniques and skills. Therefore, senior team members, clients, suppliers, internal/external experts, internal data bases, and the Internet are extensively adopted for finding solutions to solve problems. However, when problems solving is involved in the application and adoption of new technology, it is sometimes determined by financial rather than professional decisions. For example, in Team A, during the team observation, a senior team member (Af, see Figure 7.5 and Table 7.1.) proposed a solution for solving a problem by employing a new technology which required a new investment to obtain new equipment. In this case, a consideration for the new investment was whether the new equipment could be used in future projects, or whether it could benefit other teams. If not, this new investment would not be accepted. In this case, the team leader said,

> *'...it is quite a lot of money... depending on the head of centre, I basically support this suggestion but the head of centre may have different considerations in terms of finance which I do not know exactly...'*

This presents a dilemma between adoption of new technology and financial considerations in innovation practice. This relates back to the discussion in chapter 6, on R&D context and process, which showed how R&D is performed within this organisational context.

Furthermore, this case provides two implications for the value of individual experiences and a team's capability of adopting new technology. Firstly, this senior team member was considered a master in this team because he has specific expertise and a few patents in his focus areas. He also has interests in some technology areas

which are not essentially associated with his work. In this case, his idea was derived from his interest areas and he applied the idea to his work. An essential feature of innovation is indeed that some ideas may be derived from unexpected areas related to individual experiences or habits. This kind of idea is usually very individualised and skilful. This corresponds to Nonaka (1994) and the importance of individual knowledge and experiences to teams and teamwork in terms of problem solving. In addition, the team member (Af) is also an example of someone who has not only a deep, but also broad knowledge in his area. This makes him an important knowledge and information source in the team. The data (see Figure 7.5 and Table 7.1) shows that he did not interact frequently with others but he interacted with different task groups and he played the role of an adviser to give ideas and information sources for solving problems. This case corresponds to the literature that knowledge activists are necessary within teams or organisations, especially when they adopt the roles of catalyst, connector, or merchant (von Krogh et al., 1997) in order to trigger knowledge related activities taking place within teams and organisations. Hence, based on this case study, this research indicates that the role of adviser may pivotally take a part of the role of activist.

Secondly, this case also shows a team's capability of adopting new technology and being flexible in the exploration of new areas in the process of innovation. This is not only associated with the team itself but also the organisational support, (see discussion in chapter 6, R&D context and process). A team's capability of adopting new technology is associated with the team's capability of absorbing the knowledge. In this team, most senior team members have similar expertise and experiences, as discussed in chapter 4. This enables the team to have a sufficient knowledge base in order for engineers to deal with new technology. A similar situation also appears in Team B as it consists of engineers who have similar expertise and experiences. This provides a knowledge basis to enable Team B to shift R&D focus from ATE to RFID because the team has accumulated sufficient knowledge and experiences in both hardware and software systems as evidenced above. Therefore, they can learn new knowledge about RFID quickly and handle related technical problems.

9.2.3 Implementation phase

In this organisational context, implementation is associated with project performance evaluation, technology transfer, and technical consulting. This relates to three different project types in the organisation. The government funded projects and organisational self-funded projects predominantly involve advanced technology development in which technological success is concerned and evaluated because it

relates to industrial needs and technology transfer afterwards. The privately funded projects focus on technology transfer and technological application in which customer satisfaction is regarded.

In the government funded projects, the project performance is evaluated by the expert board which consists of external experts from related areas. This examination does not only comment on the projects but also gives feedback and suggestions in terms of future research and further applications. That feedback helps the teams to explore new topics and plan an innovation focus for the future, which assists them to create new projects. Moreover, government's technological development policy is also a guideline which helps the teams find the directions and foci.

In the organisational self-funded project, project performance is evaluated by an internal expert board which looks for future potential for application because it is associated with the organisation's investment and future return. In this organisation, such type of project usually moves onto technological application through cooperating with other companies for the commercialisation of the outcomes or technological transfer.

In the privately funded projects, project performance is evaluated by the customers (firms). Customer satisfaction is not only based on the final products but also the degree of interaction with customers and consulting firms, because they need expertise from the project teams to help them to commercialise transferred technologies. Thus, in some cases, apprenticeship is adopted in training sponsors' engineers during the project period. This is a specific phenomenon in this organisation. For example, Team B (ATE project: organisational self-funded project but applied technology to privately funded project) allows sponsor's engineers working with them to learn how to maintain the system during developing the system for Taipei Metro. This enhances the effectiveness of technology transfer and raises customer satisfaction. In general, privately funded projects enable the organisation and its teams to connect with industry and make sure the research efforts can support industrial firms.

In this organisational context, the implementation phase does not essentially involve the after-sales service. When the final products or reports are delivered to the sponsors, it means that the projects have been finished and the next project will follow. Therefore, the implementation phase could be very short. However, the

opinions from the external experts or customers could be very important to the teams to move onto the new projects.

The above discussion shows that different problems emerge in different stages of the innovation process and call for different knowledge inputs. The teams' knowledge management activities within this process are centred on seeking knowledge sources and inputting knowledge sources for solving problems. This relates back to the discussion of R&D contexts and R&D processes and their significance for knowledge related activities. Moreover, the knowledge sources can originate from internal sources or outside the team. This constructs a team's knowledge interaction. However, from time to time, a team's knowledge related interaction is different. This relates to how work is designed and distributed. This innovation process shows that problem solving and knowledge acquisition drive knowledge related interaction within the teams. Through such interaction, knowledge can be shared between team members and also stored through holding of knowledge by team members. In order to enhance such interaction, how a team operates is an important issue which relates to the theme team operation. Furthermore, problem solving in this process is an important event which relates to applying knowledge and creating knowledge in order to solve problems. This influences a team's innovation capability and accumulation of knowledge from a project. This knowledge may keep a team's innovation ongoing, which relates to how a team selects the next project. However, the data from the interviews shows that project selection in the teams is associated with performance evaluation mechanism in this organisation. Therefore, next section will discuss how performance evaluation is undertaken in this organisation.

9.3 Evaluation of innovation performance

Performance evaluation is an important means to draw people's attention to a given direction in the organisation. In order to encourage and manage innovation and knowledge management activities, putting the teams on the scale to evaluate their performance is necessary. There are some criteria that have been discussed in the literature according to the domain of innovation (Ahmed and Zairi, 2000; Bullinger, 1994; Haner, 2000) such as, product/service, processes, and enterprise. As this dissertation focuses on the team level and its undertaking of projects, the product/service domain seems most relevant. In the domain of product/service, there are several measures that have been illustrated, such as: value-added to the customer, cost-against target, stability of design, product return on investment, product performance, etc. (Haner, 2000). However, such measures are rather close to the

evaluation of the product itself and do not seem to fit in with what the organisation is engaging in. In this organisation, innovation performance is regarded highly because technology is its final product. Thus, innovation has been naturally embedded in the organisational mission without a special emphasis. This leads its project performance evaluation to be addressed on three dimensions: technology success, technology diffusion and project return.

In terms of technology success, the number of patents and publications are considered the crucial criteria to evaluate a project's innovation performance. However, this standard is not applied on all projects that take place in the organisation. In fact, there are three types of projects in the organisation according to the project characteristics. Government funded and organisation self-investment projects are required to produce patents or publications because both types of projects are usually aimed at the development of advanced technology. Therefore, technology success is a priority to the project performance. Moreover, the number of patents and publications that are required depends upon the sponsors. However, technology success in a privately funded project does not require patents and publications. It is instead customer satisfaction in which the projects need to meet contract and be delivered on time.

The second dimension is technology diffusion which is associated with organisational mission and commitment to the industry. Technology diffusion in this organisation is defined as technology transfer. Through technology transfer, the organisation can assist individual firms and enhance industrial capability in the technology. Thus, the number of technology transfer cases is the criterion to evaluate project performance in terms of technology diffusion. However, technology transfer usually takes place when an advanced project has been successfully achieved. Therefore, its performance may appear in the following years. This is an important aspect, as it also indicates that time span should be considered as a dimension in evaluating a project's performance. Furthermore, a successful technology also brings advantages to the team. Based on the developed technology, the project team can engage in co-operation projects with firms to develop new application technology. This is usually considered a path to raise team performance by creating extra income/return.

The third dimension is project return which is linked to the organisation's operation and R&D investment in the future. In the organisation, each team has a responsibility to bring in income and create profit from undertaking projects. This third dimension is also associated with the extra reward that a team will obtain at the end of year. Therefore, this dimension more or less influences a team to arrange its resources and

select projects, e.g. human resource, budget, and the types of project to achieve financial performance. A degree of commitment to this dimension is dependent upon a team leader's intention and his/her division's operating strategy (balance between financial performance and innovation performance).

In this research, team A was engaged in a project which was funded by a private firm (moreover, a new project was created in 2004, which was funded by government). Team B's project was funded by the organisation itself, and engaged in technology transfer based on a previous successful technology. Team C and D were engaged in the projects that were funded by government. More specifically, team C was engaged in industrial services, and team D was developing an advanced technology.

In these projects, team A's project performance was also marked as fair in 2003, but the new project in 2004 was considered to have high potential to reach technology success and transfer performances. Team B's project performance was marked as fair in 2003, but its new project (started middle of 2003, lasting until 2004) gained a high performance in technology success, but fair performance in technology diffusion. It is expected to make a high contribution to the financial performance in 2005. Team C's project gained an award for the best project in 2003 in an internal campaign, because it was a completely new model for an industrial service. Team D's project was marked as having high performance in technology success (3 publications plus 2 potential publications), and fair performance in technology diffusion. The evaluation of project performance of these four teams is presented in Table 9.1.

