An Investigation of the Acquisition and Sharing of Tacit Knowledge in Software Development Teams

Sharon M. Ryan

BA, Dip. Stats. MSc.

Submitted for the degree of Doctor of Philosophy

Dublin City University, Business School

Supervisor: Dr. Rory O'Connor

February 2005

Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of PhD, is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: Shara Rye **ID No:** 99141760

Date: February 2005

Abstract

Knowledge in general, and tacit knowledge in particular, has been hailed as an important factor for successful performance in knowledge-worker teams. Despite claims of the importance of tacit knowledge, few researchers have studied the concept empirically, due in part to the confusion surrounding its conceptualisation. The present study examined the acquisition and sharing of tacit knowledge and the consequent effect on team performance, through social interaction and the development of a transactive memory system (TMS). TMSs are important for the acquisition and sharing of tacit knowledge, since they enact 'collective minds' of teams, and are also a factor in successful team performance. In order to conduct this research, a team-level operational definition of tacit knowledge was forwarded and a direct measure of tacit knowledge for software development teams, called the Team Tacit Knowledge Measure (TTKM) was developed and validated. To investigate the main premise of this research an empirical survey study was conducted which involved 48 software development teams (n = 181 individuals), from Ireland and the UK. Software developers were chosen as the example of knowledge-worker teams because they work with intangible cognitive processes. It was concluded that tacit knowledge was acquired and shared directly through good quality social interactions and through the development of a TMS. Quality of social interaction was found to be a more important route through which teams can learn and share tacit knowledge, than was transactive memory. However, transactive memory was not a mediator between social interaction and team tacit knowledge, indicating that both provided separate contributions. Team tacit knowledge was found to predict team performance above and beyond transactive memory, though both were significant. Based on these findings recommendations were made for the management of software development teams and for future research directions.

Acknowledgements

I would firstly like to thank my supervisor Dr. Rory O'Connor for his guidance and support in completing this research. I am also grateful to Professor John Hurley for guidance during early stages of this process.

The advice provided by Professor Tony Moynihan, Dr. Edel Conway, and Dr. Finian Buckley is also gratefully acknowledged.

My thanks to the participants who took time from their busy work schedules to complete the survey. My sincere thanks to the Irish Software Association and Mr. Fergus O'Connell for their valuable help and input.

I would also like to thank Skyhawk at Redbrick and David Molloy in the Faculty of Engineering for hosting and providing technical support for the online questionnaires.

Thanks also to all the members of the BGA, for the diversion. In addition, the support provided by June, Nick and Art is also gratefully acknowledged.

Finally, I would especially like to thank Andy, for his constant encouragement and support.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AI	Artificial Intelligence
aTK	Articulable Tacit Knowledge
CASE	Computer-aided Software Engineering
CIP	Cognitive Information Processing
CMMI	Capability Maturity Model Integration
DTI	Department of Trade and Industry (UK)
FCA	Formal Concept Analysis
GDP	Gross Domestic Product
IDA	Industrial Development Authority (Ireland)
IM	Information Management
IS	Information System
ITS	Information Technology System
KBS	Knowledge Based System
KM	Knowledge Management
LOC	Lines of Code
NSD	National Software Directorate
MBTI	Myers Briggs Type Indicator
MNC	Multi-National Company
NBA	National Basketball Association
NSD	National Software Directorate
PCP	Personal Construct Psychology
RDR	Ripple Down Rules
SES	Socio-economic Status
SJT	Situational Judgement Test
SKD	Synergistic Knowledge Development
SME	Small to Medium Enterprise
SNA	Social Network Analysis
SPICE	Software Process Improvement Capability dEtermination
TMM	Team Mental Model
TMS	Transactive Memory System
TTKM	Team Tacit Knowledge Measure
XP	eXtreme Programming

Chapter 1
Introduction

1.1 Introduction

The acquisition and sharing of knowledge and of tacit knowledge in particular, is of increasing importance to economic and organisational competitiveness. The importance of knowledge to the economy of a country is now recognised at a government level in both Ireland and the UK. The end of year review published by the Industrial Development Authority of Ireland (IDA, 2003) claims that Ireland is now a 'knowledge economy'. According to the IDA, this 'knowledge economy' has come about because of key competitive features which make Ireland attractive for a new breed of high level projects based on knowledge and the way we use it. Ireland's transformation is now being conveyed to the international marketplace by the IDA through a new marketing message – 'Ireland, knowledge is in our nature.' The Irish government is not alone in acknowledging the value of knowledge to the economy; the UK's Department of Trade and Industry (DTI) also recognises the importance of the 'knowledge economy' in its white paper 'Competitive futures: Building the Knowledge Driven Economy' (1998).

Knowledge driven industries such as the software sector rely on employees' expertise to produce a finished product. Knowledge is the means of production in such organisations, and this expert knowledge is owned by employees. Expert knowledge is mainly tacit or inarticulable, and so difficult to communicate however, it is thought to be a core competitive advantage (Nonaka & Takeuchi, 1995; Spender, 1998; Spender & Grant, 1996; Thompson et al. 2001). Social interaction between team members is forwarded as the means through which tacit knowledge is acquired and shared (Busch et al. 2003; Edmondson et al. 2003; Nonaka & Takeuchi, 1995). Software products are developed in teams and it is therefore essential to the effective development of these products that knowledge is acquired and shared within the development team. The study described in this thesis investigates the process by which tacit knowledge is acquired and shared in software development teams. In particular, the role of social interaction in the development of shared mental models, specifically transactive memory, is explored in order to assess their relationship with tacit knowledge and team performance.

1.2 Overview of the Research Domain

The focus of this thesis is on the acquisition and sharing of tacit knowledge in software development teams. Knowledge is an elusive, complex concept and abstracted definitions do not clarify its nature. One approach to understanding knowledge is to view it as a dichotomy between tacit, contextualised knowledge and explicit, codified knowledge. This segregation is echoed in the realms of philosophy, psychology, sociology, Artificial Intelligence (AI) and organisational theory. A second approach to classifying knowledge, views knowledge as possessed by an individual or/and by groups (Baumard, 1999; Gourlay, 2002; Spender, 1998). The psychological, AI, and organisational fields in particular, recognise that the domain knowledge required by experts to perform expert roles in organisational contexts, is largely tacit. Principles and techniques have been established within these disciplines to measure tacit knowledge, but these have occurred for the most part, at the individual level.

Measures of tacit knowledge have mostly been developed in laboratory studies (Cleeremans, 1977; Reber, 1967, 1969; 1976) and few have been applied to 'real world' environments (Busch et al. 2003; Hedlund et al. 2003; Sternberg, et al. 2000). Two measures of team tacit knowledge have been identified, both of which are proxy measures, using performance as the surrogate indicator (Berman, et al. 2002; Edmondson, 2003). Theoretical links between social interaction and tacit knowledge (Choo, 1998; Hansen, et al. 1999; Nonaka & Takeuchi, 1995), have been demonstrated through case study research (Busch et al. 2003; Edmonson et al. 2003). In addition, the link between social interaction and transactive memory has also been established empirically in laboratory studies (Hollingshead 1998a, 1998b; Moreland, 1999; Wegner et al. 1991) and in one field study (Lewis, 2003). In principle, there should be a connection between social interaction, tacit knowledge and transactive memory, but this link has never been demonstrated empirically. Furthermore, there is no direct measure of tacit knowledge, at the team level.

The approach taken in the present work is to treat tacit knowledge as context-specific, related to expertise, and team-based. The aim is to connect principles and techniques devised by psychologists, organisational theorists and AI researchers and apply them to software development teams. Members of software development teams are considered to be knowledge-workers – experts who own the means of production i.e. knowledge.

There are three reasons as to why this perspective is adopted: firstly, because theory and some case study research have indicated an increase in tacit knowledge in interacting teams (e.g. Busch et al. 2003; Choo, 1998). Furthermore, transactive memory has been found in one field study to be related to social interaction (Lewis, 2003). These tentative findings, if applied to the environment of software development, could add something new to the domain of team performance in knowledge based teams. Therefore, tacit knowledge is an important factor in a software organisation's performance and by extrapolation is also an important factor in team performance, since most software development is team-based. Secondly, tacit knowledge is also a source of competitive advantage since the principle assets of many knowledge organisations, particularly software firms, are intangible and held in the form of employee expertise or 'know-how'. Thirdly, the development of a direct measure of tacit knowledge at the team level, would address this gap in the research domain and help expand the research body in a new direction.

In summary, this thesis explores the relationship between the social interaction and tacit knowledge within software development teams. More specifically, the research explores the role of social interaction quality and quantity in the acquisition of tacit knowledge through socially shared cognition and transactive memory. This research also examines some other team factors that influence tacit knowledge acquisition. In order to achieve this, a suitable definition of tacit knowledge was developed, and then a generalised measure of team tacit knowledge for the domain of software development was devised, validated and implemented. Moreover, a model for the acquisition and sharing of team based tacit knowledge, founded on existing theory, was developed and tested.

The remainder of this chapter will briefly outline the main issues explored in this thesis based on the research literature from philosophy, psychology, AI, organisation theory and information technology management. The characteristics of tacit knowledge will be outlined, highlighting problems associated with defining it. Following this, an introduction to knowledge-worker teams is presented. A new theory of the process of tacit knowledge acquisition and sharing in software development teams will be proposed. This theory was developed in response to gaps in the literature linking social interaction to tacit knowledge at a team level. A number of research aims will be identified which will be addressed in the rest of this thesis. Finally, the structure of the remainder of the thesis will be outlined.

1.3 Investigating Tacit Knowledge

1.3.1 Why Study Tacit Knowledge?

The ultimate aim of this research is to search for theoretical understanding and to add to the body of academic knowledge. In addition, the outcomes of this research will provide practical applications and benefits to people who work in and manage knowledge-worker teams in general, and software development teams in particular. From a theoretical and practical perspective, an understanding of tacit knowledge cannot be produced in a vacuum. This position is based on the approach that knowledge is socially constructed and embedded in context (Clancey, 1995).

The main purpose of investigating expert tacit knowledge is to uncover some principles which can be transferred to others in order that:

- Knowledge-worker teams can gain an insight into how tacit knowledge affects their performance
- Knowledge-worker teams can be given tools and skills to enhance and explore their own team's tacit knowledge
- Changes can be made in the organisation or team (be they physical, social and/or cultural)

These practical benefits should be based on sound theory and rigorous methodology. The development of such a theory and methodology is necessary to help clarify the problems of definition and measurement, and to address some of the gaps in the literature.

1.3.2 Problems in Defining Tacit Knowledge

The main obstacle to investigating tacit knowledge is the problem of definition. Tacit knowledge is not data or information, and cannot be codified, since codified knowledge is actually information and can be easily transmitted between people. Information does not become knowledge until understood by the receiver and incorporated into the individual's own knowledge structures (Wilson, 2002).

Polanyi (1966) coined the term tacit knowledge and defined it according to the idea that 'we can know more than we can tell' (p .4). Since then, there has been much debate in the literature as to how tacit knowledge can be conceptualised and operationally defined. Some researchers argue that 'tacitness…is a matter of degree' and that the same knowledge may be more tacit for one person than another (Nelson & Winter, 1982, p.78). Others argue that there is a middle ground between tacit and explicit knowledge, which is articulable tacit knowledge (aTK) (Busch et al. 2003; Sternberg et al. 2000; Nonaka & Takeuchi, 1995). Yet others dispute that tacit knowledge can ever be articulated (Polanyi, 1966, Wilson, 2002) and refer to this middle ground as implicit knowledge.

In this research tacit knowledge refers to articulable knowledge about software development projects, which is possessed by a team. The term 'tacit knowledge' rather than 'implicit knowledge' is used, to allow comparison with previous research conducted by Hedlund et al. (2003), Sternberg et al. (2000), Busch et al. (2003) and Berman et al. (2002).

1.3.3 How do we Acquire Tacit Knowledge?

Nonaka and Takeuchi (1995) popularised the term tacit knowledge and posited that new knowledge is created through iterative social interaction, where tacit knowledge is made explicit. However, a more appropriate explanation may be that rather than making tacit knowledge explicit through social interaction, evidence of tacit knowledge acquisition may be seen in our skilled performance (Tsoukas, 2003). In this thesis it is proposed that tacit knowledge acquisition is a reciprocal process which originates with individuals and becomes group and organisational knowledge as a result of social interaction (Berman et al. 2002; Leonard & Sensiper, 1998).

It is also proposed that informal and face-to-face interpersonal communications are the richest medium for transferring knowledge because they allow for immediate feedback and the embodiment of tacit knowledge cues (Koskinen, et al. 2003). The definition of social interaction used in this study is face-to-face conversation, which is work related, personal or social. The interaction does not refer to formal interactions like a scheduled project meeting, performance appraisal etc.

Social interaction in teams is related to 'shared mental models', where team members tend to rely on one another in a cognitively interdependent manner. A transactive memory system is a type of shared mental model, where there is a cooperative division of labour for learning, remembering, and communicating relevant team knowledge (Hollingshead, 2001; Wegner, 1987). It is proposed in this research, that social interaction is the means through which tacit knowledge is created. In addition, social interaction is central to the development of a transactive memory system. This transactive memory system is in turn, the means through which tacit knowledge is acquired and disseminated in teams.

1.4 The Research Context: Knowledge-Worker Teams

Knowledge-worker teams have members who use expertise and experience to solve problems and create knowledge-based products. Knowledge workers are characterised as individuals who have high levels of education and specialist skill combined with the ability to apply these skills to identify and solve problems. In this thesis, software development teams are the knowledge-worker teams of interest. Members of software development teams are considered to be 'intellectual workers' (DeMarco & Lister, 1987) or 'knowledge workers' and since they work with intangible cognitive processes rather than physical tangibles, the rules for developing tangible goods do not apply (Brooks, 1987). Knowledge, held in individual minds, is the means of production in software development. The process of developing software involves the tacit coordination of expertise of these team members (Faraj & Sproull, 2000). Knowledge sharing is therefore a key process in developing software, and since expert knowledge is tacit, the acquisition and transmission of tacit knowledge is significant in the development process. In addition, the software development teams in this research were obtained from small to medium enterprises (SMEs) in Ireland and the UK. It is argued that these two countries have comparable software development industries.