Table 9.1 Project Performance 2003/2004

	Team A	Team B	Team C	Team D
Technology success	Fair/High	Fair/High	High/High	-- / High
Technology diffusion	Fair/High	Fair/High	-- /--	-- / Fair
Financial performance	Fair/--	Fair/Fair/(high, 2005)	High/High	-- / --

Source: interviews and documentary review

However, these dimensions are not the only criteria for evaluating project performances. The leaders of Team A and B indicated that political considerations are also a factor influencing performance evaluation within the organisation. This influence usually comes from higher management level, such as the head of centre,

the chief of laboratory, or vice president (VP). For example, Team B successfully developed a new technology (RFID technology) in 2004. This technology has been seen as a cash cow in the future of the organisation. The leader said,

> *'...in general, our team should be ranked as a high performance team in 2004. However, we would not gain this honour. Conversely, we will be only ranked in fair performance. This is a political affection from someone in top/senior management.... They are going to create another team in another laboratory to develop the same technology that we have done, the new project seems to be involved in a large amount of investment...'*

The leader of Team A also indicated,

> *'It is sometimes affected by higher management's consideration. If they want to promote a particular person, they would give a higher performance rank because there is a rule how people get promoted. It is very political when it comes to performance evaluation at the end of a year. But in general, it has never gone too far. It just appeared in some case in my opinion...'*

This seems to indicate that team or project performance within the organisation is not completely determined by explicit criteria, but is also determined by individual subjective judgement and preference. This may also reflect a different point of view between different management levels within the organisation. First of all, as for the location of the project, the top/senior management may consider that the technology should be located in the laboratory that is more closely related to the technology domain, and can give essential support in terms of resources. For example, Team B is considered as not having enough resources to support further development in terms of technological application. Secondly, team competition is also a factor to influence top/senior management's decisions. It provides options for top/senior management to inspect teams, and invest in a team that is considered to have potential in this particular subject. Thirdly, team performance evaluation may be a political decision which is based on top/senior management's preference, or other unknown factors. For example, the leader of Team B considers that this reason is possible, but he believed that the last reason, political consideration, may have a stronger influence. However, this research does not consider any of these motivations in depth due to the limitations set for this research, but considers that it is necessary to make readers aware of the potential factors that may influence the evaluation of project performance and the measures of the innovation process.

In this research, the examination of project performance may not be the main focus, but how evaluation impacts on knowledge management activities, and its effects within the organisation, are considered. A set of performance criteria guides organisational members' behaviour towards what the organisation expects. This is an idea to set criteria in the annual performance evaluation section to ensure that knowledge management activities are undertaken in the whole organisation. However, for most organisations, knowledge management is seen as a tactical tool in organisational practice and is not considered as making any measurable contribution to production. Therefore, it is often given a lower priority than other organisational procedures and likely to be neglected under time pressure and work load when teams are not available to practise it. Also, intangibility and immeasurability are also a problem, as it is difficult to exactly quantify the effects of knowledge management in any organisational hierarchical setting. This may make it difficult to set criteria for the evaluation of the effects of knowledge management. However, the literature (e.g. Cowan et al., 2000; Eppler and Sukowski, 2000; Davenport and Prusak, 1998; Schulz and Jobe, 2001) suggest that documentation or codification of knowledge is a significant method to sustain and diffuse knowledge within the organisation. This may be one possible valid measure to evaluate knowledge management performance.

However, the data of this research has evidenced that in these four teams and the whole organisation, no clear criteria have been set to measure knowledge management related activities. The data also shows that it is rather dependent on team leaders or heads of centre's attitude to ask the team members and the teams to undertake these activities. For example, in Team B, the team leader uses a measure of co-operation to evaluate team members' efforts on knowledge sharing. Co-operation is defined as the mutual-assistance between team members. It includes efforts of helping other team members and also the efforts of sharing knowledge and experiences and solving problems. However, it is measured by the team leader through observation from day to day work and specific events. The team leader indicated that he did not set any appropriate evaluation form but he did frequently talk to team members and observe their interactions, he said,

> *'When they successfully solve problems or finish tasks, I usually ask them a question "if any one helps you" or "did someone (a particular person that the team leader expected) help you", and also "what did he do for you"...'*

By doing so, the team leader can ensure that team members are engaged in co-operation and that they help each other. This seems to be a significant factor that

distinguishes that team B has much more active knowledge interaction than the other teams. This may explain why this team has developed slightly consistent and stronger technical capability which enables the team to successfully move innovation focus from ATE technology to RFID technology. As the team leader indicated,

> *'...ATE projects built up our technological capabilities in hardware systems, this contributes to the development of RFID technology...'*

Although Table 9.1 illustrates that all four teams have high performance on the technology success dimension, the difference is that team B seems to pay more attention to developing its core capability and puts more emphasis on technological synergy based on succeeded technologies when they move from one project to another. This allows the team to develop its own core competency in a specific area. Unfortunately, similar notions and practical actions do not emerge in the other three teams. This may indicate that setting a performance criterion for a certain purpose is essential to stimulate team members to make efforts to improve performance and its related activities. Moreover, this case also indicates that a team leader's intention and attitude are significant factors to keep team members working on the required criteria. This may be the reason that while knowledge related interactions are undertaken in the other three teams, their efforts are not emphasised by the team leaders and seen as an item of individual performance.

Moreover, at the centre level or even above this level, the efforts of knowledge interactions are not really emphasised and taken as an important performance by top/senior management, as none of the data showed such commitment. Therefore, knowledge interactions within teams, centres and units are not given priority in comparison with other activities. This results in an inconsistency of investment in knowledge interaction efforts within the organisation. This reflects that knowledge related activities concern all levels of management's participation and should be taken seriously. In this case study, team leaders and heads of centres are seen as the important management level that should be involved. This may correspond to Nonaka and Takeuchi's suggestion (1995) that middle managers are playing a significant role to initiate and sustain knowledge creation processes. In this research context, team leaders and heads of centres are the key people responsible for initiating knowledge management related activities and sustaining those activities to take place within their units (7.1).

9.4 Summary

Innovation strategy can be seen as a significant guideline to make a clear goal to integrate a team's innovation and knowledge management activities. However, innovation is inherently embedded in an uncertainty in the time frame in terms of when and how. This makes innovation strategy difficult to be precisely formed. More specifically, it involves many decisions of organisational future development. This implies that formulating an innovation strategy at team level may be unnecessary and unhelpful. This leads knowledge related activities to be difficult to focus on certain areas. A continuous focus in innovation facilitates a team and its members to accumulate knowledge, experiences and expertise in depth. Conversely, a shifted focus in innovation makes a team lose technological focus, but it seems to allow a team to build a diversity of knowledge and expertise in different areas. However, diversity of knowledge and expertise may not last very long because a team may never have to put it into practice again. In the aspect of building core capability, a continuous focus of innovation seems to be better than shifted focus of innovation in terms of accumulating knowledge and building specific knowledge and expertise in depth, in other words, building core capability.

Knowledge management activities are embedded in the process of innovation. Different innovation phases are associated with different knowledge related activities. This is derived from a team's knowledge gap between its existing knowledge base and the required knowledge for the project. In this specific organisational context, team leaders and senior team members play a significant role in generating and selecting ideas. When the innovation process moves onto the development phase, knowledge related activities appear differently in incremental and radical innovation teams. The incremental teams focus on intra-team knowledge sharing and diffusion, while the radical teams' knowledge related activities focus on interaction with external agencies in order to obtain essential knowledge and information. In the implementation phase, different sponsors have different criteria to evaluate the projects. This feedback could lead the teams to re-focus their innovation areas and create new projects.

The evaluation of innovation performance is a tactical tool to drive the teams toward a given direction. Innovation performance in this organisation is evaluated by several factors, namely, technology success, technology diffusion and financial contribution. These three dimensions are associated with organisational mission and future development respectively. In this specific organisational context, top/senior and

middle management's subjective judgement and strategic consideration are factors whose influence on the evaluation of performance cannot be ignored. This can be a positive or negative factor to impact a team's inputs in the innovation processes. This implies that lack of communication within an organisational hierarchy may lead to conflicts in setting goals and selecting projects, which implicitly influences the teams' innovation and knowledge management efforts.

The above discussion refers back to Research Question 1 that the purpose of undertaking knowledge management at team level is not easily or clearly defined to be aligned with team development in the future. The previous chapters have identified emerging needs such as problem solving as an important initiator to trigger knowledge management activities. However, such initiator driven knowledge acquisition and sharing may not turn into Nonaka's spiral process to lead to knowledge creation within the teams or double-loop learning to lead to development at individual level. In other words, emerging needs driven knowledge related activities may only focus on solving current problems by using existing knowledge, which may not necessarily lead to the creation of knowledge or future development. In order to guide the team members' behaviours and align their actions toward continuous knowledge creation and double-loop learning, this research suggests that project evaluation should be able to guide the teams to select projects and decide on the future focus. Thus, project selection and evaluation of innovation performance may also provide essential influential factors to answer Research Question 3.

Chapter 10 A Team knowledge management model

10.0 Introduction

In chapter 2, this thesis outlined that effective knowledge management in organisations is associated with contexts, team dynamics and taking learning as foundation. Knowledge management within an organisation is described as dynamic and situational. It is embedded in organisational daily operations and also entails various contexts. This allowed this thesis to form an initial conceptual framework of team knowledge management (Figure 2.1). Based on this conceptual framework derived from the literature, project characteristics, R&D process, R&D context and team operation were considered important themes. These themes therefore were used as basis for further investigating R&D teams' knowledge management activities. In later investigation of teams, these four themes were connected to interview data. Also, team observation data formed complementary evidence for the theme team operation; documentary review complemented data for the themes project characteristics and R&D context in terms of project proposal and organisational R&D practice.

During data analysis, four more themes emerged from the interview data as outlined in chapter 3. These themes were knowledge management in practice, information technology, individual and team learning and innovation practice and performance. In addition to interview data, team observation also complemented data for knowledge management practice in terms of knowledge acquisition and sharing; documentary review complemented data for innovation practice and performance.

Although the literature has suggested that learning and information technology are an important part of knowledge management, these were not sufficiently related to the initial research question to include them as analysis categories. However, during the data analysis, both emerged from the data as factors which influence across knowledge management and innovation practice in terms of aligning team action, knowledge acquisition and knowledge sharing. Also, information technology influences the teams to carry out their R&D work. Therefore, both were considered as important themes, independent of knowledge management activities, in order to strengthen their importance in both knowledge management and innovation.

Based on the initial conceptual framework of team knowledge management (Figure 2.1), this chapter further develops this initial framework to be a comprehensive model of team knowledge management within innovation teams by using the eight themes. Considering the themes that emerged, the author felt it was important to incorporate

those within the original model. Also, the discussion in the previous chapters has shown that each of those themes has an influence on knowledge related activities. Thus, the author considered it necessary to represent this interdependence in a model. The model was constructed based on a traditional team research input-process-output model to which the initial model corresponds also.

This chapter aims at displaying the model in order to outline how this research answers the research questions as the model shows the contextual influences on a team's knowledge management and the relationship between the analysis themes. This model gives an idea on how knowledge management starts and is integrated with innovation activities. Therefore, this chapter shows the relationship between themes within this research context through describing how these eight themes could form a model of team knowledge management within an innovation context.