The failure of many large software projects has highlighted the challenges in managing team-based work (Faraj & Sproull, 2000). The majority of software projects do not meet budget and schedule, function unsatisfactorily, and around 25% are never completed (Gibbs, 1994; Standish Group International, 2001). Research has shown that human factors rather than technological developments may be the prime factors influencing performance on successful projects (Curtis et al.1988; Faraj & Sproull, 2000; Guinan et al. 1998; Kraut & Streeter, 1995). Team performance on software development projects is dependent on many different and interacting factors like effective plans, good communication, clear goals etc. In addition, internal group processes, particularly those focussing on the team's relationships, are more likely than technical factors to be associated with team performance on successful projects (Guinan, et al. 1998).

1.5 Research Aims

In this research study tacit knowledge is measured at the team level; it is context specific and therefore knowledge that is specific to a team should be measured at team level. Tacit knowledge is seen as a form of expert knowledge that is acquired through social interaction. Different team members will acquire different amounts of tacit knowledge which is coordinated within the team through the development of a transactive memory system. A model for the acquisition and sharing of tacit knowledge in knowledge-worker teams will be proposed in order to act as a possible explanation of how tacit knowledge is acquired and disseminated in software development teams.

The main aim of this study is to progress towards the goal of understanding how tacit knowledge is acquired and shared in software development teams. In so doing, advances in assessing the utility of focussing on the tacit component of team members' knowledge in bringing about effective performance may be made.

In order to progress towards the overall goal, there are four key questions that need to be addressed:

i. How do we define and measure tacit knowledge?
ii. How is tacit knowledge acquired and shared in knowledge-worker teams?
iii. What impact does tacit knowledge have on team performance?
iv. Why is tacit knowledge important for knowledge-worker teams?

To provide answers to these questions, there are many other issues that require investigation. These will form the research aims of this thesis. Investigation of these will require coverage of a wide range of background literature, as well as substantial empirical work. The research aims are divided into four areas corresponding to the four research questions. The first research question is concerned with the definition and measurement of tacit knowledge and has four concomitant aims:

- To examine the philosophical and psychological conceptions of knowledge in general and tacit knowledge in particular.
- To investigate the difference between individual tacit knowledge and team tacit and explicit knowledge.
- To analyse the notion that tacit knowledge is a form of expert knowledge.
- To identify and evaluate techniques for measuring tacit knowledge in teams in the software domain.

The second research question concerns the acquisition and sharing of tacit knowledge in knowledge-worker teams. There are three aims associated with this question:

- To identify theories and techniques for the acquisition of tacit knowledge.
- To explore the role of social interaction and other factors, in tacit knowledge sharing.
- To apply these theories of tacit knowledge acquisition and sharing to software development teams.

The third question to be investigated deals with the value of tacit knowledge for knowledge-worker teams and have four related aims:

- To identify the unique compositional aspects of knowledge-worker teams, specifically software development teams.
- To identify the factors affecting team performance in the software domain.
- To assess the importance of tacit knowledge as a factor in team performance.
- To examine the issues for managing software teams.

Finally, the impact of tacit knowledge on team performance is addressed. There is one aim linked to this question:

- To identify the effect of tacit knowledge on team performance.

1.6 Thesis Structure

The thesis contains eleven chapters; following the introductory chapter, the remaining ten chapters fall into three parts: Chapters 2, 3, 4 and 5 cover background literature, Chapters 6 to 9 describe the empirical work, and Chapters 10 and 11 contain discussion and conclusions to the research.

The first part of the thesis (Chapters 2 – 5) reviews a wide range of literature in order to critically assess the research questions and develop a clear direction for the empirical work. Chapters 2 and 3 explore the philosophical, psychological and organisational approaches to conceptualising and defining knowledge. Chapter 2 focuses on the individual and group-level approaches to knowledge conception and representation, while Chapter 3 outlines approaches to the conceptualisation and representation of tacit knowledge. Chapter 4 centres on previous empirical work into the acquisition and sharing of tacit knowledge. Chapter 5 covers the characteristics of knowledge-worker teams, in particular, those associated with software development teams. This chapter concludes with the development of a theoretical model for the acquisition and sharing of team based tacit knowledge.

The second part of the thesis (Chapters 6 – 9) covers the empirical work. Chapter 6 describes the overall design of the study. It explores the methodological issues involved, including paradigm choice and methods of assessment used by different disciplines. The core of the chapter involves the selection of the appropriate technique to assess tacit knowledge, social interaction and transactive memory in software development teams. Chapter 7 covers the testing of the proposed model using an online interactive survey technique. Chapter 8 describes the development of the team based tacit knowledge measure using the repertory grid technique. Chapter 9 brings together the results obtained from the survey.

Finally, Chapter 10 provides a discussion of the results in light of previous research and Chapter 11 addresses the research questions posed earlier and outlines a number of areas that future work might address. Firstly, Chapter 11 presents some conclusions to the research aims, and describes further issues that have arisen. Then some implications of the research conducted are discussed and finally, how future work might address the research findings, is outlined.

Chapter 2

Conceptualising Knowledge: Individual and Social Approaches

2.1 Introduction

Knowledge is complex, and theoretical conceptions of knowledge originate in philosophical discourses that later acquire psychological roots. This chapter outlines the philosophical bases to psychological and organisational approaches to conceptualising knowledge. This chapter is in two parts reflecting individual and group level approaches to knowledge conceptualisation. The chapter begins by addressing the problem of knowledge, then individual level theories of knowledge representation are outlined from philosophical and psychological perspectives. The traditional and commonly used definition of knowledge as 'Justified True Belief' (Moser et al. 1998) is described and criticised as is the cognitive approach to representing knowledge. The second part of the chapter focuses on the group-level, social approach to knowledge, with particular reference to the development of team mental models and transactive memory systems.

2.1.1 The Problematic Nature of Knowledge

The problem of how we organise and represent knowledge has been the most difficult to solve in both philosophy and psychology (Paivio, 1986). According to Davis et al. (1993):

> Any intelligent entity that wishes to reason about its world encounters an important, inescapable fact: reasoning is a process that goes on internally, while most things it wishes to reason about exist only externally...This unavoidable dichotomy is a fundamental rationale and role for a representation: it functions as a surrogate inside the reasoner, a stand-in for the things that exist in the real world (p.18).

One of the most important issues in Western philosophy is the question of knowledge. Put simply how does philosophy deal with the question 'What is knowledge?' This enquiry has been of concern to philosophy since the inception of philosophy itself, and remains unanswered today. In an attempt to deal with the complexities of this philosophical enquiry, it has been argued by Legge (1995, p.1) that 'it is the search for a satisfactory answer that reveals that the question is not as straightforward as it looks and that to achieve an answer that is not only neat in form but satisfactory in content requires the unpacking of the substance of the question'. The purpose of posing this question may be to ultimately achieve a greater understanding of what it is we are asking (Fernie et al. 2003).

It is important to distinguish here between data, information and knowledge. '[D]ata, information, and knowledge are not interchangeable concepts' (Davenport & Prusack, 1998, p.1). Data are 'a set of discrete, objective facts about events' (Davenport & Prusack, 1998, p. 2) becoming information when given relevance and purpose. The nature of information changes the way the receiver perceives something; it has to inform. As Davenport and Prusak (1998) state 'the receiver, not the sender, decides whether the message he gets is really information' (p. 3). Here the importance of the role of perceiver is emphasised in constructing knowledge from data via information.

A further issue in conceptualising knowledge is whether knowledge is constructed in the mind of the individual or whether knowledge is a social phenomenon. Philosophy and psychology have both addressed this issue.

PART I: INDIVIDUAL-LEVEL CONCEPTUALISATION OF KNOWLEDGE

2.2 Philosophical Approach

Philosophical enquiry into knowledge is concerned with metaphysics, the branch of philosophy that deals with the combination of ontology and epistemology. Guba and Lincoln (1994) define ontology and epistemology in terms of the questions they seek to answer. Ontology is a search for the nature of being and seeks to answer the questions 'What is the form and nature of reality and therefore, what is there that can be known about?'(p.108). Epistemology is concerned with the origins, nature and limits of knowledge, especially with regard to its methods and validation. Epistemology attempts to answer the question 'What is the relationship between the knower and what can be known?' (Guba & Lincoln, 1994, p.108). The answer to the epistemological question is constrained by the response to the ontological question i.e. if a 'real' world is assumed (as in scientific enquiry) then the knower is a detached observer. Therefore, different philosophical approaches to knowledge hold different perspectives on ontology and epistemology.

2.2.1 Traditional Definition of Knowledge: The Mind Mirrors Reality

Western philosophy emphasises the individual knower separated from the real world, methods and processes by which we acquire knowledge and the source of what we know are based on two approaches: reason and experience. Historically, beginning with Plato and Aristotle, there has been a division between two different sources from which knowledge arises, i.e. rationalism and empiricism. According to Plato's rationalist theory of ideas, the physical world is a shadow of the perfect world of ideas. It is to the world of ideas that we aspire, and this world can only be known through reason not sensory perception. Aristotle, a pupil of Plato, refuted this stating that 'there is nothing in the mind except what was first in the senses', arguing that ideas cannot be isolated from the senses (Anderson et al. 1986). This division re-emerged in the 17th Century with Descartes' dualism of mind/body, subject/object. Descartes argued that the ultimate truth can be deduced only from the real existence of thinking self, a body may exist in space, but does not think, a mind has no extension but thinks, hence 'I think, therefore I am' or '*Cogito, ergo sum*'.

Both rationalists and empiricists believe in metaphysical realism, which is 'the platonic doctrine that universal or abstract have being independently of mind' (Gellner, 1980, p.60), where objects have intrinsic meaning and where propositions or thoughts are seen as 'representing' how things are. The traditional definition of knowledge is described by the tripartite theory which analyses knowledge into three components; justification, truth and beliefs (Moser et al. 1998). It posits that if we believe something, have a justification for believing it, and it is true, then our belief is knowledge. 'Justified true belief' treats the knower as a spectator of an objective reality, where the mind is a mirror, reflecting reality. This theory focuses on 'knowledge that' or propositional knowledge as opposed to 'knowledge how' which is a skill or competence.

2.2.2 Limitations of the Traditional Philosophical Approach to Knowledge

The assumption here is that if reality exists separately from the human mind, then the acquisition and transfer of knowledge is simple. But this view limits the knower to knowledge that is abstracted from the experience itself, like bodily knowledge (Rescher, 1989).

This correspondence theory of truth assumes that a belief (proposition, sentence, statement, etc.) is true when it corresponds to reality (Wittgenstein, 1958). However, the main barrier to the knowing mind being a spectator, is that it cannot observe itself in the process of knowing (Anderson et al, 1986; von Glaserfeld, 1995). In addition, Tarski's (1956, cited in Mulligan, et al. 1984) semantic theory of truth, rejects the possibility of complete correspondence. Thus, questions raised by various authors (e.g. Dummett, 1978, Putnam, 1981) about whether facts are knowable or can exist independently of our ability to discover them, are problematic for objectivists.

In conclusion, there are several problems with the traditional view stemming from the separation of subject and object and the assumption of an independent reality. Phenomenological and constructivist approaches to studying knowledge do not separate the knower from the knowledge they possess and advocate a socially agreed upon reality. However, before these social approaches can be discussed it is necessary to investigate how psychology has dealt with the problem of knowledge at the individual level.

2.3 Psychological Approach

Philosophical approaches to knowledge form the roots of the psychological approach. Many of the questions of contemporary psychology can be traced back to related questions in philosophy and many of psychology's methods also have their philosophical forebears (Holtzman, 1978). As with philosophy, there are many arguments as to how the mind functions. The scientific method based on positivism is the dominant modern paradigm in the philosophical study of knowledge and is applied to the psychological study of human behaviour and the mind.

Early psychological thought was divided into two groups: *behaviourism* and *cognitivism* corresponding to the two philosophical approaches empiricism and rationalism, respectively. Cognitive psychology deals with attention, perception, learning, memory, language, emotion, concept formation, and thinking (Eysenck & Keane, 2000). Cognitive psychology, and its close relative cognitive science, developed out of the criticism levelled against behaviourism's disregard for mental processes. Behaviourism, as forwarded by Skinner (1938), rejected the notion of mental categories or contents as 'unverifiable nonsense' and went so far as to claim that conscious experience did not exist.

Cognition may be defined as 'the activity of knowing: the acquisition, organization, and use of knowledge' (Neisser, 1976, p.1). Cognitive psychology examines the intervening variables between stimulus and response, i.e. the processes of the mind. Theory building in cognitive psychology has taken the form of metaphors relating to the nature of mental representation and to the processes involved in constructing and using these representations. The elements of cognitive psychology are unified under a dominant paradigm; the computer metaphor (Kuhn, 1962; Massaro & Cowan, 1993).

2.3.1 The Computer Metaphor: The Mind as an Information Processor

Cognitive scientists study the nature of the human mind from a psychological point of view, mostly building computer models that help elucidate what happens in our brains during problem solving, remembering, perceiving, and other psychological processes (Eysenck & Keane, 2000). One major contribution of AI and cognitive science to psychology has been the information processing model of human thinking in which the metaphor of brain-as-computer is taken quite literally.

Cognitive information processing (CIP) is not associated with the work of a single theorist; rather, it builds on the work of a number of researchers who share a common paradigm (Anderson, 1983, 1993; Newell et al. 1956, 1958). The basic CIP model is concerned with fundamental mental operations, mainly how we perceive and remember events and information; it seeks to explain how the mind works. It is associated with learning but concentrates on how information is processed.

In 1956, Simon and Newell began to use computer programming to build theories of human symbolic behaviour, explaining problem solving in information-processing terms, and modelled with computer programs. The process involves logical rule-based thinking for translation of the perceptual input into symbols (language), that the computer (mind) understands. These symbols are organised by attentional processes into patterns (syntax) and a storage system.

2.3.2 Representing Knowledge: Mental Models

The manner in which knowledge is represented and organised in the mind is a fundamental question about the architecture of the mind where a representation stands for something in the absence of the thing (Eysenck & Keane, 2000). According to Sternberg and Ben-Zeev (2001) 'knowledge representations strip off peripheral details and preserve the essence of our experiences' (p.58).

There is a variety of terminology in cognitive science to explain the process by which individuals make sense of their surroundings, including mental models (e.g. Rouse & Morris, 1986), categories (e.g. Rosch, 1978) scripts (Schank & Abelson, 1977), schema (Bartlett, 1932), frames of reference (Minsky, 1975) and cognitive maps (Neisser, 1976). Mental models are often used in a way that is synonymous with 'knowledge'in general (Rouse & Morris, 1986). They are built from past experiences and comprise internally represented concepts, and relationships among concepts, that an individual can then use to interpret new events. According to Holyoak (1984, p. 193), a mental model is a 'psychological representation of the environment and its expected behavior.' The view of mental model taken in this section, is that of Klimoski & Mohammed (1994) who state that mental models refer to a general class of cognitive constructs that have been invoked to explain how knowledge and information are represented in the mind.

At an individual level semantic knowledge may be stored as propositions or units of *declarative* knowledge i.e. knowledge about facts and production networks or *procedural* knowledge i.e. knowledge about how to do something (Gagné, 1995). Furthermore, semantic knowledge may also be represented by schemata, which become more complex as a person develops expertise in a given domain.

2.3.3 The Connectionist Metaphor of Knowledge Representation

Developments in AI and neuropsychology have challenged the computer machine-like metaphor of the mind. The physiology of the brain does not support the computer metaphor, cognition occurs not as a series of processes but more as patterns of activation (St. Julien, 1997). These patterns require that many things may be happening both simultaneously and very rapidly. There is a co-evolution between the neurosciences and information processing psychology (Kobes, 1991). This approach is called the Artificial Neural Networks (ANN) or connectionist model of cognitive architecture (McClelland & Rumelhart, 1986). All ANNs have a set of processing units, but they do not include a central processor. They are connected to each other in complex, changing ways. The pattern of connections determines the system and how it will respond. The brain's collection of neurons forms a neural network which consists of simultaneously active units. In the network model, connections, meaning, and learning are intertwined concepts: 'When no meaning (no connections) can be created, nothing is learned' (Gagné, 1985, p.79). These are not physical arrangements of actual networks of neurons but a model of the functioning of actual neural networks (Omidvar & Elliot, 1997).

2.3.4 Limitations of the CIP and Connectionist Approaches

The computational model is limited and Gardner (1985) argues that the methods used in cognitive science will fall short in explaining knowledge categorisation. He points out that the computer metaphor 'has helped scientists to understand the ways in which human beings are not very much like prototypical computers' (p.44). Computational models do not capture the wider aspect of cognition e.g. moral and social aspects of behaviour (Eysenck & Keane, 2000).

More recent approaches to knowledge representation have built upon constructivism and situational cognition. As Tsoukas and Mylonopoulos (2004) stated '[W]e now appreciate that theoretical knowledge, practical application and social context are all inextricably linked' (p.2). Jerome Bruner a leader in the cognitive revolution of the 1950s felt the emphasis had shifted from the 'construction of meaning' to the 'processing of information'. He viewed the computer metaphor as too limiting in that it did not allow for the role of culture in shaping our thoughts and the words we choose to express them. For Bruner, an understanding of mind must include mental states like 'believing, desiring, intending, and grasping a meaning,' (Bruner,1990 p.8) and must consider the mediating effects of culture and language. He argued that scientists should not continue studying cognition in isolation, because the symbolic systems that individuals used in constructing meaning were systems that were already there, deeply embedded in culture and language. Therefore the social aspects of cognition influence the manner in which we acquire knowledge.

2.4 Summary of Part I

In philosophy, knowledge was seen as either rationalist or empiricist and the definition of knowledge viewed the knower as separated from the knowledge. Knowledge was represented in the mind as a reflection or 'mirror of reality'. Cognitive psychology has traditionally represented knowledge using the CIP metaphor. Individuals are seen as symbolic processors where objects of knowledge are processed. Semantic knowledge is represented in the form of mental models, as semantic networks, of which there are two types, propositional and production based, reflecting declarative and procedural knowledge respectively. In addition semantic knowledge may also be represented by schemas, scripts and frames. Limitations of both the philosophical and psychological approaches, based on the separation of the knower from the knowledge, have led to philosophers, psychologists and organisational theorists addressing social aspects of knowledge.

PART II: GROUP-LEVEL CONCEPTUALISATION OF KNOWLEDGE

2.5 Knowledge is Personally and Socially Constructed

According to Still and Costall (1991), the domination of psychology by cognitive psychology, and cognitive psychology by cognitivism, has left at least two questions unanswered. Firstly, how can the knower ever reach beyond internal representations to the reality they are supposed to represent? Secondly, how can the individual's mutual interdependence with the environment be captured by a system of formal rules? Knowledge therefore may also be conceptualised as personally and socially constructed.

2.5.1 Philosophical Underpinnings of Socially Constructed Knowledge

The phenomenological challenges to Cartesian dualism, looks at the self in interaction with the outside world and is associated with writings of Edmund Husserl at the beginning of the 20th century. According to Husserl, all forms of knowledge have their roots in consciousness, and the key to discovery is that all forms of consciousness are characterised by intentionality (Guignon, 1992). By intentionality he meant that all our thinking, feeling, and acting are always about things in the world. Knowledge is therefore derived from our intentional acts in the world of 'lived experience' or *Lebenswelt* (Anderson et al. 1986). The main phenomenological argument is that all knowledge begins in consciousness and comes from subjectivity. The 'objective' rules of science are rooted in consciousness (Anderson et al. 1986). Phenomenology was the beginning of viewing knowledge as a socially constructed phenomenon.

The philosophical approach which holds that knowledge is personally and socially constructed by the cognising subject (von Glasersfeld, 1989) is called '*constructivism*'. Constructivism posits that knowledge does not correspond to objective reality, but to an agreed upon reality which 'is made up of the network of things and relationships that we rely on in our living, and on which, we believe, others rely on, too' (von Glasersfeld, 1995, p.7). This means that we cannot share understandings but rather we can test the degree to which our individual understandings are compatible. In contrast to von Glaserfeld's position known as *radical constructivism*, for many, *social constructivism* has emerged as a more acceptable form of the philosophy.

2.5.2 Social Constructivism

Berger and Luckmann (1967) forwarded a discourse called 'The Social Construction of Reality'. They contend that the sociology of knowledge is concerned with the analysis of the social construction of reality which is the relationship between human thought and the social context within which it arises. According to these authors consciousness is always intentional. The reality of everyday life presents itself to individuals as an inter-subjective world, a world that is shared with others where the most important experience of others is the face-to-face situation. Berger and Luckmann (1967) assert that knowledge begins with the individual, but through face-to face interaction, a shared reality is constructed that is agreed upon socially and is situation dependent. Knowledge in everyday life is socially distributed being possessed differently by different individuals and types of individuals.

In conclusion, philosophy has provided us with several different approaches to understanding the question 'what is knowledge?' but does not provide a definitive answer. Knowledge is thus ultimately an individual's ability to make judgements, or as Tsoukas and Vladimirou (2001) propose, 'knowledge is the individual ability to draw distinctions, within a collective domain of action, based on an appreciation of context or theory, or both' (p.979). All knowledge is therefore personal, which is defined as 'the cognitive resource which a person brings to a situation that enables them to think and perform' (Eraut, 2000, p.114.)

2.5.3 Personally Constructed Knowledge: Kelly's Personal Construct Psychology

The constructivist perspective holds that knowledge is a constructed entity made by each and every learner through a learning process. Knowledge can thus not be transmitted from one person to the other; it is constructed by each person. George Kelly's theory of personal constructs was the first constructivist attempt to devise a theory of personality and psychotherapy based on a formal model of the organisation of human knowledge. Kelly's (1955/1991) philosophy of constructive alternativism asserts that reality is subject to many alternative constructions. Objective reality is therefore a myth and subjective reality is based on how we construct the world, i.e. we cannot separate the knower from the knowledge (Banister, et al. 1994). Kelly's (1955/1991) Personal Construct Psychology (PCP) consists of a Fundamental Postulate and 11 corollaries (Appendix A). The fundamental postulate holds that a 'person's processes are psychologically channelized by the ways in which he anticipates events' (Kelly, 1955/1991, Vol.2, p.32/1991). The processes include those of our self-definition and our relationships with others, as well as the tasks at hand (Kelly, 1955/1991). PCP is based on the model of *man-the-scientist* [*sic*] (Kelly, 1955/1991). Within this model,

- the individual creates his or her own ways of seeing the world in which s/he lives; the world does not create them for her/him;
- (s)he builds *constructs* and tries them on for size;
- the constructs are sometimes organised into systems, groups of constructs which embody subordinate and superordinate relationships;
- the same events can often be viewed in the light of two or more systems, yet the events do not belong to any system; and
- the individual's practical systems have particular foci and limited ranges of convenience.

Kelly did not ignore the social aspect of construing with individual reality, shared reality and social reality being acknowledged in corollaries. According to Kelly (1955/1991), our personal frameworks or construct systems are made up of similarity-difference dimensions or bipolar constructs which are unique and personally understood and which Kelly refers to as the individuality corollary. Two individuals will not construct an event in the same manner. Conversely, Kelly also posits that individuals can share a view and understand another's interpretation of the world (commonality corollary). When people share an understanding then their psychological processes are similar. Reality is social 'to the extent that one person construes the construction processes of another, he [*sic*] may play a role in a social process involving the other person' (Kelly, 1955/1991 Vol.2, p. 5/1991; sociality corollary).

Based on the preceding discussion it can be concluded that from a philosophical perspective, knowledge may be viewed as personal and social. This view has implications for the psychological and organisational approaches to knowledge at the group level, which is ontologically subjective and epistemologically sees the knower in interaction with the outside world. In addition, this theory forms the background to the repertory grid technique, which is discussed in Chapter 8.

2.6 The Role of Social Interaction in Social Cognition

2.6.1 Social Cognition

Although mental models and other cognitive constructs have traditionally been considered at the individual-level of analysis, there has been a renewed effort to expand consideration of these phenomena to the group level (Klimsoki & Mohammed, 1994; Mohammed et al. 2000). Larson and Christensen (1993, p.6) define social cognition as the 'social processes that relate to the acquisition, storage, transmission, manipulation, and use of information for the purpose of creating a group-level intellectual product' and also posit that these occur collectively through social interaction.

2.6.2 Defining Social Interaction: Quality, Quantity and Formality

Theory and research surrounding the concept of social interaction, do not tend to delineate between quality and quantity of interaction and definitions tend to be broad rather than focussed. Indeed, most definitions use social interaction and communication interchangeably. For example: social interaction may be defined as the process of communication among group members (Barker & Camarata, 1998) where communication within a team provides the means for information exchange among team members (Pinto & Pinto, 1990).

Quality and quantity of social interaction are interdependent. Hoegl (1998; as cited in Lechler, 2001) stated that the quality of communication within a team depends on frequency, formalisation, structure and openness of the information exchange. Although, not explicitly stated, quality and quantity (frequency) of social interaction appear to be mutually dependent, where frequency is how often members communicate (Lechler, 2001).

However, it should be noted that not all communication is positive. Buckley et al. (1998) argue that it is too simplistic to suggest that organisations which are successful in times of transition necessarily have good explicit communications. Evidence suggests that the opposite may be the case (Eisenberg, 1984). Eisenberg argues that "strategic ambiguity" embedded in logos or jargon phrases can, in their ambiguity, be defined by individuals within their own conceptual framework yet be considered universally defined across organizations or institutions because each person perceives a unified understanding. The functional relationship between communication and effective organisational outcomes may not be positive or linear (Buckley et al. 1998).

Quality of social interaction, also depends in part on formalisation, and structure of the communication. Formalisation relates to how much preparation is required before communication among team members can occur (Katz, 1982). Informal social interactions are concerned with spontaneous conversations and unstructured meetings, rather than formal channels, such as highly structured meetings and written communication and is expected to facilitate the ease and frequent flow of communication among team members. Structure of communication depends on whether there is direct communication between team members or if the information exchange occurs through mediators (e.g. team leaders). Face-to-face interaction is considered the richest medium for transferring knowledge because it allows for immediate feedback and the embodiment of tacit knowledge cues (Koskinen, et al. 2003). Indeed, Hammer and Champy (1993) argue that the non-verbal communication in face-to-face interactions is probably more important that the actual words spoken. Finally, openness refers to how openly and sincerely team members share information with each other, this element is discussed in greater detail with psychological safety in Chapter 4.

It is argued here, that social interactions are tied to a goal. This argument is based in part, on the findings from social exchange theory. Social exchange theory focuses on social aspects of the communication. Instead of acting out of economic calculation, individuals 'benefit one another on the basis of concern for the other's welfare' (Mills & Clark, 1994, p. 29). Original research by Blau (1964), in social exchange theory, suggests that relationships based upon this principle will involve future reciprocity of an unlimited and unspecified positive nature. The underlying concept of enriched relationships is inferred from this research. Rousseau and McLean-Parks (1993) posited that exchanges occur along a continuum with primarily economic agreements (usually short-term arrangements indicating the limited involvement of each party) at one end and relational agreements (including the exchange of socio-emotional aspects, which are open-ended and long-term) at the other. Again, although not explicitly stated, social exchange theory with its continuum, reflects the quality of interactions.

Furthermore, the goal tied, aspect of social interaction is evident in a study by Chiu et al. (1995), of 95 students. These authors developed a measure for the quality of the interactions. The results of their study and associated measure, reflected the authors operational definition where the quality of social interaction was defined as the achievement of personal goals as well as the improvement of personal relationships.

This discussion on social interaction, has highlighted several issues, namely that less formalised, face-to-face, social interactions, enable the flow of communication in teams, that social interaction involves exchange, and that there are two attributes of social interaction, quality and quantity, which are interdependent. Much empirical evidence for the importance of such interaction for team performance is discussed in Chapter 5.

In the present study, social interaction is defined as face-to-face, tied to a goal and informal. Taking this as the definition, the first hypothesis relating to social interaction is forwarded.

Hypothesis 1

There will be a positive relationship between quality and quantity of social interaction.