This chapter is divided into three sections. The first section will remind the reader of the themes which are identified based on the literature and the data as outlined in chapter 3. The second section will show how the model is constructed. The third section will explain the model and the relationships between elements. The final section will summarise the discussions in each section and explain how this framework provides support in search of answering the research questions of this thesis.

10.1 Summary of themes

The data analysis as described earlier has left the author with eight themes that are identified and emerged in this thesis. Below is a brief summary of the themes to provide the basis for the author's creation of the model.

The first theme is *project characteristics* which in general outlines a project's features in terms of aim and the final products. Chapter 5 described what this research identified as significant in relation to knowledge management activities. The second *(R&D contexts)* and third *(R&D processes)* theme outline, in general, the R&D functions and the ways of undertaking R&D; these two themes were discussed in Chapter 6. Theme number four is *team operation* which involves how a team works and interacts. This theme relates to team dynamics. In this theme, the role of the team leader was shown to have significant influence on team interaction and the development of a supportive atmosphere for teamwork and knowledge related

interaction (Chapter 7). These four themes are originating from the literature and have been the base for the initial model describing influencing factors for situated knowledge management.

Chapter 8 evidenced three of the four emergent themes – *information technology*, *individual and team learning*, and *knowledge management in practice*. These three themes deal with how to undertake knowledge management in teams and what process are important to be considered.

Chapter 9 discussed the final theme, namely *innovation practice and performance*, which showed how the teams relate knowledge related activities to innovation success by synthesising previous evidence.

10.2 Model construction

As described previously, based on the initial conceptual framework (Figure 2.1), this thesis adopts a traditional input-process-output model (Hackman, 1987) as a foundation to construct team knowledge management. In the initial idea (Figure 10.1), project characteristics are seen as the inputs, which influence a team on planning R&D processes and R&D contexts. Hence, with a team's tradition and new situations it faces, a team decides how it operates to achieve a project. It was described in earlier chapters that under the influence of those four themes, knowledge management activities are undertaken in which there are several achievements that are expected to result from performing knowledge management. This relates to research question 1 in regards to purpose of knowledge management. Subsequently, R&D processes and R&D contexts conduct the way a project is being carried out and which sources and support are required. This is associated with when and how knowledge related interaction take place and what knowledge is required. This relates back to research question and the way these processes are integrated. How a team operates involves a team's tradition and the way it deals with new situations derived from a project. This also influences the way a team interacts in order to acquire, share, store and apply knowledge. However, how these processes occur in teams was not described particularly detailed within the literature reviewed. However, the data from the case studies provides the details which are discussed in chapter 5 to 9. The following content will describe how the initial conceptual framework is further developed based on the eight themes.

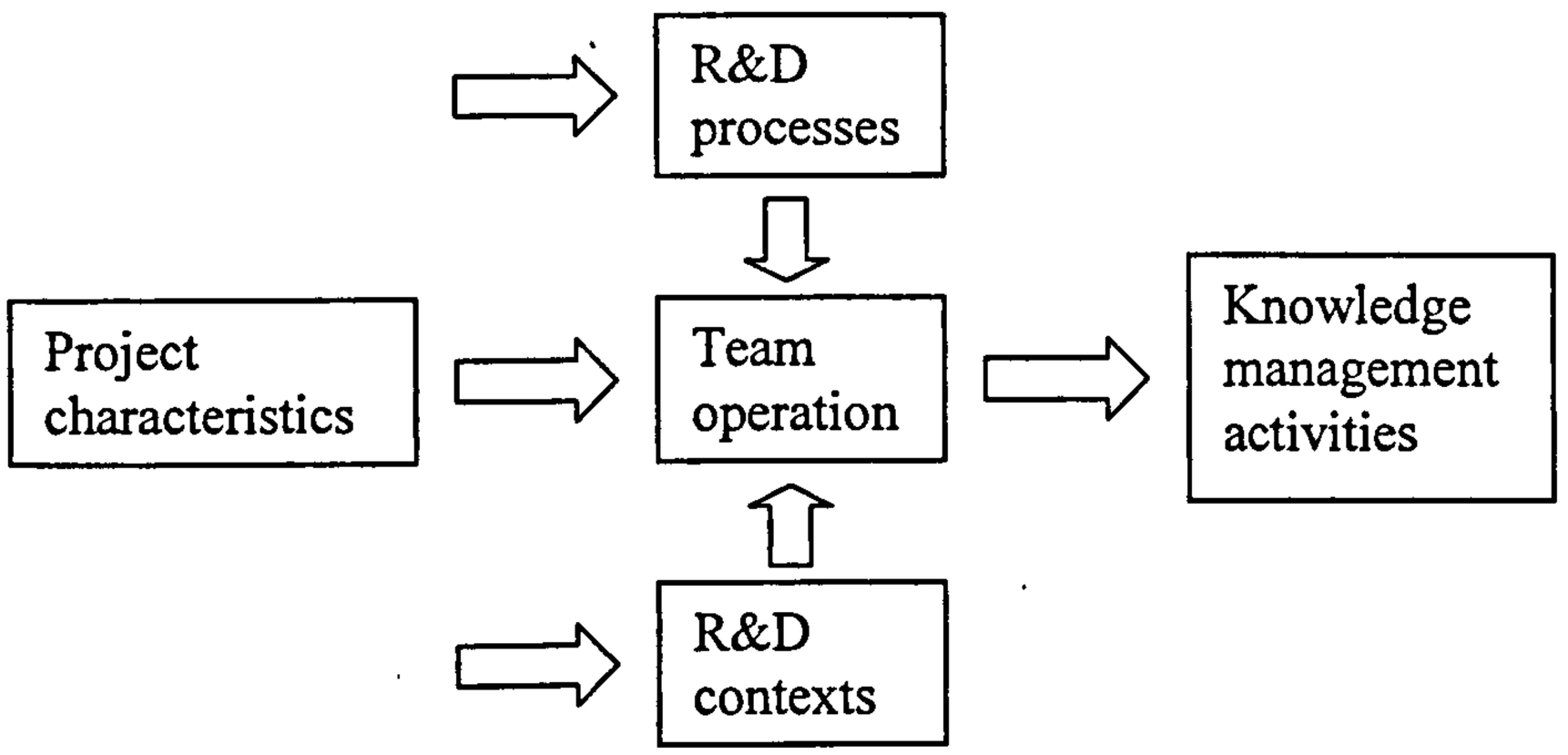


Figure 10.1 Conceptual process of team knowledge management activities

The thesis identifies project characteristics including three categories: funding sources, types of innovation and the products (2.3.2 also chapter 5). These three categories highlight the final destination of a project and its innovation features, which determines the knowledge inputs for a project and implementing a project. Funding sources in this model are seen as an initial characteristic. It is associated with the type of innovation and the resulting products. Its influence in this model is through highlighting a project's innovation type and final product. Both characteristics in this model influence the ways the projects are undertaken and the knowledge inputs required. In this research, knowledge inputs and the way projects are undertaken are connected with R&D process, R&D context and a team's operations.

As described in chapter 2, the R&D processes (2.3.4 also chapter 6) can be seen as the approaches by which a project's tasks and schedule are outlined and coordinated. It comprises a sequence of tasks and the actions by which the project can be accomplished in a specific order and time frame. To knowledge management activities, it is associated with when knowledge related interaction takes place. The R&D contexts (2.3.3 also chapter 6) can be seen as the mechanisms which connect resources to support R&D performance. The R&D contexts in this research include both the professional functions and the support functions that are provided by the organisation or built by the project teams. With those functions, the teams are able to access information and knowledge sources and also obtain essential resources. In both themes, information systems appear to have a strong influence and are considered part of R&D process and R&D context. This is because information systems, especially the personal computer and the Internet, have become important facilities in the

workplace. The findings of this research have highlighted this, as a separate category emerged. It influences R&D processes and contexts, as well as knowledge management activities.

Team operation (2.4 also chapter 7) in this research is seen as a central theme of knowledge related interaction which represents team dynamics. In this case study, team operation consists of a leader's role, team experiences, team cohesiveness, personal attitude, team atmosphere and team interaction in which a leader's role, team members' personal attitude and team cohesiveness are considered the most important factors, because they influence the creation of a supportive atmosphere for team interaction and knowledge sharing. In this thesis, sharing of knowledge is considered a spontaneous behaviour without ordering. Therefore, knowledge management activities in the teams are fundamentally underpinned by this supportive atmosphere. Moreover, team structure and team size were mentioned as they are considered the mediation factors influencing the efficiency of team interaction and communication. Team interaction, as a mechanism for knowledge related activity, is the most important part in this research. The interview data and team observation data have evidenced that knowledge management in the teams are socially orientated. It is dependent upon how people support the team and how people interact.

The knowledge management related activities in R&D scenario are associated with the specific objectives related to the tasks such as solving problems, creating ideas and sustaining knowledge (chapter 8, 8.1). In this research, they include five categories: the acquisition, sharing, storing, integration, and application of knowledge. These take place in the teams, though not necessarily in a specific order but associated with situations and the progress of the project. Problem solving and sustaining knowledge within the team are the important motivation as well as purposes of undertaking knowledge management related activities. Indeed, they directly influence a team's performance and the accumulation of knowledge. Therefore, knowledge management related activities within the teams take place subject to the situations and purposes that are aimed at by the teams. As these two knowledge management related activities take place, team interaction and information technology becomes important to enable acquiring and sharing knowledge take place. This refers to the themes team operation and information technology.

The use of information technology (chapter 8, 8.2) is considered as having great impact on team interaction and knowledge management related activities. The influences of information technology on knowledge management, emerged in

interview data and team observation data, are acquisition, sharing and storing of knowledge. A recent online communication technology is also frequently used instead of face-to-face interaction within the teams. Furthermore, the organisational knowledge management system is an IT-based system. The system not only provides a function of information storage but is also supposed to be a platform for the exchange of information and access to internal and external knowledge sources. In addition to knowledge management, information technology in the case studies is also an important facility which is a working platform for the teams to carry out projects. Thus, information technology in this research is an important theme which influence across knowledge management and innovation.

Moreover, individual and team learning (Chapter 8, 8.3) are considered significant foundations when knowledge sharing and internalisation of knowledge take place. The interview data highlighted that when interviewees talked about sharing knowledge, they also attached learning, practising and common language to this discussion. Sharing knowledge no only means sharing information but also considered sharing the understanding. This also refers to team learning which suggested that team learning influences knowledge management in the way of aligning team members' action and enabling a common understanding to be formed within the teams; this was clearly emphasised as emergent from the data. This effect not only influences knowledge management taking place within the teams but also informs mutual help among team members. This benefits the whole team and the effectiveness of teamwork in current projects and the future.