2.6.3 Teams and Groups

Social cognition gives rise to shared mental models using groups or teams of people as the unit of analysis. A clarification needs to be made about whether the unit of analysis is a group or a team. Groups are defined by Klimoski and Mohammed (1994) as 'collections of individuals whose tenure together and division of responsibilities can vary considerably,' whereas, 'a team consists of differentiated and interdependent members' (p. 404). Dyer (1987 pp. 24-25) defines a team as 'a collection of people who must collaborate, *to some degree,* to achieve common goals.' He goes on to suggest that various types of teams can be placed along a continuum according to the amount of collaboration (integration and role differentiation) required. At one end of the continuum are teams, such as golf teams, that are composed of a set of individual performers. At the other end he places the crew of an Air Force bomber where every member of the crew has a specific set of assignments that are critical if the venture is to be successful. Often times, group and team are used interchangeably (Edmondson et al., 2003; Hackman 1987).

In the present study the unit of analysis is referred to as team rather than group as this implies that there is interaction between members. In addition, software development teams may be placed towards the collaborative end of the continuum.

2.6.4 Team Mental Models

Team mental models form a collective knowledge base of task and team-relevant information. Cognition in groups or teams has been approached using a variety of terms including shared internal frames of reference (Mitchell, 1986), team mental models (Cannon-Bowers et al. 1993; Klimoski & Mohammed, 1994), team member schema similarity (Rentsch & Hall, 1994). The emphasis of these is on common representations within a team (Woehr & Rentsch, 2003). In addition, terms referring to the collaborative nature of memory have been proposed, including joint (Edwards & Middleton, 1986) or group remembering (Clark & Stephenson, 1989), and transactive memory (Wegner, 1987). Furthermore, a number of researchers are postulating the existence of information processing effects at the group-level (e.g., Cannon-Bowers & Salas, 1990; Resnick, 1991; Walsh & Fahey, 1986), and distributed cognition (Hutchins 1991).

Much of what we know about teams is actually derived from research on groups. According to Klimoski and Mohammed (1994) groups and teams, at a minimum have similar dynamics and antecedents of performance. As highlighted earlier, research on organised knowledge structures is fairly well developed in social/cognitive psychology, so it is not unusual for concepts like 'schemas' and 'scripts' to be used as a way of characterising team mental models. Team Mental Model (TMM) theory holds that when members share similar or compatible conceptualisations of the team, tasks, and environment, they are better able to predict others' actions and coordinate their activities effectively and efficiently (Klimoski & Mohammed, 1994). A TMM is defined as 'an organized understanding of relevant knowledge that is shared by team members' (Mohammed & Dumville, 2001, p.89).

Cannon-Bowers et al. (1993) are the most widely cited source on the topic of shared mental models. They describe how the idea of shared mental models provides insight into team decision making and teamwork in general. They discuss four types of mental models that may be useful for effective team performance. The *equipment model* refers to content on functioning of tools, operating procedures and equipment limitations. The *task model* contains information about task procedures, strategies, and other likely scenarios. The *team interaction model* deals with roles and responsibilities, information sources, patterns of interaction and channels of communication. Finally, the *team model* refers to knowledge about team-mates' knowledge, skills, abilities, preferences and tendencies. Cannon-Bowers et al. (1993) argue that team models and models of the task can be shared among members.

The character of a shared mental model may reflect the state of group development as well as methods used to investiate them (Klimoski & Mohammed, 1994; Mohammed et al. 2000). In addition, Klimoski and Mohammed (1994) hold that shared mental models may change over time where an abstract general model becomes more specific with experience. According to McClure (1990) a 'collective mind' emerges in all groups but the form that it takes depends on the group members' experiences with one another.

2.6.5 The Role of Social Interaction in the Development of Team Mental Models

TMMs help team members develop accurate explanations and expectations about the task and members' behaviour which helps them to coordinate implicitly. The development of shared mental models is related to social interaction. The more group members communicate with each other, the more likely it is that they will form a common frame of reference and develop a shared mental model among members (Klimoski & Mohammed, 1994), which can occur at different levels of analysis. It has been found that interactions among organisational members lead to similar interpretations of organisational events (Schein, 1985; Schneider & Reicherts, 1983). Athans (1982) established that frequent communication within a team of military commanders lead to a strong understanding of one another's tactical expertise. In addition, Forgas (1981) found that social interaction in rugby teams leads to more consensus and integrated team understandings. These studies refer to the quantity of social interaction only, or at least to not distinguish between quality and quantity.

Task structure also affects interaction. Where the task is shared, individuals communicate significantly more than when the task is divided (Bowers, et al. 1992). Therefore, team interaction to coordinate work is partly a function of the division of labour; there are situations that are more or less conducive to the formation of shared mental models. Coordination is 'the effective management of dependencies among sub-tasks and people (Malone & Crowston, 1994).

When interaction is reduced, this will inhibit the formation of shared mental models, which can also occur in geographically distributed teams and where people do not interact with one another. Support for this perspective comes from Levesque et al. (2001) who, in a study of 62 student software development teams, found that shared mental models did not increase over time, and this was related to the reduction in the quantity of interactions. The more specialised the teams became the more they worked at an individual level. Task is therefore not a constant, and this may reflect temporary task teams which form and reform. In complex tasks, people become more specialised and so need more coordination.

2.6.6 Development of Mental Models: Empirical Studies

The empirical work has lagged behind the conceptual work and much confusion exists with respect to measuring cognition in teams (Mohammed, et al. 2000). Researchers have used various methods including repertory grids, verbal protocols and card sorting (Smith-Jentsch et al. 2001). Mohammed et al. (2000) found that pathfinder analysis, multidimensional scaling analysis, interactively elicited cognitive mapping and text based cognitive mapping as four promising techniques for assessing cognition in teams. These techniques have been applied as or evaluated as methods for examining the degree to which team members have common mental representations of team-related information. Most empirical research has been in strategic decision making and team dynamics/performance and on top management teams. In terms of team performance TMM's are assumed to enhance the quality of teamwork skills and team effectiveness (Cannon-Bowers & Salas, 1990; Cannon-Bowers et al. 1993; Orasanu & Salas, 1993).

Smith-Jentsch et al. (2001) examined teamwork mental models. This refers to the understanding of the components of teamwork that are critical for effective performance as well as the relationships between those components. In a study involving 176 navy personnel they found that there was greater similarity of mental models within high ranking groups and within groups where people had been in the service for a long time. They also found that training increased accuracy and similarity of mental models.

Stronger evidence concerning shared cognition was provided by Hutchins (1991). Using computer simulation modeling and a connectionist framework for thinking about cognitive phenomenon at the group level of analysis. Hutchins' (1991) results show that the cognitive properties of groups can differ from those of their participating members. Marks et al. (2002) found that, using computer simulation methodology, cross-training enhanced the development of shared team-interaction models and that coordination mediated the relationship between shared mental models and team performance.

Another study found relationships between team schema agreement, team structure, demography and effectiveness (Rentsch & Klimoski, 2001). Finally, Mathieu, et al. (2000) found that both shared-team- and task-based mental models related positively to subsequent team process and performance.

2.7 Transactive Memory and Team Mental Models

One construct especially relevant for understanding team knowledge processes is a transactive memory system. Mohammed and Dumville (2001) developed an integrative framework which describes team mental models as the broader concept, and transactive memory systems as addressing a specific dimension of team mental models.

Transactive memory systems were conceived by Wegner (1987), who observed that members of long-tenured groups tend to rely on one another to obtain, process, and communicate information from distinct knowledge domains. Wegner termed this system of cognitive interdependence, a Transactive Memory System (TMS). Wegner (1987) posited that knowledge specialisation is greater in groups with well-developed TMSs. Specialisation enables individuals to define their expertise more deeply. A TMS is the cooperative division of labour for learning, remembering, and communicating relevant team knowledge, where one uses others as memory aids to supplement limited memory (Hollingshead, 2001; Wegner, 1987). By specialising knowledge in a group and having a shared awareness of who knows what information, cognitive load is reduced, greater access to expertise can be achieved, and there is less redundancy of effort. Retrieving the information stored in another person's memory, however, depends on transactions (communication, interpersonal interactions) between individuals (Lewis, 2003). This specialisation needs to be coordinated, which resolves task dependencies that result from work differentiation (Crowston, 1997).

Transactive memory is concerned with heedful interactions and awareness of the location of expertise and implies the development of a collective mind (Weick & Roberts, 1993; Berman et al. 2002). Weick and Roberts (1993) introduced the concept of 'heedful interrelating' where each action is modified by its predecessor. This is an important concept for understanding how teams coordinate their actions. When people engage in tasks with similar people for a period of time, then collaborative patterns emerge.

It can be concluded from the preceding discussion, that transactive memory involves the awareness of specialisations (or expert knowledge) and coordination of this differentiated knowledge. Specialised knowledge and its coordination may be acquired through experience of working in a domain. Transactive memory associated with expertise and experience, leading to the following predictions:

Hypothesis 2

Transactive memory will be positively related to the presence of expertise.

Hypothesis 3

Transactive memory will be positively related to experience.

2.7.1 Transactive Memory and Team Performance: Empirical Studies

Most research in transactive memory and its relationship to team performance, has been conducted in groups which are brought together for the express purpose of studying transactive memory. The teams are generally asked to complete a task and disbanded after the task is complete (Austin, 2003). Team performance in these studies is measured by both the efficient and effective completion of the task, where efficiency refers to budget and schedule and effectiveness is the achievement of project goals (Daft, 2004). The findings of the mostly laboratory based studies are now outlined.

Moreland and colleagues (Liang et al.1995; Moreland et al. 1996) in a series of laboratory experiments investigated the development of transactive memory through training. Transactive memory was measured by observing student groups as they assembled AM radios. These authors uncovered group dynamics that contributed to the existence of a transactive memory system. These dynamics included specialisation of task, task coordination activities and task credibility and concluded that a 'transactive memory system can substantially improve a work group's performance, and that training the group members together is a reliable way to produce such a system' (p.18). Studies by Wegner and colleagues (Wegner et al. 1991) and Hollingshead (1998a; 1998b) provide evidence that these cooperative cognitive systems do develop in dyads. Wegner argued that similar systems exist in groups. Like the TMSs of dyads, a group TMS exists when members actively use their transactive memories to draw upon and combine others' knowledge to perform a joint task.

Lewis (2003) developed a field measure of TMSs, holding that TMSs could be discerned from the differentiated structure of members' knowledge (specialisation), members' beliefs about the reliability of other members' knowledge (credibility), and effective, orchestrated knowledge processing (coordination). In one study of 64 MBA student teams, Lewis found that total scores on the TMS measure and scores on all three factors were associated with successful performance. However, another study of 27 teams from high technology industries, revealed that total scores on the TMS and the factors of coordination and credibility were associated with successful team performance, but specialisation was not. Lewis (2003) argued that there were three team types, project, cross-functional and functional and that team type may be a boundary. Functional teams work in parallel where specialisation may be important but its integration is not, the relationship between specialisation and team performance was weak (only $r = 0.04$). However, Lewis (2003) cautions that the small sample size limits generalisation.

Finally, Austin (2003) examined the relationship between transactive memory and performance in 27 mature, continuing groups and found that transactive memory was related to group performance.

These studies form the basis for the following prediction:

Hypothesis 4

Transactive memory will be positively related to team performance as measured by effectiveness and efficiency.

2.7.2 Evaluation of the Transactive Memory Construct

According to Moreland (1999) expertise recognition is an important part of transactive memory, as it guides group members to those members with relevant information and to evaluate the information based on the source. There may also be a downside to the benefits of differentiated knowledge and transactive memory systems (Lewis, 2003). Teams do not need to share some overlapping knowledge to perform well, what is not known is how much knowledge must be overlapping, and how much specialisation is too much. Too much specialisation will only create 'islands of expertise', without mutual dependence. Members may also possess complementary specialisations that are not efficient but persist anyway. If members have developed tacit coordination patterns they may be less likely to question the credibility of members' expertise.

Mohammed and Dumville (2001) point out that developing a transactive memory system reduces the rehashing of shared information and allows for the pooling of unshared information. The development of a transactive memory system is probably slow and gradual (Moreland, 1999). As workers spend time together they become more familiar with one another.

2.7.3 The Role of Social Interaction for the Development of a TMS

Transactive Memory is a form of TMM. As such, it is developed through social interaction within the team, where informal interaction is considered the most successful type of communication in groups. TMSs develop as team members learn about one another's expertise (Wegner, 1987), accomplished predominantly through interpersonal communication (Hollingshead, 1998a). Evidence for the relationship between transactive memory and social interaction is found in the field study by Lewis (2003) who measured functional or 'task-relevant' communication and found that it was related to transactive memory. Laboratory studies have also consistently shown TMSs to predict higher performance in couples' recall (Hollingshead, 1998a; Hollingshead, 1998b), and work team performance (Liang et al. 1995; Moreland & Myaskovsky, 2000), than non-interacting dyads. However, it must be noted that these studies do not differentiate between quality and quantity of interaction. On the basis of this discussion the following hypothesis is forwarded:

Hypothesis 5

Social interaction (quality and quantity) will vary according to transactive memory

2.8 Organisational Cognition and Knowledge

Organisational cognition is a form of social cognition with most theories based on the information processing approach, where organisations are conceptualised as hierarchical information processing machines, focussing on top management decision making (Ungson et al. 1981).

The information processing paradigm is associated with Herbert Simon (1957), where the goal was to establish simple decision rules or heuristics that make use of the information. This view has been overtaken by constructivist approaches such as 'The Garbage Can Model' (Cohen, et al. 1972), which incorporates the idea of shared information, tacit knowledge and organisational learning. Similarly, Karl Weick's theory of 'sensemaking' (1979, 1996) sees the organisation as a system handling equivocal information in its environment, trying to make sense of that information and as such makes 'retrospective sense of what occurs' (Weick & Roberts, 1993, p.635). These constructivist approaches highlight the importance of culture where '[C]ulture is a learned product of group experience' Schein (1985, p.7) The organisation is a shared meaning system, where people can learn, change and evolve through social interaction among the members themselves and the environment.

Blackler (1995) categorises forms of organisational knowledge as *embedded* in technologies, rules and organisational procedures; *embodied* into the practical activity-based competencies and skills of key member (i.e. practical knowledge or know how); *encultured* as collective understandings, stories, values and beliefs of organisational members; or *embrained* as the conceptual understandings and cognitive skills of key members. It may be argued that there is no such thing as knowledge but rather a continual emergent process- knowing. The process of knowing ' is composed not just of symbolic interaction, but rather from a unique and situated relational patterning of embrained, embodied, encultured, embedded, *and* encoded components of context (Thompson & Walsham, 2004, p.741).

Organisational knowledge is therefore, akin to group-level knowledge, with the added component of extending beyond teams and groups to the culture and context of the organisation as a whole.

2.9 Implications for Software Development Teams

Software development teams have a relatively unique structure, wherein the division of labour among members is highly interdependent (Sommerville, 2004). This is mainly to do with the way in which the finished product is produced; the emphasis being on the process of development which is an intangible cognitive process in the minds of team members (the nature and structure of software development teams are discussed in Chapter 5). Members of software development teams may be considered to be knowledge workers. The nature of the software development process is such that the product cannot be seen in its progressive development, unlike say building a bridge and this has implications for team members. These knowledge workers have specific individual expertise which is embrained and embodied (Blackler, 1995), the more each individual's knowledge is shared among members of a team, the larger and more dispersed the knowledge base becomes. At the same time team members become more aware of where the expertise is located within the team. In sharing and coordinating expert knowledge each team member will construct their own knowledge personally and socially, through their interactions with one another. In addition the team will develop a shared mental model, therefore about the task and or team. The particular type of TMM most relevant to software development teams is transactive memory, since the transactive memory construct is specifically related to expertise, and so is important to knowledge worker teams (Mohammed & Dumville, 2001).

Depending on the view of cognition taken, there are different implications for members of software development teams. Developing software involves complex problem solving and decision-making based on previous experience. The dominant information processing approach, which objectifies knowledge and sees knowledge as separate from the knower, may imply that the success or failure of technical innovation depends on the cognitions of key people, which shape choices in patterns of design and choice of technology (Weick, 1990; Swan & Clark, 1992). Problems occur when one person dominates, since that person will be incorporating knowledge through their own schemata which are difficult to change. People from different functional backgrounds have very different beliefs and expectations. In addition, team work may be affected by stereotyping as a result of the development of social schemas. This approach does not account for interactions between people and the environment, nor does it account satisfactorily for tacit knowledge being based mainly on explicit knowledge.

Social and situated cognition involve naturally occurring learning events which are embedded in day-to-day work activities. Members of software development teams may exchange knowledge over lunch and discover new insights as a result of informal social interaction. The social approach is also important because team members individually have a limited capacity for processing information so that, when dealing with complex problems like software development, they can rarely process all the information that would be relevant. Their mental models help team members to select information and to decide what actions are appropriate (Weick, 1979). Thus individuals' cognitions may shape organisational decisions, although the extent to which this will occur will depend on the socio-political context and on their ability to influence decisions in their organisation.

2.10 Summary

This chapter has provided an overview of individual and group level conceptualisations of knowledge from philosophical, psychological and organisational perspectives. The traditional philosophical view of knowledge, sees reality as independent of the knower in contrast to the constructivist view, which sees the knower as acting intentionally in the world to construct knowledge.

The computer metaphor dominates the cognitive approach to knowledge however, this approach is inadequate in explaining how all knowledge is represented, and does not account for individuals' interactions with their environment. Other approaches to cognition advocate that cognition is individually and socially constructed, through interactions with the environment. Social interaction is an important aspect of social cognition where quality and quantity of social interaction are thought to be related to one another. Social interaction was forwarded as the means by which TMMs are developed. Evidence for the existence of team mental models was outlined with particular reference to the development and existence of transactive memory systems, a subset of TMMs. The second prediction made in this study positively relates social interaction to transactive memory. Finally, organisational knowledge is a form of social cognition, where knowing may be a continuous interplay of embrained, embodied, encultured, embedded, *and* encoded components.

In the present study the philosophical approach to knowledge is that knowledge is personal and socially constructed. Members of software development teams construct TMSs to divide the cognitive labour of the task, and this division of labour must be coordinated.

Chapter 3

Conceptualising Tacit Knowledge

3.1 Introduction

In this chapter the conceptualisation of tacit knowledge is explored from philosophical, psychological and organisational perspectives. Issues related to the definition, representation and capture of tacit knowledge are investigated and an operational definition is forwarded. Empirical studies of tacit knowledge and performance are outlined and finally, the implications for software development teams are discussed.

3.2 Conceptualising Tacit Knowledge: Philosophical, Psychological and Organisational Approaches

Lam (2000) forwards a useful framework for understanding the role of tacit knowledge in organisational learning. This framework illustrates the coherence and interdependence between three levels of analysis: cognitive, organisational and societal and argues that 'knowledge configurations of firms and patterns of learning cannot be separated from specific organizational forms and institutions' (Lam, 2000, p508). Drawing on Blackler's (1995) organisational categorisation of knowledge (see Chapter 2), Lam (2000) forwards a four-fold typology at the three levels, providing links for the interactive relationship between dominant knowledge types and organisational forms. The level of interest in the present study is the micro-level, which constructs a typology of organisational knowledge and analyses knowledge along two dimensions: the epistemological and the ontological. The former is concerned with forms of expression and deals with the tacit-explicit dichotomy. The latter is concerned with knowledge residing at the individual or group (collective) levels. The two dimensions give rise to Blacker's (1995) embrained (individual-explicit), embodied (individual-tacit) encoded (collective-explicit) and embedded (collective-tacit) knowledge. These two dimensions are explored in the following sections, which begin with the philosophical underpinnings of tacit knowledge.

3.2.1 Philosophical Underpinnings of Tacit Knowledge

Polanyi (1966) coined the term tacit knowledge and described it in the frequently cited quotation 'we can know more than we can tell' (p. 4). Polanyi (1966) proposed an integrative philosophy of thought, which holds that we understand the world through tacit knowledge. Polanyi's ontology is that reality is personal and his epistemology is that knowledge is constructed through tacit integration. Polanyi's theory of tacit knowledge may correspond to Gestalt psychology, where perception is determined in the way that it is integrated into an overall pattern or Gestalt. Polanyi (1966) himself stated that his 'analysis of knowledge is closely linked to *this* discovery in Gestalt psychology' (p.6). The *'this'* refers to the integration of parts to form a whole without being aware of the parts. Gestalt psychology holds that this integrating function is innate, whereas Polanyi holds that the 'whole' is:

> an outcome of an active shaping of experience performed in the pursuit of knowledge. This shaping or integrating I hold to be the great and indispensable tacit power by which all knowledge is discovered and, once discovered, is held to be true (1966, p.6).

In evaluating Polanyi's integrative philosophy it can be concluded that Polanyi has provided an alternative way of knowing, which is based on the actual practice of the pursuit of knowledge (Ruzits-Jha, 1995).

However, in constructing a clear definition of tacit knowledge showing causal connections and providing an algorithm for predictions of specific outcomes, Polanyi's definition does not meet this criterion. In his estimation, this is a criterion for a rule-following mechanistic conception of scientific investigation, not a philosophical enterprise such as his inquiry (Ruzits-Jha, 1995).

Whilst a universal definition of knowledge remains elusive, it is necessary for the development of knowledge sharing theories, to have at least a working definition to inform development. For the purpose of this research the philosophical approach taken draws on the phenomenological and constructivist theories of Von Glaserfeld (1989, 1995), Berger and Luckman (1967), and Polanyi (1966, 1958, 1969). This study's philosophical approach to knowledge, sees knowledge, as personal, socially constructed and rooted in tacit knowledge.

The next section further explores the nature of tacit knowledge in contrast to explicit knowledge. According to Polanyi (1966) there are three types of knowledge: tacit knowledge, explicit knowledge and focal knowledge. Tacit knowledge is personal and context specific, and may be impossible to formalise and communicate. Explicit or codified knowledge is knowledge, which is transmittable in formal systematic language. Focal Knowledge is knowledge about the object or phenomenon in focus.

3.2.2 Conceptualising Tacit Knowledge in Relation to Explicit Knowledge

One of the biggest problems in conceptualising tacit and explicit knowledge is the plethora of terms used to describe the two knowledge types. There have been various attempts to define and classify different types of knowledge (e.g. Nonaka & Takeuchi, 1995; Ryle, 1949; Sveiby, 1999). One of the most common distinctions is explicit versus tacit knowledge.

Most cognitive scientists operate under the supposition that there are two knowledge types, declarative and procedural (e.g. Anderson, 1983; Bransford, 1990; Bruer, 1992). The distinction between procedural and declarative knowledge was introduced from AI research by McCarthy and Hayes, (1969) and Winograd (1975), and was taken for use in psychology by Anderson (1976).

Declarative knowledge is represented explicitly and is accessible, whereas procedural knowledge is represented implicitly and is inaccessible (Anderson, 1983). Gilbert Ryle (1949) further explained the distinction between tacit and explicit knowledge in terms of 'knowing-how' and 'knowing-that', respectively. Tacit knowledge in knowing-how is typical of an expert who no longer needs articulated instruction. This explicit knowledge may be needed to acquire a skill, but it no longer becomes necessary in the practice of those skills. In the organisational literature Nonaka and Takeuchi (1995) equate Polanyi's tacit conception of knowledge with a subjective nature and explicit knowledge with objective nature. Table 3.1 provides a summary for some of the labels given to the tacit–explicit dichotomy.

Table 3.1 Labels for the Tacit-Explicit Dichotomy

Theorist	Explicit	Tacit
James (1890)	Conscious	Unconscious
Ryle (1949	Knowing-that	Knowing-how
Anderson (1976)	Declarative	Procedural
Dreyfus & Dreyfus (1987)	Analytical	Intuitive
Smolensky (1988)	Conceptual (publicly accessible)	Subconceptual (inaccessible)
Nonaka & Takeuchi (1995)	Objective	Subjective
Cleeremans (1997)	Explicit	Implicit

3.3 Overcoming the Tacit-Explicit Dichotomy

In order to say anything constructive in research, it is necessary to overcome the tacit/explicit dichotomy. As Newell (1973) contends, a real theory of tacit and explicit knowledge should first answer the question of whether it is useful to have the distinction at all. Although Polanyi describes the three types of knowledge, he posits that articulated explicit knowledge is only 'the tip of the iceberg' and maintains that all knowledge is rooted in tacit knowledge. Indeed, Polanyi appears to reject the notion of explicit knowledge. He argues:

> The ideal of a strictly explicit knowledge is indeed self contradictory; deprived of tacit coefficients (personal to the individual), all spoken words, all formulae, all maps and graphs, are strictly meaningless' (Polanyi, 1969, p. 195).

Therefore, knowledge that is made explicit through articulation was at some time tacit, and this includes facts. Polanyi posits that we cannot separate the knowledge from the knower, in that humans create knowledge by involving themselves with the object. This is what Polanyi calls 'indwelling' and this lack of distance between the knower and the object breaks the mind/body dichotomy. Polanyi (1958) asserts that when we acquire a skill, we acquire a concomitant tacit understanding that defies articulation.

Shotter (1993) has highlighted the significance of situated practical-moral knowledge, inviting us to focus on 'knowing of the third kind' – a kind of knowing from within an episode of interaction, rather than a knowing what or how (p.19).

Some theorists believe that there exists a middle ground between tacit and explicit knowledge (e.g. Wilson, 2002). They call it implicit knowledge, which is the subset of tacit knowledge that can be transformed into explicit knowledge. According to Wilson (2002), implicit knowledge is something we might know but do not wish to express, while tacit knowledge is something that we know but cannot express. Implicit knowledge is that which we take for granted in our actions, and which may be shared by others through common experience or culture. Such knowledge may not be written down, but is known by people living and working in the culture and is capable of being communicated (Wilson, 2002). Nonaka and Takeuchi (1995) expand Polanyi's idea of tacit knowledge 'in a more practical direction' (p.60), positing that tacit knowledge can be expressed. It is argued here, that this expressed aspect of tacit knowledge is really 'implicit knowledge'.

3.4 Defining and Representing Tacit Knowledge

Is tacit knowledge the same as procedural, implicit, unconscious and intuitive knowledge? Providing a working definition of tacit knowledge has been problematic for researchers in business, AI and cognitive science. Tacit knowledge is unconscious, inaccessible, cannot be articulated and therefore, in pure form is un-measurable. Attempts have been made by some researchers to operationally define and subsequently measure tacit knowledge (e.g. Sternberg et al. 2000; Busch et al. 2003). However, these attempts have led to the problem of overlap and confusion in definitions.

Much of the confusion of definition in the literature stems from the term tacit being used interchangeably with other terms particularly, implicit (e.g. Cleeremans, 1997; Reber, 1995). In order to address this issue a distinction between tacit and implicit knowledge is made. Tacit knowledge cannot be articulated (Polanyi, 1966), whereas implicit knowledge can be articulated but has not yet been articulated, therefore, researchers who measure or make tacit knowledge explicit are really measuring implicit knowledge or aTK (Busch et al. 2003).

Mindful of the problems associated with defining tacit knowledge, it is necessary to provide some sort of definition. This definition would ideally incorporate the individual and social aspects of tacit knowledge (Table 3.2), thus accounting for the view that knowledge is both personally and socially constructed (Bruner, 1966; Kelly, 1955/1991; Vygotsky, 1978). In addition, this definition would elucidate the role experience plays in organising knowledge. Sternberg et al. (2000), forward a definition which incorporates these aspects of knowledge and extends beyond into the realm of problem solving and expertise.

3.4.1 Defining Tacit Knowledge at the Individual Level

According to Sternberg et al. (2000), tacit knowledge is an aspect of practical intelligence and as such gives insight into the factors which underlie successful performance in a real-world setting. Tacit knowledge:

> reflects the practical ability to learn from experience and to apply that knowledge in pursuit of personally valued goals. Tacit knowledge is needed to successfully adapt to, select, or shape real-world environments (p. 104).

Furthermore, tacit knowledge is related to expertise in that, 'tacit knowledge distinguishes more successful individuals from less practically successful' (Sternberg et al. 2000, p.105).