During a project life cycle, the performance of a project and the improvement of a team's capability of carrying out innovation are reasonable to be examined at the end (Chapter 9). In the case studies, knowledge management was undertaken for the improvement of a team's innovation capability in which knowledge management impacts on innovation performance through creating solutions for solving problems. The benefits for the teams are through solving a number of problems and practising to gain experience and accumulate knowledge. This enables the teams to move onto the next project by which the selection of a future project is another challenge for the teams. The experience, expertise and knowledge accumulated from the past provide the knowledge for selecting new projects. This drives the teams to start another innovation journey. The first issue a team faces and deals with is project characteristics.

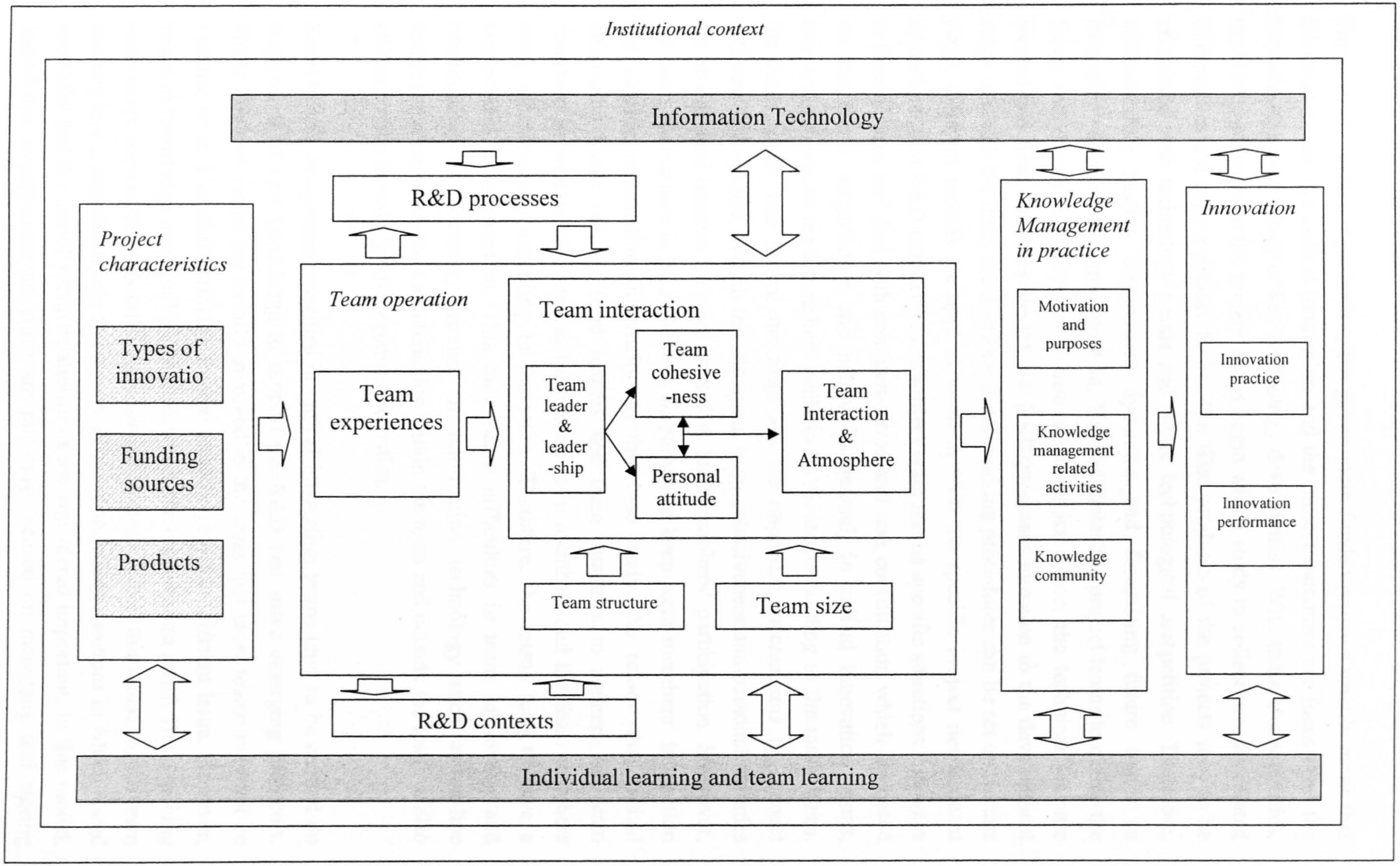
The above discussion shows that all the themes discussed are connected and appear related.

Based on these eight themes, this research further developed the initial model into a comprehensive model (Figure 10.2). This model includes project characteristics, R&D contexts, R&D processes, team operations, knowledge related in practice, information technology, individual and team learning, and innovation practice and performance. The relationship between themes was highlighted the above. The next section will explain how this model works.

10.3 The explanation of the model

In order to make sense of how this model works. This section explains the model (Figure 10.2). This is a process model which aims at demonstrating the process of team knowledge management activities combined with innovation activities. The model is developed based on the four teams in the R&D institute by generalising the evidence presented. However, the influence of each theme differs from team to team, which was shown in the previous chapters. This chapter shows how the model is applied in general.

Figure 10.2 Model of team knowledge management activities



For example, in this organisation, the government funded projects usually mean that the projects involve radical innovation and the project outcomes are focused on the breakthrough technology or key technology development. With these characteristics, the R&D processes in the project teams begin with a study to collect broadly related information and seek a project focus. The final products of the projects tend to be associated with technology trends and future technological competition. Therefore, understanding leading laboratories dynamics and forecasting future trends in technology development are important. This facilitates the project teams to define the focus and decide the adoption of new technologies. Once, the technical foci are located and final outcomes are set, the R&D processes move on to the development stage in which the tasks are distributed and working procedures can be set up. In this stage, different models are applied to fit in with the specific project needs, team operations, and R&D contexts. Each project team has its specific situations and ways to handle tasks and deal with communication and task coordination which are based on the teams' experiences and habits. In general, in radical innovation teams, interaction between team members tends to be divided according to the tasks. Thus, the team leader and formal meetings are the important mechanisms to connect different task groups. Within this situation, team cohesiveness and personal attitudes are emphasised because they are related to team members' participation. Moreover, the team atmosphere is recognised as important to keep team members' interaction and sharing information informally. In this case study, the reason that radical innovation teams rely on team leaders and team meetings to connect the team members is because they tend to have more team members and the team members work independently according to the tasks. Therefore, the teams tend to have a hierarchical team structure. This may cause difficulties in team interaction and communication. However, the use of information technology such as on-line communication increases the interaction within the team and outside the team. It also influences the knowledge management activities.

Knowledge management activities in radical innovation teams tend to be centred on acquisition of new knowledge to support the R&D and solve emerging problems. These kinds of teams are usually involved in the areas that most teams may not be familiar with. Therefore, bringing in new knowledge is a significant issue. However, required knowledge may not be available within the organisation itself. Thus, seeking knowledge sources from external agencies is required. Within this situation, the team leader plays a significant role to connect external knowledge sources in which social networks and the use of social relationships are considered important. In this model, knowledge management activities are not only focused on managing and storing

knowledge but also applying knowledge. This is associated with individual and team learning; in the radical innovation teams in this case study, individual learning and professional training tends to be emphasised. This seems to result from the situation in which the teams lack strong knowledge to support the project, as well as individuals. Therefore, professional training and seminars are the important ways to improve individual skills and expertise.

Knowledge management activities enable the teams to develop their own knowledge or increase their knowledge base which can be applied to innovation practice to improve a team's ability of managing innovation processes and also improve innovation performances. In radical innovation teams in this IT institute, technological success may be much more of a concern, because it creates the future for the teams and the organisation to compete for new projects. It also creates the opportunities for future technology transfer. This enhances team performances as well as organisational performances. It also means raising a team's negotiation power to obtain resources from the internal or external organisations to carry out innovations.

The above discussion shows how the model is applied to the radical innovation team. However, the model could also be applied to incremental innovation.

For this case study, the incremental innovation projects are usually funded by private firms. They aim to assist firms to develop specific technologies or prototypes of new products by applying organisationally developed technologies. With this situation, the project teams have different R&D processes from radical innovation teams. In general, the R&D processes start directly with development without preliminary studies because the teams normally possess related knowledge and know-how to process the projects and apply the knowledge. Also, there may be a ready developed process and R&D contexts can be applied and adopted for the projects. This allows the teams to move directly to the development stage.

Moreover, in this type of team, the evidence for this thesis' case study shows that team members have often been working together for certain periods of time in similar projects. This makes them familiar with each other's expertise and personality. This enables team operation to be more flexible in terms of communication and task coordination because the team members know how to carry out their tasks and when they need to communicate and coordinate with each other. Interaction and communication between team members therefore tends to be more spontaneous. Moreover, the team leader tends to empower team members to carry out the tasks and

tends to play the role of connector with external sources when the project encounters problems and needs external knowledge sources involved. However, this spontaneous behaviour is based on a supportive team atmosphere. This model is associated with leadership, team cohesiveness and personal attitude, especially from the team leader who is considered to influence team members' behaviours and attitude, and guide the team to develop a supportive atmosphere. In this type of team, flexible structure and small team size are also considered the factors that enable the teams to have frequent interaction and communication and reach such team atmosphere. Moreover, the use of information technology also increases team interactions through on-line communication. In this type of team, due to team members' better understanding of each other and each other's task, on-line communication has become an important team interaction platform. This use of information systems also influences the team knowledge management activities by which the information and knowledge can be shared spontaneously and efficiently.

The knowledge management activities in this type of team are focused on sustaining team knowledge in which frequent and spontaneous team interactions are emphasised. The way of sustaining knowledge within this kind of teams is diffusion of knowledge through assigning senior team members and junior team members working together by which senior team members' experiences can be shared through their supervision of junior team members. Also, the knowledge related activities in these types of teams tend to be restricted within the team because external knowledge sources may not be required as frequently – at least not in the presented case study. This enables the teams to focus on internal interaction and developing team knowledge. This emphasis on team interaction and sustaining team knowledge in this model may be seen as the team learning processes because through such activities individual knowledge can be diffused across the team to become team knowledge, which not only includes technique or skill but also involves the ways that the team undertakes the tasks.