According to Sternberg et al. (2000), there are three characteristics of tacit knowledge:

1. Tacit knowledge is acquired with minimum environmental support – people or media that help the individual acquire the knowledge. It is acquired through personal experience on one's own with little reference to other people's experience.
2. Tacit knowledge is procedural, taking the form of 'knowing how' rather than 'knowing that'. Procedural knowledge has specific use. All tacit knowledge is procedural but not all procedural knowledge is tacit; people are capable of articulating general rules when probed but, these procedural rules are abstract and complex and represent the characteristic structure of tacit knowledge and serves as the basis for identifying and measuring tacit knowledge. It is situation and context specific, more than a set of abstract rules and may be represented in the form of condition-action pairings such as:

   IF < *antecedent condition*> THEN <*consequent action*>

   [this is simple, but tacit knowledge is more complex]
3. Tacit knowledge is practically useful and is instrumental in attaining personal goals. Sternberg distinguishes, practically useful knowledge from knowledge, however acquired, formally or informally, that is not relevant to personal goals.

The first characteristic of tacit knowledge appeared to contradict the idea that tacit knowledge is acquired through social interaction. Sternberg clarified this stating that 'There is no contradiction. Your own social interactions are part of your experience.

You are acquiring the tacit knowledge from picking it up, rather than someone explicitly telling you about it during the social interactions' (R. J. Sternberg, personal communication, September, 2002). The second characteristic takes the form of propositions, and so is in actuality referring to 'implicit' knowledge. Taking these factors into account, this definition can be operationally defined and so is useful for quantitative, empirical investigations.

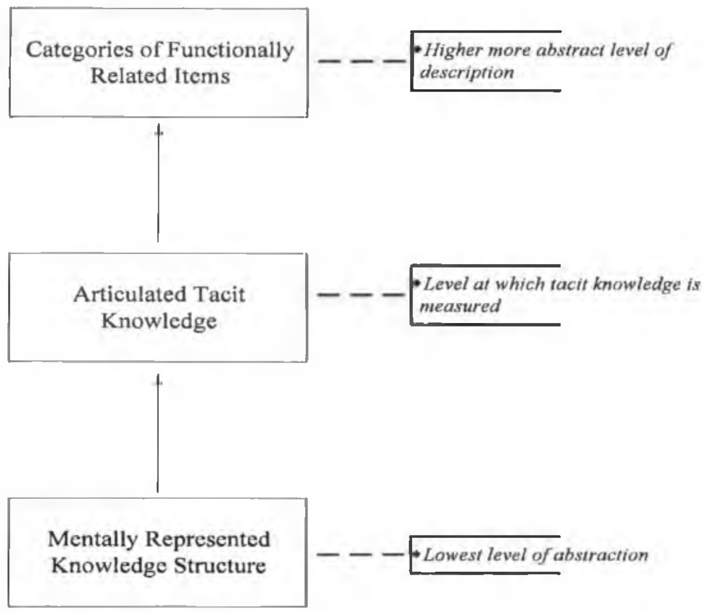
Sternberg et al. (2000) point out that tacit knowledge is not the same as job knowledge or a proxy for general intelligence (i.e. '*g*'). 'g' is by far the most widely studied predictor used in personnel decisions and although *g* may be a valid predictor of performance in many jobs, there are several limitations and controversies surrounding *g* and the prediction of job performance including, questionable validity (Schmidt & Hunter, 1993), which is related to the premise that intelligence tests often have little to do with the problems individuals encounter in real life (Neisser, 1976; Wagner & Sternberg, 1986).

Tacit knowledge is not synonymous with job knowledge; they are overlapping concepts. Tacit knowledge measures have the potential to explain individual differences in performance that are not explained by traditional measures of job knowledge, which tend to assess more declarative, explicit forms of knowledge (Schmidt & Hunter, 1993). In addition, tacit knowledge is not a proxy for general intelligence. Tacit knowledge is not merely academic intelligence. The ability to acquire tacit knowledge is a dimension of practical intelligence that conventional ability tests do not measure adequately.

3.4.2 Cognitive Representation of Tacit Knowledge at the Individual Level

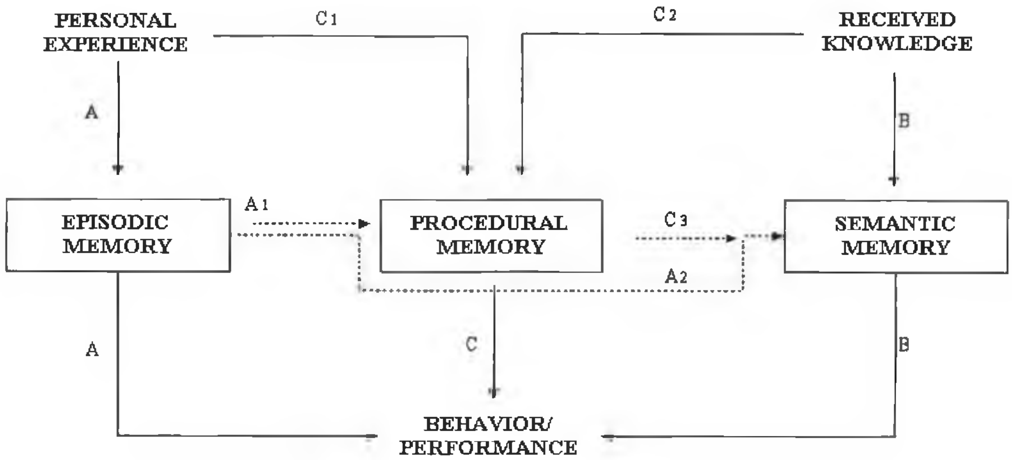
According to Sternberg et al. (2000) tacit knowledge can be conceptualised at qualitatively different levels of abstraction; 'we can conceptualize tacit knowledge at the level of its cognitive representation and at the level at which it is measured in the behavior and articulated knowledge of the individual' (p.112). A graphical illustration of Sternberg et al's (2000) levels of abstractions is demonstrated in Figure 3.1.

Figure 3.1 Different Levels of Abstraction for Tacit Knowledge.



Sternberg et al. (2000), provide an explanation of how tacit knowledge is cognitively represented based on Tulving's (1972, 1987) memory research. Tulving (1972) made a distinction between episodic and semantic memory in long-term memory. Episodic memory is personal memory of particular events in one's life. Such memories contain both a focal and contextual content and are tied to a specific learning episode or experience. The more the event is experienced in different contexts, the more it loses the contextual component ('I remember'). Semantic memory is part of generic memory concerned with the meaning of words and concepts. It is general knowledge not tied to experience ('I know'). In 1987, Tulving added a third component, *procedural memory*, which is knowledge of how to do things. This develops first, followed by semantic memory and then episodic memory. Sternberg et al. (2000) illustrate these three memory stores along with relations among them in terms of encoding, storage and retrieval processes, as depicted in Figure 3.2. This model is based on existing theory. It is an illustration of how tacit knowledge is represented cognitively and of how tacit knowledge can be identified and measured.

Figure 3.2. Cognitive Model of Tacit Knowledge



The A pathway represents personally experienced events which are stored in episodic memory, and then influences behaviour directly or indirectly through further encoding in procedural (A1) and semantic memory (A2). The B pathway deals with generalised knowledge acquired directly through formal instruction. Path C knowledge, acquired directly (personal experience, C1), and indirectly (received knowledge, C2), is stored in procedural memory. Information in procedural memory may be further encoded into semantic memory (C3).

According to Sternberg et al. (2000), 'tacit knowledge is a subset of procedural knowledge that is acquired through personal experience (via either path A1 or C1), is not readily articulated, and directly influences behavior [*sic*]' (p.116). This knowledge takes the form of 'knowing how', is not conscious, and is likely to support action towards personally valued goals. Tacit knowledge (acquired through paths A1 or C1) will reap advantage for those who possess it, but because tacit knowledge is not well supported in acquisition, some will fail to acquire it. Experiential knowledge will bring with it concomitant situational and contextual factors. Knowledge acquired through paths A1 or C1 is more relevant to the pursuit of one's personal goals.

3.4.3 Defining Tacit Knowledge at the Group Level

In a review of the literature on tacit knowledge, Gourlay (2002) identified two issues associated with tacit knowledge. The first is whether tacit knowledge is an individual trait or a trait that can be shared by both individuals and groups, and the second is whether tacit knowledge can be made explicit. To some degree these issues are interconnected, as one of the goals of making tacit knowledge explicit is to enable it to be shared throughout the organization (e.g., Collis & Winnips 2002; Lindley & Wheeler 2001).

Spender (1998) highlights the individual and social modes of cognition and combines them with the implicit (tacit) – explicit distinction (Table 3.2).

Table 3.2 Individual and Social Modes of Cognition

	Individual	Social
Explicit	Conscious	Objectified Scientific
Implicit	Automatic Intuitive	Collective Cultural

Social implicit knowledge is collective and cultural, while social explicit knowledge is objective. This is a reflection of Berger and Luckman's (1967) theory of social construction of knowledge, and theories of TMMs discussed in Chapter 2. From this situational point of view knowledge is already present in established activities and cultural norms and imported through the contributions of new participants. For the individual, prior knowledge is resituated in the new setting and integrated with other knowledge acquired through participation. Individuals' knowledge can be described as having expanded, modified or even transformed.

Von Krogh and Roos (1995) argue that tacit knowledge is an individual characteristic, which is embedded in action in specific contexts. However, according to Grant (1996) there is a capacity for aggregation of tacit knowledge, which reflects the ability of individuals and teams to absorb new knowledge and add it to existing knowledge. This may occur at the individual or team level. Therefore, for tacit knowledge to be a group-level construct, it must characterise the team rather than individual members of the team, and team members must hold similar perceptions of it. Using TMM theory provides a good theoretical basis for the conception of tacit knowledge at a group level.

In particular, the development of a transactive memory system, can be extended to tacit knowledge about team tasks and team knowledge, which will be held by different people and needs to be coordinated. Conversely, tacit knowledge about individual level phenomena will not be held in shared pattern of mental models.

3.4.4 Definition of Tacit Knowledge in the Present Study

The philosophical basis for defining tacit knowledge was posited by Polanyi but his definition cannot be extended to a working definition and was never intended to be, since it is in the realms of philosophy not science (Ruzits-Jha, 1995). It is important to distinguish between tacit knowledge that can be made explicit or articulated and tacit knowledge that cannot be made explicit, the former being called implicit knowledge (Wilson, 2002; Tsoukas, 2003) or tacit knowledge at the articulable level of abstraction (Sternberg et al. 2000).

In the present study tacit knowledge is defined at the articulated level of abstraction (Sternberg et al. 2000) or what Busch et al. (2003) refer to as 'articulable tacit knowledge' (aTK). In defining tacit knowledge at this level it is acknowledged that 'implicit knowledge' may be a better term, since it accounts for Polanyi's definition of non-verbalisable knowledge. However, the confusion in the literature and the overlap of these two terms, make it more practical to use the term 'tacit' but with the proviso that it is the articulated level under discussion.

Furthermore, the definition offered by Sternberg et al (2000), is the basic definition used in this study. However, there is one modification, this definition of tacit knowledge is also conceptualised at the group or team level. This is defined as the aggregation of individual tacit knowledge to the team level, where different members of the team will possess different aspects of the tacit knowledge. Tacit knowledge is therefore related to TMM theory. There is both individual and group tacit knowledge.

In addition, tacit knowledge according to Sternberg et al (2000) is not synonymous with explicit, declarative job knowledge, the type of knowledge found in training manuals and job descriptions. This leads to the following prediction:

Hypothesis 6

There will be a positive correlation between team tacit knowledge and explicit job knowledge as measured by familiarity with written job procedures and reliance on these written procedures.

The operational definition of team tacit knowledge in the present study defines tacit knowledge as being measured at the implicit level of the individual, as differentiating novices from experts and can be aggregated to team-level. This team tacit knowledge is held by different people in a shared pattern or mental model.

Furthermore, in answer to the question posed at the beginning of section 3.4 "Is tacit knowledge the same as procedural, implicit, unconscious and intuitive knowledge?" It may be concluded that tacit knowledge is a subset of the procedural knowledge exhibited by experts, is measured at the implicit level, is unconscious and akin to intuition as defined in Section 3.6.

3.5 Knowledge Management and Tacit Knowledge

Tacit knowledge of workers, is associated with terms such as 'skill,' 'know-how,' 'working knowledge,' and 'expertise' that are used to describe knowledge about and ability to perform work (Cooke 2003; Farrell 2001; Hager 2000; Sveiby 1999). Recently, the role of tacit knowledge in knowledge management has been explored (Gourlay 2002; McInerney 2002).

There is no agreed upon definition of Knowledge Management (KM) (Scarbrough & Swan, 2001; Schultze & Stabell, 2004). A broad definition by Hult (2003) states that:

> Knowledge management is defined as the organized and systematic process of generating and disseminating information, and selecting, distilling, and deploying explicit and tacit knowledge to create unique value that can be used to achieve competitive advantage in the marketplace by an organization (p.190).

There are many themes in the knowledge management literature 'including the nature of knowledge, information management, information technology, people management (knowledge roles, knowledge workers), knowledge creation, knowledge sharing, transfer of learning, intellectual capital, tacit knowledge and so on' (Ryan & Hurley, 2004, p.46). We conducted a bibliometric analysis of publications with KM as a key word and found that KM emerged from the literature on the Learning Organsiation in around 1995 –1996 (Ryan & Hurley, 2004), superseding the literature on total quality management and business process reengineering.

Knowledge management theory is currently at the forefront of management theory, with a publication rate that is rising exponentially (Ryan & Hurley, 2004; Wilson, 2002). A KPMG survey found that of the 200 large US firms studied, 80% of corporations had knowledge initiatives (KPMG, 2000). Proponents of knowledge management often do not to make a distinction between information and knowledge, failure to do this 'results in one or other of these terms standing as a synonym for the other, thereby confusing anyone who wishes to understand what each term signifies' (Wilson, 2002, p.2). Knowledge involves the mental processes in an individual's mind whereas information is codifiable and easily communicated. It has been argued by Smoliar (2003) that it is not the knowledge that is in people's heads, that is managed, but the people themselves. Smoliar (2003) argues that a more useful term would be 'interaction management'. Knowledge management may therefore be seen as object, as in managing information, and also as subject, as in managing people, and the two should not be confused. Hansen, et al. (1999), describe the two overall strategies in knowledge management as 'codification' and 'personalization'. Codification strategy centres on computer usage, which spans the codification and storage of knowledge in databases which can be accessed and used by anyone in the company. The personalization strategy is where knowledge is closely connected to the person who develops it, and is shared, first and foremost through direct person-to-person contact.