In this type of team, knowledge management activities strengthen a team's knowledge base and also enhance its abilities of solving problems and managing innovation processes. This may facilitate a team to seek new challenges by engaging in the development of breakthrough technology.

10.4 Summary

In this model (Figure 10.2), project characteristics are the initial theme that determine a project team's R&D processes and required R&D mechanisms. This provides a team

with a map to follow and act on. However, team knowledge management activities are embedded in team operations. Therefore, team knowledge management activities are undertaken according to the purposes a project has been set.

In this model, team operation, computer-based IT systems and individual/team learning are the significant themes which influence knowledge management and innovation activities in practice. Team operation is associated with team dynamics, a supportive environment, connection with knowledge sources and sharing knowledge. In this theme, team leaders play the crucial role of creating a supportive environment for knowledge management activities and connecting with knowledge sources. Within this context, social networks are emphasised as the crucial channel to access knowledge sources.

Computer-based IT systems are a significant tool which is associated with processing tasks, accessing/exchanging/storing information/knowledge and being part of a learning facility. Individual and team learning are the important mechanisms to connect knowledge management and innovation activities. In this context, it can be seen as the processes of sharing, learning and practising.

This chapter demonstrates how the themes fit the model and explains how the model applies to different types of innovation teams in this specific Taiwanese research organisation. However, the way that the model (Figure 10.2) applies to these four R&D teams is slightly different, which is determined by the initial project characteristics and team situations. However, the examples above have shown that it is relevant to radical and incremental innovation teams, whereby only the extent of influence of each theme is different within each team. Thus, the author believes that the model could provide a good starting point to develop a generic model for knowledge management activities within an innovation context.

This thesis considers that this model responds to the initial research question in Chapter 1 by showing the process and related factors involved in knowledge management and innovation. Also, the themes R&D processes and R&D contexts, team operation and knowledge management in practice are able to answer the refined research questions in Chapter 3. Firstly, this model shows the position of knowledge management in an innovation process. In these four teams, problem solving is an important initiator to trigger team members' interaction in order to acquire and share knowledge for solving problem. Moreover, sustaining knowledge is also an initiator of triggering knowledge management related activities. However, problem solving

and sustaining knowledge have different meanings but often take place at the same time and in a similar way, such as sharing knowledge. The difference is problem solving relates to solve unknown problems. In contrast, sustaining knowledge relates to keeping knowledge to respond to situations that are likely to occur as part of innovation processes. In this thesis, sustaining knowledge is relevant to the use of assigning supervisors (formally or informally) who team members work with. Such arrangement facilitates both problem solving and sustaining knowledge to take place. Through such arrangement, team members can develop new knowledge through learning and practising with senior members. This is able to respond to the research question about the purpose and initiator for undertaking knowledge management.

Secondly, the model shows how knowledge management related activities integrate with innovation processes within specific projects and team contexts. In this model, problem solving is related to solve technical problems; however, the way problems are solved and knowledge that is created for solving problems is related to knowledge management. For the teams, they expect that knowledge can be sustained and applied to different context. Therefore, R&D processes, R&D contexts and team dynamics are the determinant elements within the model to integrate knowledge management related activities and R&D activities. Thus, this model is able to answer the research question 2 in chapter 3.

Finally, the elements within the model are considered important for undertaking knowledge management and integrating knowledge management and innovation activities. Therefore, the model itself answers the research question 3 – what factors underlie the processes of undertaking knowledge management within teams.

Chapter 11 Conclusion and contribution

This case study investigated four IT R&D teams in an IT institute in Taiwan to explore how knowledge management related activities take place within technological innovation contexts. It was evident from the literature that knowledge management and its associated activities tend to be discussed generically, but lack a deeper understanding of the exact processes that influence knowledge management within specific contexts. Thus this research aimed to examine in more detail knowledge management activities within an innovation context. In order to achieve this, the research adopted an interpretive research framework that allowed a detailed exploration of the type of processes and activities involved in knowledge management and its related activities. The data from the four teams shows that project characteristics, R&D process, R&D context, team operation, information systems, and learning systems are the important influences upon team knowledge management activities. The data furthermore clarifies that knowledge management related activities are purpose-driven to solve problems, sustain knowledge and create knowledge. The research, subsequently, generated a conceptual team knowledge management model which comprises eight themes. The model justifies that knowledge management activities within teams are context-based activities influenced by many factors and situations. The following section will firstly conclude this research by relating back its findings to the research questions and secondly outline the contributions that this research believes it can make.

11.1 Findings of this research

This research firstly raised the question: 'What is the purpose and initiator of knowledge management in innovation teams?' Based on the case studies, this research suggests that knowledge management within the organisation starts with an ideal that is organisational competitiveness. In this research context this means innovation and R&D capability can be improved through undertaking knowledge management. This led to an IT-based knowledge management system to be established across the whole organisation to enable information to be shared. However, the case studies show that it did not work well especially at team level. The reason emerged from the data in that the IT-based knowledge management system is just a platform for storing information and documents. The effort behind the system to make the system work requires large amounts of human force to engage codification of information and knowledge. However, such effort invested often causes doubt within the teams. In contrast, the case studies show that knowledge management within the teams are actually

associated more with team interaction. This is derived from the factor that R&D is a dynamic process in which problems appear unexpectedly. Therefore, in the case studies, problem solving was identified as an important initiator to trigger knowledge related interaction between people. Moreover, sustaining knowledge is an important motivation to continue knowledge related interaction. This leads knowledge sharing to be emphasised and practised in many different ways. However, the case studies also outline a gap between organisational level and team level in which the organisation and teams have different perspectives of why and how they undertake knowledge management activities. From an organisational perspective, knowledge management is recognised as diffusion of knowledge across the whole organisation to enable knowledge to be used by different units or members. From a team perspective, knowledge management is recognised as facilitating problem solving and sustaining a team's R&D capabilities. For the teams, diffusion of knowledge across teams is not an important issue but a wide range of knowledge sources for access was found to be important. This is derived from the differentiation of project types. Social networks and social relationship are emphasised. Therefore, this research suggests that organisations should be concerned with the differences in the projects between teams and encourage teams to develop appropriate ways to undertake knowledge management activities. Thus, the main findings to answer this research question are that motivators are problem solving and the need to sustain knowledge – each concept is given different priorities, according to project characteristics, but both are relevant.

This research also raised a second research question, 'How are knowledge management activities integrated with innovation processes?' Based on the case studies, this research suggests that knowledge management activities are undertaken alongside how a team carries out the project in which project characteristics, R&D processes and R&D contexts influence the teams to decide the ways of performing projects. The case studies suggest that completing tasks on schedule often takes priority to undertaking specific knowledge related activities, for example codifying documents. Therefore, the extent to which knowledge related activities are undertaken depends on the situations such as needs, time frame, availability of team members and also the stages of the R&D process. Moreover, five knowledge management related activities – knowledge acquisition, sharing, codification and storage, integration and application – are applied within the teams, whereby it could not be established that these are systematically performed. For example, a solution created for solving problems may not be coded for storing and sharing. Therefore, this research suggests that knowledge management related activities are not standard operational processes. Indeed, it is a principle that is constructed to respond to purposes and needs and

embedded in the practice such as R&D activities. Therefore, R&D processes, R&D contexts and team operation are the factors that determine how knowledge management are performed within the teams to improve their project performance and innovation capabilities. Hence integration of knowledge related activities is happening at a practice level and is determined by the influencing factors.

The third question raised in this thesis is 'What factors underlie the processes of undertaking knowledge management activities by teams?' Based on an IT innovation context, this research identifies eight themes and develops a team knowledge management model. The model illustrates the factors that are considered to influence knowledge management activities to be undertaken within the teams. These elements explain what contextual factors impact on the IT R&D teams. The model also refers back to the initial research question in Chapter 1 by showing the processes of how knowledge management enhance innovation activities. The contextual factors are summarised as below.

Firstly, the organisation this research investigated portrayed a particular relationship between funding sources for projects, type of innovation undertaken, and type of products developed within the teams. These project characteristics are associated with the organisation's mission and operation. Funding sources determine a project's innovation types and products, and further influence a project's implementation and performance evaluation. Based on the differences in this relationship of project characteristics within the different teams, different scenarios of team knowledge management activities emerged.

Secondly, R&D processes influence how teams undertake projects and problem solving activities. This further determines when and how team interaction and knowledge sharing activities take place. R&D contexts are associated with knowledge inputs and the knowledge related interaction pattern. The data suggests that incremental innovation teams tend to emphasise the use of internal knowledge sources. Conversely, radical innovation teams tend to emphasise the interaction with external knowledge sources.

Thirdly, team operation is concerned with team routines and team contexts. The data shows that efficient team interactions with regards to knowledge related activities are associated with the team leader, team cohesiveness and team members' attitude to form a supportive team atmosphere. A supportive atmosphere facilitates team members' knowledge-related interactions to be turned into a routine that is

spontaneously used by team members without external motivators. A team leader's roles in team knowledge management activities sustain essential activities through providing help and encouraging team interaction. Thus, a team leader may play the role of initiator, consultant/master /tutor, connector, negotiator, distributor, and/or coordinator/mediator. The role adopted is dependent upon the situation. The data suggests that a team leader's situational roles are not only influenced by the formal position within the team, but by the team's social context. This enables a team leader to use personal relationships to influence team members to form team cohesiveness and enhance team members' participation.

Fourthly, it is evident from the data that social networks are a significant factor that influences the access to knowledge sources in order to solve problems. Personal social relationships, whether formal or informal, internal or external, are emphasised, as they improve the quality of knowledge sharing between people. The data specifically highlights that when accessing external knowledge sources, mutual trust can be substituted by mediated social relationships. This strengthens team leaders and senior team members' importance in the teams as they hold and build most of the networks. Mutual trust also justifies the necessity of informalisation in knowledge sharing among people and among teams. The author considers this specific phenomenon to be influenced by the Taiwanese social context. In contrast, in intra-team interaction interpersonal relationships among team members do not match with the above finding. Indeed, questions themselves are a concern for people. The data suggests that knowledge-related activities in incremental innovation teams tend to focus on sustaining knowledge by emphasising intra-team interaction through socialising junior team members. In contrast, knowledge-related activities in radical innovation teams tend to primarily focus on eliciting new knowledge through interaction with external agencies.