3.5.1 Tacit Knowledge as a Core Competitive Advantage

KM may be seen as a genuine core competitive advantage (e.g. Allee, 1997; McKern, 1996; Ruggles, 1998; Skyrme & Amidon, 1998), but this is mainly to do with making tacit knowledge explicit. Tacit knowledge is an important element in work and workplace learning but one that needs to be examined closely in terms of how it is incorporated into organisational practices. Baumard (1999) explores tacit knowledge from an organisational perspective, seeing it as a source of competitive advantage, which is critical in daily management of an organisation and is necessary for expertise.

Others such as Choo (1998) highlight the importance of leveraging tacit knowledge.

The conversion of tacit knowledge to explicit knowledge is a major theme in the knowledge management literature. This conversion process is discussed in Chapter 4. For tacit knowledge to be used in knowledge management systems, it needs be made explicit. Particularly important in this context, is the tacit knowledge possessed by the employees in the company, which is difficult to imitate by competitors (Rumelt, 1984; 1987; Nelson & Winter, 1982; Teece, 1987; Winter, 1987). However, making this tacit knowledge explicit highlights a contradiction in the KM literature since this tacit knowledge is really the core competitive advantage (Fernie et al. 2003; Hult, 2003), but, once tacit knowledge is made explicit then it can be imitated, leading to loss of competitive advantage (Schultze & Stabell, 2004).

This view has come in for much criticism. McInerney (2002) argues that organisations should create a 'knowledge culture' that encourages the learning, creation and sharing of knowledge, rather than attempting to 'extract knowledge from within the employees to create new explicit knowledge artifacts' (p. 1014). Indeed, Wilson (2002) argues that we cannot make explicit that which is 'inarticulable'; what we can do is express previously unexpressed or implicit knowledge. These problems have led to most of the confusion in the literature, and are indicators of fad-like qualities in knowledge management. This confusion in epistemology has resulted in many organisations referring to the presence of an Information Technology System (ITS) as a knowledge management system. The concentration on systems that seek to capture and manage only explicit knowledge is a major criticism of knowledge management (Scarbrough, et al. 1999; Whitley, 2000).

As has been previously discussed, tacit knowledge cannot be captured but there is a part that can be made explicit, i.e. implicit knowledge. In addition, some authors argue tacit knowledge can only be demonstrated through our expressible knowledge and through our acts (Tsoukas, 2003; Wilson, 2002).

3.6 Tacit Knowledge and Intuition

The term tacit knowledge has in common parlance been associated with 'intuition' (Hayashi, 2000). According to Reber (1989) the most compelling aspect of intuition, is that the individual has a sense of what is right or wrong, a sense of what is the appropriate or inappropriate response to make in a given set of circumstances, but is largely ignorant of the reasons for that mental state. Intuition may be the result of implicit learning, an intuitive sense of what is right and proper, a vague feeling of the goal of an extended process of thought, 'to "get the point" without really being able to verbalize what it is that one has gotten, is to have gone through an *implicit* learning experience and have built up the requisite representative knowledge base to allow for such judgment' Reber (1989). It is argued, however, intuition, may be in the realm of personality research. For example: Gorla and Lam (2004) investigated personality style, as measured by the Myers-Briggs Type Indicator (MBTI), and team performance in 20 software development teams. Gorla and Lam (2004) measured the intuitive/sensing personality where the intuitive person makes impressions without emphasising details, is more imaginative and futuristic. The sensing individual seeks detailed information. These authors found that IS teams with an intuitive team leader outperformed those with a sensing team leader.

In summary, tacit knowledge is seen as a team level construct which is not synonymous with job knowledge and is related to intuition. In the present study intuition is operationalised as 'gut instinct' since project managers, who were consulted when developing the measures in this study preferred this terminology (see Chapter 7, for the survey measure). The following is therefore hypothesised:

Hypothesis 7

Tacit knowledge at the team level will be related to gut instinct.

3.7 Empirical Studies of Tacit Knowledge and Performance

Tacit knowledge has been measured at the individual, articulated level of abstraction by Sternberg and his colleagues at Yale University, using what Busch et al. (2003) call the 'Yale Group Approach'. This approach is outlined in detail in Chapter 8. In addition, tacit knowledge has been measured at the team level using proxy measures. Empirical studies using both these approaches are now outlined.

The Yale group has measured tacit knowledge in sales teams, (Sternberg & Wagner, 1988; Wagner et al. 1999) academic psychology (Wagner & Sternberg, 1985) managers

(Wagner & Sterberg, 1991) and military leaders (Hedlund et al. 2003). Others such as Somech and Bolger (1999) have applied the Yale group approach to 243 undergraduate students in an Israeli university investigating tacit knowledge and socio-economic status (SES) found that students with low SES made more use of tacit knowledge than students with high SES. Students high in TK achieved higher academic grades.

In a Yale group study by Hedlund et al. (2003), tacit knowledge was defined as knowledge drawn from everyday experience that helps individuals to solve real-world, practical problems. Interviews were conducted with Army officers at three levels of leadership in order to identify the type of practical, experience-based knowledge that is not necessarily part of formal training or doctrine. Subsequently, the Tacit Knowledge for Military Leaders (TKML) inventory, consisting of a series of leadership scenarios, was developed to assess the amount of knowledge leaders possess. Three versions of the TKML were administered to a total of 562 leaders at the platoon, company, and battalion levels. At all three levels, TKML scores correlated with ratings of leadership effectiveness from either peers or superiors, and the scores explained variance in leadership effectiveness beyond a test of general verbal ability and a test of tacit knowledge for managers. These results indicate that domain-specific tacit knowledge can explain individual differences in leadership effectiveness and suggest that leadership development initiatives should include efforts to facilitate the acquisition of tacit knowledge.

In another Yale group study, Sternberg and Wagner (1988) investigated tacit knowledge of sales people, (n = 30) selling cars, furniture or houses and compared scores to 50 novices (undergraduates students), using salesperson's rules of thumb. They found that in subsequent studies that salespersons outperformed undergraduates with no sales experience.

Tacit knowledge at the non-articulated level and performance has also been measured at the team level but using proxy measures. Berman et al. (2002) used data from the National Basketball Association (NBA) to construct a measure that taps into team-based tacit knowledge. This measure is based on cumulative experience that members of a team have playing with one another. Berman et al. (2002) argue that their measure is a reasonable proxy for the sort of tacit knowledge at team level. The sample consisted of 23 teams that competed in the NBA for 1980-1981 season through the 1993-1994 season. Shared team experience was the proxy for the value of the stock of tacit knowledge held in the collective mind of a team. This was measured by assessing how many years experience each player had on a specific team at the end of a season. Years of player team experience was weighted by the minutes played in the games that season by that player and an average was then calculated for each team year. The study concluded that team success increased as the team's tacit knowledge increased and concluded that tacit knowledge is gained through experience rather than formal study methods and can be acquired at an individual or group level.

Edmondson et al. (2003) examined the effect of tacit and codified knowledge on performance improvement with new technology in cardiac surgical teams in 16 hospitals. According to these researchers knowledge about how to execute and coordinate interdependent tasks is tacit and action based. Two measures of performance efficiency (a) improvement as measured by reduction in time required to perform the operation and (b) breadth of use of the new technology were employed. Edmondson et al. (2003) found heterogeneity across hospitals in efficiency measured in procedure time reduction than for breadth of use. These authors argue that this was due to the tacit knowledge required to coordinate action, where each team had to figure out by trial and error, how to get faster. In addition, teams were unable to describe why they got faster (more efficient).

On the basis of these studies it can be concluded that tacit knowledge at the team level is related to team performance, giving rise to the next hypothesis:

Hypothesis 8

Tacit knowledge at the team level will be related to team performance as measured by efficiency and effectiveness.

3.8 Implications for Software Development Teams

Software development teams are project based and consist of knowledge workers (Drucker, 1993; Turner, 1999). The project management literature accepts the link between knowledge economy and competitive advantage, where knowledge can be captured and acquired (Fernie et al. 2003). However, this highlights the tendency to view knowledge as a codified, objective and easily transferable (Lanzara & Patriotta, 2001). Most project managers concede that there is no substitute for experience and experiential knowledge is difficult to codify, since it is embedded in context (Fernie et al. 2003). This knowledge can therefore be considered tacit.

In addition, tacit knowledge leads to efficient and effective performance in basketball and surgical teams, and so will probably influence performance in software development teams. Tacit knowledge at the team level, will be possessed by different individuals in the team.

3.9 Summary

Traditionally, tacit knowledge has been conceptualised in its opposition to explicit knowledge. However, tacit knowledge cannot be represented using the dominant cognitive approach because it cannot be articulated. Tacit knowledge is conceptualised at the articulable level of abstraction. In addition, tacit knowledge may be construed at different levels of analysis i.e. the individual or team level. Tacit knowledge is not articulated and therefore is not represented in written documentation. In addition, tacit knowledge is akin to intuition or acting on gut instinct. Tacit knowledge can lead to competitive advantage, but not when it is captured *per se*. Capturing tacit knowledge may actually have the opposite effect on competitiveness.

A definition for tacit knowledge at the team level was forwarded in this chapter, along with three hypotheses relating to explicit job knowledge, gut instinct and team performance.

Chapter 4 will focus on the acquisition and sharing of tacit knowledge through social interaction.

Chapter 4
Acquiring and Sharing Tacit Knowledge

4.1 Introduction

This chapter focuses on how knowledge and tacit knowledge are acquired or learned, at the individual and group levels. Three areas of knowledge acquisition are examined; psychology, organisation theory specifically knowledge management and the domain of AI. This chapter begins with the general approaches to knowledge acquisition, followed by individual level acquisition of tacit knowledge concerning implicit learning and expertise. Group level approaches to knowledge acquisition and sharing are then outlined, with particular emphasis on the role of social interaction. Several hypotheses are forwarded concerning the relationships between tacit knowledge, social interaction and transactive memory. In addition, factors affecting social interaction are addressed.

4.2 Acquiring and Sharing Knowledge

Knowledge acquisition and knowledge sharing are interrelated concepts, and there is overlap between the two, in that learning or acquiring knowledge may require the simultaneous sharing of knowledge. Knowledge sharing is explored with particular reference to the role of social interaction in the development of transactive memory and the factors which may constrain social interaction in teams. In psychology, AI and organisation theory the traditional view of knowledge acquisition reflects the CIP paradigm, where objective knowledge can be easily transferred between people. However, constructivist views of knowledge acquisition involve personal and socially constructed knowledge, and account for the environmental and social factors involved in learning. Modern approaches in psychology, AI and organisation theory model knowledge using a constructivist approach.

4.2.1 Psychological Approaches to Knowledge Acquisition

According to Reber (1995) cognitive psychology has concentrated on knowledge representation rather than the nature and acquisition of knowledge. Reber (1995) argues that the topic of learning has been neglected in contemporary psychology, where 'learning and conditioning are now typically represented within a cognitive framework' (p.3). This view is echoed by Glaser (1990) who posits that the information processing approach was critical in the move away from learning and research into learning reflects the dominance of the information-processing paradigm, with much research focusing on the scientific experimentation and logical steps involved in learning, specifically the acquisition of knowledge.

Learning in psychology is defined as 'a relatively permanent change in behavioural potentiality that occurs as a result of reinforced practice' (Kimble et al. 1961, p.6) and evidence of learning is found in actual or potential changes in behaviour as a result of experience. According to Taatgen (1999) 'task performance is an intricate interplay between learning and performance. Just focusing on performance will only give a very limited insight into what is going on.' (p.22). It is important to look at the process of learning, even if it is difficult to quantify, since performance does not yield enough information about what has been learned. The information processing approach to learning and knowledge acquisition looks at how information is processed, resulting knowledge and perception or behaviour, but not all learning is explicit and follows this method.

4.2.2 Situated Cognition: Acquiring Knowledge is Social and Context Dependent

Emerging from anthropology, sociology, and cognitive science, situated cognition theory represents a major shift in learning theory from traditional psychological views of learning as mechanistic and individualistic, and moves toward perspectives of learning as emergent and social (Greeno, 1998; Lave & Wenger, 1991; Salomon, 1996). Situated cognition involves taking into account interaction between the individual's inner state and the external environment and trying to record all the influencing factors (Richards & Busch, 2003). According to Lave (1988) 'the point is not so much that arrangements of knowledge in the head such as schemas scripts and frames, correspond in a complicated way to the social world outside the head, but that they are socially organized in such a way as to be indivisible' (p.6). Clancey (1997) posited that 'what is "socially shared" is not just language, tools, and expressed beliefs, but conceptual ways of choreographing action, by which descriptions and artefacts develop and are given meaning' (p.277). This situated view of cognition has implications for learning and knowledge transfer.

4.2.3 Situated Learning

Regarded as leaders in the situated cognition movement, Lave and Wenger (1991) describe learning as an 'integral part of generative social practice in the lived-in world' (p. 35). Lave (1986, 1993, 1997) researched the discontinuities in performance of mathematical activity by the same persons in different settings, suggesting that the competence of the individual is situation specific. Hanks (1991) suggests that '[L]earning is therefore a process that takes place in a participation framework, not in an individual mind' (p.15). From a situational point of view, knowledge is already present in established activities and cultural norms and is imported through the contributions of new participants.

Therefore, social interaction is a critical component of situated learning because learners become involved in a 'community of practice' which embodies certain beliefs and behaviours to be acquired (Brown & Duguid, 1991). As the beginner or newcomer moves from the periphery of this community to its centre, they become more active and engaged within the culture and hence assume the role of expert or 'old-timer'. Furthermore, situated learning is usually unintentional rather than deliberate. These ideas are what Lave and Wenger (1991) call the process of 'legitimate peripheral participation.'

Situated learning is usually unintentional, is embedded in context, propagated by social interaction and involves practice. This type of learning is related to implicit learning and the acquisition of tacit knowledge.