Fifthly, information systems are an important facilitator to access knowledge sources and interact with people. The data shows that IT facilitates teams to update information and knowledge through connecting with world wide agencies. Moreover, on-line interaction enables people to exchange information and knowledge more quickly and more often. It facilitates people to develop and maintain social networks across and outside the organisation's boundary. However, the data also suggests that the use of information systems mostly happens when people already know each other.

Sixthly, the data provides evidence that learning is part of knowledge management processes to develop team consensus and team knowledge. However, individual

learning is still highly emphasised within the four teams. It takes place in many ways, such as learning on the job, self learning, and taking specific courses. In contrast, team learning is not explicitly emphasised in the teams. Alternatively, team cohesiveness and team consensus are emphasised as ways to align team members towards the same direction. Thus the notion of team cohesiveness substitutes for team learning in this organisation. Team leaders play a particularly important role to communicate, educate, and guide the team members to enhance team cohesiveness.

Finally, effective knowledge management activities are associated with goal setting and performance evaluation. This research suggests that the goal of undertaking knowledge management should be merged with a team's innovation strategy. The data portrays that formulating an innovation strategy at team level may not be possible because innovation is influenced by uncertainty in the time frame of a project and organisational intention. This makes it difficult to precisely formulate an innovation strategy. Thus, this case study raises the issue of continuous focus or shifted focus in knowledge related activities. In the aspect of building core capability, a continuous focus of innovation facilitates a team to build up specific, in-depth knowledge and expertise. In contrast, shifted focus of innovation may lead a team to build up experiences and knowledge more broadly. However, specific features of the organisational mission may prevent teams from continuously focusing on the same areas. Meanwhile, performance evaluation is also a consideration. In this organisation, innovation performance is evaluated by technology success, technology diffusion, and financial contribution. Among these three criteria, financial contribution is a variable which impacts on a team's project selection, which, in turn, further influences its focus. The data suggests that financial consideration results from lack of communication within the organisational hierarchy, and fuels further conflicts in setting goals and selecting projects, which implicitly influences the teams' innovation and knowledge management efforts.

11.2 Contributions

This research provides several contributions which can be classified into theoretical contributions, empirical contribution, and management implications.

11.2.1 Theoretical contribution

This research has previously argued (2.2.2) that Nonaka's SECI model (1994) can be seen as a general process model for knowledge creation. However, it was argued that

the model lacks considerations of contextual influence on the processes of knowledge creation. Although Nonaka and his colleagues' later work noticed and suggested that knowledge management is influenced by organisational contexts, they did not explain what organisational contexts are and how they influence knowledge management. By investigating an IT innovation context in a Taiwanese research institute, this research suggests that different project contexts and team contexts result in different goal setting and ways of undertaking knowledge creation and knowledge management activities. Hence, it provides evidence that project characteristics, R&D processes, R&D contexts, and knowledge sources construct a team's operational contexts which influence the teams' operation and knowledge management related activities. The data also shows that problem solving initiates knowledge related interaction in R&D teams and the location of knowledge sources influences a team's interaction patterns with regards to access to knowledge sources. This evidence provides details that team knowledge management actually takes place alongside a team's R&D process and its specific R&D contexts. Therefore, in comparing this research's model (Figure 10.2) with Nonaka's SECI model (1994) and his later work with von Krogh et al (2000), this thesis' model does not concentrate on the knowledge management processes itself, but focuses on exploring situational factors on how teams react to different situations to carry out knowledge management. Also, this thesis takes learning processes into consideration to show how learning is a foundation of knowledge sharing and knowledge sustaining within the teams. The emphasis in this thesis' model is that knowledge management within organisations is influenced by an organisation's contexts. Therefore, how knowledge can be managed within the teams needs to respond to the situations, i.e. project characteristics, R&D processes, R&D contexts and a team's operation, and project needs, and react to the situations to develop their own practice for managing their knowledge. This aspect was derived from Snowden's (2002) perspective that context is an important element in knowledge management by which this thesis suggests eight themes as the contextual factors. Furthermore, this thesis' model also responds to von Krogh et al. (2000) that every organisation has its own contexts and the way of operating the organisation as well as managing knowledge. This difference of managing knowledge between organisations also leads to what Tidd et al. (2001) called organisational core capability as it is valuable practice and unimitated by others. Thus, the way a team manages its knowledge to achieve success in projects and subsequently developed knowledge and expertise contribute to the formation of the team's core capability, namely innovation capability in this research context.

Moreover, this research also responds to an argument (e.g. Glisby and Holden, 2003; Weir and Hutchings, 2005) on Nonaka's model in that knowledge creation processes are culturally embedded and context-influenced. In this research, there is limited evidence to support that Nonaka's model would perform differently in Taiwanese R&D teams; however, this research evidences that team atmosphere, social relationship and connection are the important factors influencing team dynamics and knowledge acquisition and sharing. This is considered a cultural influence within a Taiwanese society. Therefore, the created model extends Nonaka's ideas and places them robustly within a cultural context whilst emphasising process on how to undertake the activities associated with knowledge management.

The thesis provides a team knowledge management model (Figure 10.2) which is based on the data to illustrate how knowledge management is practised in the teams. The contributions of this model are; firstly, the model integrates innovation contexts and knowledge management activities into a framework to demonstrate how knowledge management activities take place alongside innovation processes. Secondly, this research has identified the eight themes which are associated with R&D and knowledge management activities. Based on these eight themes, this thesis' model outlines the processes of knowledge management at team level. Thirdly, the model provides an assessment of team contexts, which responds to this research's argument that knowledge management are context-based activities rather than standardised practice. Therefore, this context-based model is not only a conceptual framework for detailing knowledge management activities, but it is also an operational framework that illustrates key contextual elements (themes) and provides empirical evidence of how these contextual elements impact knowledge management activities to be undertaken within a Taiwanese R&D organisation. This adds further theoretical research of knowledge management to the literature.

Moreover, this model (Figure 10.2) also responds to the issue raised earlier in regards to the initiator of knowledge management, namely knowledge creation or problem solving. This research presents evidence that problem solving is one of most important factors that motivates knowledge related interaction for sharing knowledge. However, an implication behind the problem solving is that solving a problem is through creating new responses which involves creating new knowledge. Therefore, problem solving can be seen as a force towards knowledge creation in this research context. However, the case studies show that different types of innovation encounter different types of problem. This causes difference in team interaction which relates to access to knowledge sources and subsequently drives different foci of team

knowledge management and related interaction. This responds to Senker (1998) that a demand of new knowledge requires researchers to interact with the sources of knowledge in order to acquire related tacit knowledge, skills and techniques – whereby this research qualifies this in that different circumstances determine where teams seek to acquire tacit knowledge, skills, and techniques. Hence, this research confirms Senker's suggestion and extends its reach to argue that there are different sources for knowledge, depending on the needs and context.

However, as this research argues (chapter 2), knowledge is a multi-trait complex phenomenon. This research shows that learning-by-doing is an important mechanism to cope with the complexity of knowledge by relating to practice and specific contexts. The reason is that no one can exactly tell how a task should be done and how problems should be solved. Any suggestions or advice arising from discussions need to be tried and practised, as similar problems within different situations might call for different solutions to solve the problems. Therefore, the interview data from this research shows that in order to efficiently share knowledge and internalise knowledge, an individual learning through either practice or apprenticeship being emphasised as a basis for sharing knowledge and internalising knowledge. This is because sharing experience or knowledge is not only receiving messages from others, but also involves reacting to the received messages in practice to internalise them and generate new insights. In this research, these learning processes take place embedded in learning-by-doing. This evidence responds to this research's argument (2.2.2) that Nonaka's socialisation and internalisation modes are based on an emphasis of individual learning processes. Thus, this research suggests that socialisation and internalisation cannot work without involving individual learning processes. This also corresponds to Ahmed et al. (2002) findings that knowledge and learning are undivided and interdependent phenomenon. Hence, this research adds a further component to specify Nonaka's model.

Moreover, this research also provides evidence to outline how team learning takes place and involves knowledge management activities. This responds to the earlier argument (2.2.2) that externalisation and combination in Nonaka's model must be underpinned by team learning in order to form common understanding. The data of this research shows that team learning is undertaken through an emphasis on team cohesiveness and consensus. Thus, a team's members can be aligned in the same direction to form a common understanding with regards to tasks and team operation. This facilitates team members to interpret one's conceptual knowledge and make it become understandable to all the team members as Nonaka suggested as

externalisation. Subsequently, on this basis, various knowledge bodies may be integrated for solving problems or developing a virtual prototype of a product. Thus, team learning provides a justification of that Nonaka's externalisation and combination modes work on the basis of team learning – something so far not explicitly stated as part of Nonaka's model. Furthermore, it also provides a linkage between individual and collective levels, which justifies how Nonaka's model can work at different levels. Thus, this research suggests that team learning is an important activity for forming common understanding and a shared meaning structure by which knowledge can exist in individuals and collectives. Hence the research furthermore adds to the theoretical debate on the lack of Nonaka to specify how his model transcendent different organisational level – the process added by this research is team learning processes.

Furthermore, this research evidences that knowledge creation processes and knowledge management processes are initiated and completed at a project team level because the team is the unit that actually deals with projects, and is involved in a large amount of interactions to communicate and coordinate for the exchange of information and knowledge. Therefore, in a technological innovation context, this research confirms Senge's suggestion (1993) that the team is the best learning unit. Also, the team is a very important unit to apply knowledge management activities. This research further suggests that the team leader is a significant management level to champion knowledge management activities, especially with regards to initiating knowledge management activities and sustaining the processes. This partially responds to Nonaka and Takeuchi's (1995) middle-up-down process of initiation of knowledge creation processes. However, what is considered middle management should be further defined. More precisely, this research suggests that team leaders and middle managers (director of centre) have different responsibilities to support knowledge management activities in which the team leaders take much more responsibility in terms of initiation, gathering team members, and sustaining the processes, while directors of the centres take on the role of a supporter to support and coordinate teams.

11.2.2 Empirical contribution

There are four pivotal empirical contributions that are made in this thesis. Firstly, an empirical research is presented based on the IT R&D context in Taiwan. The study provides evidence of how knowledge management related activities are undertaken in IT R&D teams in a Taiwanese research institute and how such activities are undertaken corresponding to its specific innovation practice and contexts.

Secondly, the teams face a difficulty in adopting continuous or shifted focus in technology when selecting projects. This therefore causes problems in the accumulation of knowledge and the development of speciality at team level. This is influenced by the institute's specific mission to be self-sustainable financially and to support industry. The organisation's specific mission and performance concern force teams to become flexible in their choice of projects. Hence, a compromised project creation loop is formed as shown in Figure 4.1. This strategy influences teams to concentrate on developing their core capability. In this situation, time frame and the trend of technological development leads teams to grasp opportunities as they come along and project to project. This responds to Teece's suggestion (2000) that '*knowledge management requires the development of dynamic capability.*' This dynamic capability is involved in sensing opportunities and employing possessed knowledge to grasp these opportunities. Thus, teams have to have dynamic capabilities to respond to the technological change from time to time and select projects from where they are. This causes a difficulty to the teams in this research institute to have certain technological focus. Conversely, flexibility is required in choice of projects.

Thirdly, access to knowledge sources (internal or external) dominates a team's interaction patterns. If a team needs more external knowledge inputs, the team will emphasise external social networks and interaction to acquire knowledge. Conversely, if a team does not need external knowledge inputs, the interaction within the team will focus on internal interaction and knowledge sustaining. These phenomena are also associated with the dimension of types of innovation in which radical innovation is associated with reliance on external knowledge sources and incremental innovation relies on internal knowledge sources. This result corresponds to some of the literature (e.g. Forbes and Wield, 2000; Pavitt, 1984; Senker, 1998) in that different types of innovation are associated with different knowledge sources.

Fourthly, the use of social relationships facilitates access to knowledge sources and sharing of knowledge when one needs to access knowledge sources, especially access to external knowledge sources. In this situation, mutual trust in the circumstances of sharing knowledge with external agencies can be substituted by the use of social relationships when it is mediated by a third party who is trusted by a knowledge holder and a knowledge receiver. This use of social relationships enhances the social tie between them. Therefore, a knowledge holder and a knowledge receiver can be more open to each other. This can enhance the quality of knowledge sharing between

them. This finding corresponds to the literature that strong social ties facilitate knowledge sharing. Furthermore, this research suggests that social ties can be enhanced through a third party's involvement. Similar notions have been highlighted by a recent published paper by this thesis' author (Wang et al (2006)), Hansen (1999) and Szwlanski (1996). This may solve the problem of sharing knowledge with external agencies.

11.2.3 Management implications

In applying the findings of this research to management, first of all project selection is an important issue. Project selection influences a team to accumulate knowledge and develop further capability. This research suggests that continuously focusing on certain technological areas or shifting the focus to different technologies can cause different results in accumulating knowledge and building core capability. This is apparent when it comes to goal setting and innovation strategy at an organisational level. At a team level, this may determine project selection and performance evaluation. Thus, this research suggests that organisations should provide a clear goal and path to guide teams to undertake innovation, and also link innovation goals to performance evaluation. If an innovation strategy aims to develop certain abilities in more detail, continuous focus of innovation should be used in project selection and criteria setting for performance evaluation. Thus teams should be selecting similar projects. If an innovation strategy aims to develop diverse capability, shifting focus should guide project selection. If there is no clear strategy it increases the complexity for teams to select appropriate projects, as there are no clear organisational performance indicators. It was argued throughout that this may cause ambiguities in team goal setting and the performance of knowledge management activities.

The second area of interest to management is the value of information systems (e.g. intranet and internet). This research shows that information systems assist knowledge management to take place. However, such systems cannot be the centre of knowledge management activities as the data of this research shows that interpersonal interaction is the most important element to successful knowledge management activities. The role of information systems in knowledge management activities acts as an information exchange platform and information storage which facilitate information to be diffused efficiently. Knowledge acquisition, sharing and integration ultimately rely on interpersonal interaction through building social networks and use of social relationships. In such circumstances, knowledge acquisition and sharing is underpinned by mutual trust which is built upon social networks and social relationships. Therefore, the value of information systems in knowledge management

activities is not only transmission of information but also building connection between people to increase communication – IT should be seen as a means to an end, not the end itself.

The third suggestions are the initiation and sustaining of knowledge management activities. The data of this research shows that developing a supportive atmosphere is necessary in which team leaders play an important role to guide team members to develop a close working relationship and to encourage team cohesiveness so as to enable team members to open up to each other. The data of this research shows that a family-like working atmosphere is one of the more successful cases. Although Nonaka has suggested a *middle-up-down* strategy to initiate knowledge management, he did not clearly define the role of middle manager in knowledge management activities. This research therefore suggests that in professional R&D teams, a team leader has an important position not only initiating such activities but also creating a supportive team atmosphere to sustain such activities. A reason is that such activities are context-influenced; therefore, a team leader has a responsibility to promote and manage such activities according to the team's specific situations. Subsequently, top/senior management's intention and support are also important to enable a team leader to promote knowledge management activities.

The final suggestion is that the priority of knowledge management activities needs to be emphasised and the activities needs to be routinised, to gain the team members' commitment to knowledge management activities and keep activities constant. In order to achieve this object, this research suggests that work load, performance evaluation and team leaders' encouragement are the significant factors to look into. Firstly work load should be taken into account in work design. This enables team members to engage in the social nature of interaction and make efforts on specific knowledge related events such as generating documents and communication. Secondly, individual performance evaluation should include factors such as mutual-aid and participation which will guide the team members' behaviours toward knowledge related interaction. Thirdly, this research suggests that knowledge management related activities are not only about the procedures but also creating the atmosphere which encourages spontaneous interaction between team members. This requires team leaders' guidance and encouragement to ensure a supportive atmosphere is established.

11.3 Limitations and suggestions for further study

This research has suggested a team knowledge management model to illustrate the influential factors that impact team knowledge management. However, this model was based on one research organisation in Taiwan with limited case studies. Therefore, the author is mindful of the fact that this model may not be able to be generalised and applied to other organisations or firms. In order to enhance the generalisability of the model, the model may need to be further tested by applying it to different organisations.

Moreover, this research has pointed out that this organisation has its specific mission which leads the organisation to have various focuses on information technology development and also engages in different types of project. These may differentiate this organisation's innovation practice from other organisations or firms. For example, this thesis identified three categories of project characteristics which may not relevant in private firms' innovation practice, especially funding sources and types of innovation. In addition, the evaluation of project performance in this organisation may differ from other organisations because it is associated with technological success, diffusion and financial contribution. These criteria subsequently influence project selection and a team's knowledge management practice. This may be different from private firms. Thus, to generalise some of the contributions, this model requires further research.

This thesis suggests that social relationships, social networks and team atmosphere are important factors influencing knowledge acquisition and sharing. The author needs to emphasise again that this is based on Taiwanese society. However, whether such factors have similar influence in different nations or regions also need to be confirmed. Therefore, further research is suggested to investigate cultural influence on knowledge related interaction in different organisation and regions to examine their influence in knowledge management activities.

The model (Figure 10.2) in this thesis is suggested as a process; however, how this process leads to the enhancement of a team's R&D and innovation capability is not entirely explored due to the constraints on this research's time frame. Comparing outcomes of projects and relating it to the model would have provided some potentially interesting data. Therefore, in order to prove the process leads to the enhancement of a team's capability in R&D and innovation needs further testing.

Appendix 1-1 Interview—team leader

Man/姓名:

Title/職稱:

Job/工作內容:

Project title/團隊或專案名稱:

Contact/聯絡方式:

Date/時間和日期:

1. **Can you talk about your previous project and your team?**
   (請您介紹一下您的團隊背景以及執行過的專案?)

2. **Could you explain your R&D processes and your R&D function?**
   (請您大致說明一下你們的專案的研發程序(R&D process)及功能(R&D function)?)

3. **How does your team undertake knowledge management?**
   (在這些專案中, 您是如何進行知識的管理? 例如知識分享(sharing), 整合(integration), 編撰儲存(codify and store)與再運用(application), 請您分別說明.)

4. **Do you encourage your team members to engage in frequent business and personal interaction? What is the purpose of those activities for your team? How do you facilitate this?**
   (您是否鼓勵您的團隊成員進行頻繁的內外部互動,不管是公事上或建立個人的社交網絡? 您的用意為何? 您如何做? 及如何評量效果?)

5. **Do you share with team members your particular personal experiences and ideas? Can you tell me more about how it has worked for your team?**
   (以您過去累積的豐富經驗,您是否會主動分享您的經驗或相關知識給您的團隊成員? 用意為何? 您通常會怎麼做?)

6. **How do you distribute work to your senior engineers? Do you give them**

particular tasks or dedicate positions within the team? Do you take knowledge management into account when you assign them those special tasks?
(就專案管理的角度,您是如何分配工作給資深工程師以及定位他們的角色? 而這樣的分配是否考慮到知識管理的相關問題?)

7. **Did you consider creating knowledge management related procedures and reward systems to facilitate knowledge management taking place within the team?**
(在執行知識管理的過程中,您是否嘗試建立相關的制度(procedures)和獎勵(reward system)措施來激勵您的團隊成員? 您是如何做的?)

8. **What do you think about knowledge management in your project? What contributions do you expect from undertaking knowledge management activities? Can you talk more about how it is worked?**
(您認為知識管理對於您所執行的專案最大的貢獻和影響是甚麼?
通常在研發過程中的哪一階段最能深切感受到它的影響? 您是否可以舉例?)

9. **How does communication take place in your team, and how do you coordinate team members with different tasks?**
(在您的專案中,您是如何建立溝通(communication)及協調(coordination)的機制?尤其是面對不同技術專長的工程師及專家,您是如何建立溝通及協調的機制?)

10. **Within your organisation, how is knowledge and information are transmitted among teams/departments? When your team need new knowledge inputs, how you find the sources and where do you get related information?**
(在您的組織中,知識及資訊是如何跨部門流通,當有一方需要引進新的知識或技術時,你們是如何獲得相關的訊息,進而獲得其他部門的協助?
是否有中間者或媒介的角色從中協助?)

Appendix 1-2 Interview—team member group

Man/姓名:

Title/職稱:

Job/工作內容:

Project title/團隊或專案名稱:

Contact/聯絡方式:

Date/時間和日期:

1. **Can you talk about your current task and past experience?**
   (請您說明目前的工作以及過去參與研發專案的經驗?)

2. **When you and your colleagues encounter problems, how do you solve the problems? (當您或您的同事遇到問題的時候, 你們如何解決呢?)**

3. **Where do you access knowledge and information sources?**
   (你們通常是怎麼找到這些人, 或相關的知識資源(knowledge sources)?)

4. **Do you share with colleagues your own particular personal experiences from past tasks? How do you share your own experiences or ideas?**
   (在你平常的工作範圍內, 你會分享(share)你的個人經驗, 心得,
   或知識給其他的同事或夥伴嗎? 你都如何做呢?)

5. **What is your difficulty in sharing experiences with others? How do you cope with this difficulty?**
   (在這些分享的過程中,你認為最困難的地方在哪裡? 以你的經驗,
   你如何去克服?)

6. **Is there any procedure or mechanism that has been created to support knowledge sharing activities? For example, has any incentive has been used to encourage organisational members' willingness to share knowledge with others?**
   (你的團隊或公司是否制定相關的規定(procedure)或建立交流平台(platfor

m)來輔助這些活動的進行?此外,是否有相關的獎勵措施來提高員工分享知識及經驗的意願?)

7. **With the exception of your colleagues, what knowledge sources do you access, and how do you acquire knowledge?**
(除了這些團隊中個人經驗和知識的分享和交流,你通常都從哪些管道接觸(access)所需要的新知識? 你又如何去獲取(acquire)這些知識?)

8. **How do you codify and store your important experiences?**
(對於這些個人的經驗和知識,通常你們是如何編撰(codify)及保存(store)?)

9. **Within your project team, how do you communicate with other team members and other teams, especially when you and your colleagues have different expertise and backgrounds?**
(在你參加過的專案中,你們是如何做到有效的溝通(communication)和協調(coordination)? 尤其是針對來自不同專業領域的團隊成員及專家.)

10. **How do you interact with your colleagues? How do your team members interact? 你們互動的情形如何? 主要偏重在哪些形式的互動? 為甚麼?**

11. **Are there some procedures and mechanisms used to facilitate a integration of people with different expertise? Who is involved? Can you talk more about how they work? (對於這些不同的專業知識,**
你的團隊是如何把他們整合(integrate)在一起? 透過哪些方法(methods or procedures)以及有哪些人參與?)

12. **How does your team solve controversy among team members?**
(對於不同專業背景所導致的爭議(controversy),你的團隊通常如何解決這些爭議?)

13. **Within your team and organisation, how knowledge is transferred and applied between teams or divisions? How knowledge is mapped?**
(在你的團隊及組織中,知識是如何被運用在不同的團隊及部門之間? 這些知識的相關訊息是如何被標示(mapping)及傳遞(transmission)?

Appendix 2 Team observation sheet

Time	Team members										Face-to-face interaction			Working and on-line interaction				Telephone		Social interaction			Inter-team interaction		Remarks
	A	B	C	D	E	F	G	H	I	J	Met.	Dis.	Cht.	Wt.	Rd.	Prog.	Sch.	B-chat	P-chat	Lunch	Game	Gossip	Business	Social	
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Appendix 3 Abstract of interviews data

	Interview questions	Team A	Team B	Team C	Team D	Summary
1	The ways of solving problem	1. internet 4/6 2. reference books 2/6 3. asking 4/6 4. training course 1/6	1. internet 2/4 2. reference books ¼ 3. asking 3/4	1. internet 3/5 2. reference books 2/5 3. asking 2/5	1. internet 2/3 2. reference books 2/3 3. asking 2/3	1. internet 10/18 2. reference books 7/18 3. asking 11/18 4. training course 1/18
2	Knowledge sharing experience	1. yes, 5/6 2. not often, 1/6 3. work related-informal 6/6	1. yes, 4/4 2. informal 4/4	1. yes, informal 3/5 2. not often 2/3	1. yes, informal 2/3 2. not often 1/3 3. formal in meeting 3/3	1. Yes, 14/18 2. not often 4/18 3. formal 3/18 4. informal 15/18
3	The ways of sharing	1. presentation 2/6 2. discussion 2/6 3. teaching 2/6 4. learning by doing (supervision) 3/6	1. discussion ¾ 2. document sharing 3/4 3. practising & questioning ¼ 4. teaching 1/4	1. presentation, 1/5 2. discussion, 1/5 3. telling stories 3/5	1. Presentation, 3/3 2. discussion, 3/3	1. presentation, 6/18 2. discussion, 9/18 3. teaching, 3/18 4. learning by doing, 4/18 5. document sharing, 3/18 6. telling stories, 3/18
4	Difficulty of sharing knowledge	1. individual knowledge background, 2/6 2. communication skills, 2/6	1. individual knowledge background, 2/4 2. personality, 2/4	1. individual knowledge background, 1/5 2. personal attitude, 2/5 3. communication skills, 1/5	1. individual knowledge background, 1/3	1. individual knowledge background, 6/18 2. personality, 4/18 3. communication skills, 3/18
5	The use of Incentive and	1. No 2. Not important,	1. No, but the team leader consider	1. No 2. Not incentive	1. No	1. No 2. Not important,

	its influence	5/6	that 2. Not important 3/4	problem 3/5		11/18
6	Influence of personal relationship on knowledge sharing	1. slightly influence (internal), 2/6 2. no influence, 4/6	1. no influence (internal), 4/4 2. yes, external, 4/4	1. yes, familiarity (internal), 1/5 2. yes, external, 3/5	1. no influence (internal), 3/3 2. yes, external, 1/3	1. no influence (internal), 11/18 2. slightly influence (internal), 3/18 3. yes, external, 8/18
7	The use of IT/KM system for sharing knowledge and information	1. yes, 6/6 2. KM system useless, 6/6 3. public server ,team-base, 6/6	1. yes, 4/4 2. KM system, not often use, 4/4 3. public server, team base, 4/4	1. yes, 5/5 2. KM system, not use, 5/5 3. public server, centre-base, 5/5	1. no, 3/3 2. FPT, 3/3	1. yes, 15/18 2. KM system, negative, 10/18 3. KM system, not use, 8/18 4. public server, 15/18 5. FPT, 3/18
8	Experience of codification of knowledge	1. not often, 2/6 2. making notes, 1/6 3. no, 3/6	1. not often, 4/4 2. individual used notes, ¾	1. not often, 4/5 2. no particular method, interview report, presentation documents, 4/5	1. no particular method, 3/3 2. PowerPoint, notes, 3/3	1. not often, 10/18 2. no particular method, 11/18 3. no, 3/6
9	The ways of Storing knowledge	1. public server, 2/6 2. personal PC, 2/6	1. public server, 3/4 2. personal PC, 3/4	1. public server, 4/5 2. personal PC, 4/5	1. FPT, 3/3 2. personal PC, 3/3	1. public server, 9/18 2. FPT, 3/18 3. personal PC, 12/18
10	Experience of using KM system	1. content, 3/6 2. interaction, 4/6 3. easy use, 2/6 4. friendly	1. technical problem, speed, 1/4 2. need push, 2/4	1. useful for quantitative, 1/5 2. less useful qualitative, 1/5	--	

		interface, 2/6				
11	How the leader manage knowledge sharing, (leader group)	1. supportive atmosphere 2. team consensus 3. top management's regard	1. harmonious atmosphere (because of small team) 2. team cohesiveness	1. fixed meeting 2. encourage and communicate	1. environment for informal discussion 2. fixed meeting 3. open access of website	1. Atmosphere, 3/4 2. Team cohesiveness, 2/4 3. Management's regard and encouragement, 2/4
12	Team member's recognition of atmosphere	1. Harmonious atmosphere, 4/5	1. family atmosphere, 3/4	1. not too close, 2/5 2. good (team leader), 1/5	1. harmonious, 3/3	1. Harmonious, 7/18 2. Family-like, 3/18
13	How to know who knows, (Access of knowledge sources)	1. team leader, 3/6 2. personal social networks, 3/6	1. team leader, 2/4 2. personal social networks, 2/4	1. team leader, 3/5 2. personal social networks, 4/5 3. team interaction, 1/5	1. team leader, 3/3 1. personal social networks, 1/3 2. internet, 1/3	1. team leader, 11/18 2. personal social networks, 10/18 3. team interaction, 1/18 4. internet, 1/18
14	The role of the leader	1. a node between internal and external 2. assign tasks 3. coordination of task 4. a friend	1. decision maker 2. a node between internal and external 3. assign tasks 4. old brother	1. control 2. distribution of information 3. a node between internal and external 4. coordinator	1. guiding project 1. decision maker 2. supervision 3. assign tasks	1. Connector (node) 2. Distributor 3. Coordinator 4. Decision maker 5. Supervisor 6. a friend 7. old brother
15	Cross-task problem solving				2. fixed meeting, 2/3 3. e-mail,	

					telephone, 2/3	
16	Cross-team sharing				1. sources, 2/3 2. limited idea sharing, 2/3	
17	Team interaction	1. work related interaction, 2/5 2. informal and spontaneous, 5/5 3. small team, 4/5	1. informal, 3/4 2. anytime, any place, ¾ 3. small team, 3/4	1. weekly meeting (formal), 5/5 2. interpersonal, informal, 5/5	1. fixed meeting, 3/3 2. frequent interaction within NTU group	1. meeting, formal, 8/18 2. informal, work related, 13/18 3. team size, 7/18
18	Team communication and coordination	1. team member's communication, 4/6 2. informal team meeting, 2/6	1. team member's automatically communication, 3/4	1. fixed meeting, 3/5 2. centred on team leader, 2/5	1. fixed meeting, formal, cross-team, 2/3 2. informal meeting, NTU team, 3/3	1. team members' automatic communication, 7/18 2. informal team meeting, 5/18 3. fixed team meeting, 5/18
19	Integration of people	1. distribution of work based on team members' personality, 1/6 (team leader) 2. matrix organisation, 1/6	1. understanding each other, 2/4 2. converging on the same viewpoint 1/4	1. enabling communication environment, 1/5 2. open mind, 1/5 3. leadership, 2/5 4. time, 2/5	1. frequent communication, 2/3	
20	Solving controversy	1. team leader's attitude 2. clearly define the issues	1. discussion 2. team leader 3. find a converged view 4. common understanding	1. facilitating generating ideas 2. sensible argument 3. coordinator 4. the use of expert power	1. team leader, leader group	
21	Cross-	1. difficult, 2/6	1. difficult, 4/4	1. difficult, 3/5	1. leader group,	1. difficult, 9/18

	divisional interaction and knowledge sharing	2. top management involved, 1/6 3. organisational procedure (unavailable exchange mechanism), 2/6 4. through intranet and internet, 2/6	2. different technology focus, ¾	2. leadership of top management, 3/5 3. organisational climate, 2/5	3/3 2. fixed meetings, 3/3	2. top management, 4/18 3. different technology focus, 3/18 4. organisational procedure, 2/18 5. organisational climate, 2/18

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