4.2.4 AI Approaches to Acquiring Knowledge

Artificial Intelligence research is mainly concerned with expert systems, where an expert system is 'a computer program that represents and reasons with knowledge of some specialist subject with a view to solving problems or giving advice' (Jackson, 1990, p. 3).

Traditionally, the term knowledge acquisition in AI research has referred to gathering expertise, primarily in the form of rules from experts in order to create an expert system (Gaines 1987; Neale 1989). Indeed, the main AI research problem in the 1980s was whether all knowledge could be reduced to explicit form. Phrases like 'Knowledge Elicitation' and 'Knowledge Acquisition' were common, illustrating the belief that knowledge could be extracted from people's heads and contained in 'knowledge-based systems' (KBS), which exhibited artificial intelligence (e.g. Feigenbaum & McCorduck, 1983). This approach does not account for the findings that expertise is probably more intuitive than originally suspected and goes some way to explaining why computer programmers and cognitive psychologists have difficulty in getting the experts to articulate the rules they follow, since experts do not follow rules (Dreyfus & Dreyfus, 1986).

The problem of context was identified as one of the main problems in capturing expert knowledge (Dreyfus & Dreyfus, 1986), since the rules typical of AI programming are context free whereas human actions are never performed without regard for context and so cannot be rule governed. In addition, the interaction between the knowledge engineer and expert is not acknowledged. In the early 1990s it became apparent that it was necessary to capture the context as well as the rules (McCarthy, 1993) and there was a movement away from the 'expertise transfer' view to the 'knowledge modelling' view. The knowledge modelling view sees knowledge as context sensitive and acknowledges that models may be inappropriate when used out of context. Researchers in AI like their counterparts in psychology and organisation theory looked to situated cognition for a solution to the problem of context. Richards and Busch (2003), posited that the situated knowledge from the expert systems perspective 'places great emphasis on incremental techniques that allow change, capture context and which acquire knowledge without relying on a human to state or codify that knowledge' (p.180).

4.2.5 Organisational Approaches to Acquiring Knowledge

Organisational knowledge is a resource, and the result of organisational learning processes. According to Edmondson (2002, p.128) an 'organisation "learns" through actions and interactions that take place between people who are typically situated within smaller groups or teams.'

The organisational learning literature incorporates both organisational level and individual level theories. Edmondson (2002) outlines three levels of theorising about organisational learning. At the macro or organisational level, theories focus on the stabilising effects of routines and adaptation over time. Individual level or micro approaches look at the behaviour of individuals and their effect on organisational change. At an individual level, organisational learning is categorised as adaptive (single-loop) learning or generative (double-loop) learning (Argyris & Schon, 1978). In adaptive learning, organisational members resolve problems within the existing norms of the organisation, while generative learning involves frame-breaking disruption that transforms the routines or norms of individuals and groups. The macro and micro levels of analysis provide a foundation for a third perspective that investigates learning at the group or 'meso' level of analysis, where a group level approach is inherently integrative, incorporating factors from two or more levels simultaneously (Rousseau & House 1994). According to Edmondson (2002) teams, or work groups, are also important in that individual cognition and behaviour, is shaped by social influences, that is, by the attitudes and behaviours of others with whom they work closely (Salancik & Pfeffer 1978, Hackman 1992).

Organisational knowledge processes and organisational learning are interdependent, and it is impossible to study one element without studying the other (Johannessen et al. 2001, Spender & Grant, 1996). Johannessen et al. (2001) also posit that situated and contextual learning are the elements that tie tacit knowledge to organisational learning.

4.3 Individual Approaches to Acquiring and Sharing Tacit Knowledge

Having looked at approaches to acquiring knowledge in general, the focus now changes to issues surrounding the acquisition of tacit knowledge. As previously stated, increased performance is the only indicator that a person has learned something. Tacit knowledge refers to the content of what is learned and it may be acquired explicitly, as in skill learning or implicitly, through implicit learning. Implicit learning is therefore a process, the outcome of which may yield tacit knowledge and/or implicit knowledge. The two approaches are discussed in the following sections.

4.3.1 Implicit Learning and Tacit Knowledge

Not all learning is explicit, representable in symbols, conscious and subject to definite rules. Implicit learning research looks at learning without awareness, the results of which yield tacit knowledge. The majority of research into implicit learning has been carried out by Reber (1967, 1995) and focussed on the existence of implicit learning and whether if, and how, implicit and explicit learning interact (Seger, 1994). Implicit learning is 'the process by which people acquired complex knowledge about the world, independent of conscious attempts to do so' (Reber, 1995, p.12). According to Seger (1994) implicit learning is acquired 'without complete verbalizable [*sic*] knowledge of what is learned' (p.163).

Experiments in Artificial Grammar (AG) learning looked at acquisition of complex information without awareness (Reber, 1967, 1969; Reber & Millward, 1968). In these studies, subjects were presented with strings of apparently meaningless letters which were generated following precise pseudo-grammatical rules. In some conditions subjects were aware of the rules, in others not. Subjects were later asked if strings followed some rules or were grammatically correct, and they performed better than chance. However, they were seldom able to verbalise the rules by which they arrived at their judgements.

Research has shown that implicit learning is not affected by ageing or IQ and so individual differences are very small (Reber et al. 1991; Myers & Conner, 1992; Maybery et al. 1995; McGeorge et al. 1997; Vinter & Detable, 2003). Implicit learning is resistant to brain damage (Reber, 1995) and is a by-product of normal processing. Explicit learning, on the other hand, is the by-product of specific learning goals and deals with explicit knowledge which is affected by IQ and ageing, therefore, it is produced by knowledge that is represented in the memory system (Taagten, 1999).

4.3.2 Skill learning and the Development of Expertise

Tacit knowledge can be acquired explicitly through skill learning and the development of expertise. At the level of the individual, the concept of tacit knowledge is closely related to the concept of skills (Nelson & Winter, 1982; Polanyi, 1966). It is the tacit knowledge used when riding a bicycle or writing a computer program. Anderson (1976, 1983, 1993) investigated skill acquisition using the ACT-R model (Adaptive Control of Thought-Revised). According to Anderson (1983, 1993), skill acquisition is characterised as going through three stages: a cognitive stage, an associative stage and an autonomous stage. The three stages can be characterised by moving from conscious, slow and error prone to unconscious, fast and error free. Anderson (1983) explains these three stages in terms of a transition from declarative knowledge to procedural knowledge. The more people practice using knowledge and skill beyond just mastery, the more fluid and automatic their skill will become.

Sun et al. (2001) advocate that 'some skills develop prior to the learning of declarative knowledge with explicit declarative knowledge being constructed only after the skill is at least partially developed' (p.205). Evidence for this position comes from studies by Berry and Broadbent (1988) and Reber (1989) who demonstrated a dissociation between explicit, declarative knowledge and skilled performance. Other research into the related area of implicit memory also indicates that a person's performance can improve by implicit retrieval from memory and the individual may not be aware of the process (Schachter, 1987). Reber (1995) argues that putting the declarative first apparently conflicts with implicit learning where initial phases of knowledge acquisition are seen as unconscious. However these are complementary as they have different applications since implicit learning theory says nothing about skill learning.

4.3.3 Expert Performance

Expert performance is viewed as an extreme case of skill acquisition (Proctor & Dutta, 1995; Richman et al. 1996; Van Lehn, 1996) and as the final result of the gradual improvement of performance during extended experience in a domain. Tacit knowledge is related to expertise in that, tacit knowledge distinguishes more practically successful individuals from less practically successful ones (Sternberg et al. 2000). Research into expertise has found that experts solve problems and make decisions based on proceduralised skills and schematically organised knowledge which operate without conscious awareness (Chi et al. 1988), where expert knowledge is situational and contextual (Groen & Patel, 1988).

Dreyfus and Dreyfus (1986) propose a five phase model of skill acquisition. They argue that human beings gain expertise through perception, intuition, and experience, rather than by following rules based on accepted facts. The ability to make more subtle and refined discriminations is what distinguishes the expert from the proficient performer. The five levels of skill acquisition distinguish the behaviour patterns of novices, advanced beginners, competent individuals, proficient operators, and experts, respectively.

These five phases are summarised by Dreyfus and Dreyfus (1986, Chapter 1) as follows:

1. The novice uses context-free rules and components to perform a task. A typical context-free rule applicable to driving a car might state, 'when the car reaches a speed of 20 miles per hour, then it must be shifted into third gear.'
2. Advanced beginners start using situational components (such as the sound of the car engine in deciding when to shift), in addition to the context-free considerations.
3. The competent individual has a goal in mind in performing a task and follows a chosen perspective using context-free, as well as situational components.
4. Proficiency is characterized by a rapid, fluid, involved kind of behaviour, in which the detached reasoning often used by beginners for problem solving gives way to holistic similarity recognition methods distinguishing relevant from extraneous facts.
5. Finally, experts use completely intuitive, instead of analytical, decision-making methods: 'When things proceed normally, experts don't solve problems and don't make decisions; they do what normally works'

In a review of the literature on expertise, Ericsson and Lehmann (1996) established that (1) measures of general basic capacities do not predict success in a domain, (2) the superior performance of experts is often very domain specific, and transfer outside their narrow area of expertise is surprisingly limited and (3) systematic differences between experts and less proficient individuals nearly always reflect attributes acquired by the experts during their lengthy training.

Data indicates that it takes 10 years to become expert (Chase & Simon, 1973). However, this may be mediated by deliberative practice. According to Ericsson et al. (1993) 'the maximal level of performance for individuals in a given domain is not attained automatically as a function of extended experience, but the level of performance can be increased even by highly experienced individuals as a result of deliberate efforts to improve' (p. 366). The accumulated amount of deliberate practice is closely related to the attained level of performance of many types of experts, such as musicians (Ericsson et al. 1993; Sloboda et al. 1996), chess players (Charness et al. 1996) and athletes (Starkes et al. 1996).

The recent advances in our understanding of the complex representations, knowledge and skills that mediate the superior performance of experts, derive primarily from studies where experts are instructed to think aloud while completing representative tasks in their domains, such as chess, music, physics, sports and medicine (Chi et al. 1988; Ericsson & Smith, 1991; Starkes & Allard, 1993). Experts differ from novices and in the amount and complexity of the accumulated knowledge and in the qualitative differences in the organisation of knowledge and its representation (Chi et al. 1982). It is interesting to note that experts were required to make explicit, the rules of thumb that govern their skill. Capturing this tacit expert knowledge is an issue for research and the premise on which the measure of tacit knowledge, developed in Chapter 8, was based.

In conclusion, at the individual level, tacit knowledge may be acquired implicitly through unintentional learning or through the explicit learning of a skill. However, it is likely that both types of acquisition occur and are compatible.

4.4 Acquiring and Sharing of Tacit Knowledge at the Group Level: The Role of Social Interaction and Transactive Memory

Individual approaches to the acquisition of tacit knowledge, are concerned with the development of expertise, through perception, intuition and experience, and involves deliberative practice. At the group level, social knowledge requires mutual adjustment and is rarely reproduced in the same way twice and so defies precise codification (Edmondson et al. 2003). It may therefore be considered as mostly tacit. Social knowledge includes an intuitive assessment of who to trust (Edmondson, 2002), and an awareness of where expertise lies (Morleand, 1999). Explicit declarative knowledge is easier to transfer across individuals and involves transmission of documents or manuals, and users are able to acquire it quickly are likely to apply it in a similar vein (Edmondson et al. 2003).

However, the relationship between medium and knowledge type is not always so straightforward. Artefacts within organisations may develop shared meaning. Yates and Orlikowski (1992) operationally define genres in the context of organisational communication as ‘recognized types of communication (e.g., letters, memoranda, or meetings) characterized by structural, linguistic and substantive conventions. These genres can be viewed as social institutions that both shape and are shaped by individuals’ communicative actions’ (p.300). These authors argue that ‘genre rules may operate tacitly, through socialized or habitual use of communicative form and substance, or they may be codified by an individual body into specific standards designed to regulate the form and substance of the communication' (p.303). These communicative practices provide information about a community's work.

Orlikowski and Yates (1994) analysed the communicative practices of geographically dispersed knowledge workers. The communication was mainly through email. The authors analysed the electronic interaction over time to identify the genres enacted, the genre repertoire and the set of organising structures. They found that for example, the presence of the memo genre and the absence of the letter genre, reveal that the participants implicitly organised themselves as a temporary organisation. According to Orlikowski and Yates (1992, 1994) people produce, reproduce, and change genres through a process of structuring.

In a similar vein, Schön (1988) describes the emergence of 'design types', which designers use as a shared method for discussing different types of design, without explicitly describing what they mean. Designers share models that serve as holding environments for ideas that cannot be articulated.

Tacit knowledge is therefore, not just related to face-to-face interactions. However, in the present study the type of tacit knowledge under scrutiny refers to informal face-to-face interaction requiring social interaction to communicate (Davenport & Prusak, 1998; Hansen et al. 1999; Nonaka & Takeuchi, 1995). Hansen et al. (1999) argue that interpersonal, relatively close relationships and personal contact, were imperative in transferring complex knowledge i.e. tacit and context dependent, but not for the transfer of simple knowledge i.e. explicit and context-independent. Tacit knowledge may be transferred in a number of ways, including mentoring and apprenticeships, but involves social interaction. Busch et al. (2003) used a social network analysis (SNA) to examine formal and informal interactions in an IT department (n = 12) and concluded overwhelmingly that tacit knowledge is diffused in human to human interaction.

The term knowledge sharing is a more appropriate expression than knowledge transfer and will be used to describe the sharing of knowledge between people with emphasis on knowledge sharing within groups and teams. Knowledge can be shared formally through scheduled meetings, training, lectures and formal discussion but this usually refers to explicit knowledge. Sharing tacit knowledge, involves the development of TMMs or a collective mind (Nonaka & Takeuchi, 1995; Weick & Roberts, 1983). The TMM of interest in the present study is transactive memory. Knowledge sharing is argued to be a complex social process that involves eliciting both explicit and tacit knowledge. The process is further complicated by the need to fully understand and consider the context within which the knowledge is embedded (Fernie et al. 2003). Tacit knowledge, like knowledge in general, may share common to a group or divided over individuals. TMMs were discussed in detail in Chapter 2, and may be applied to both tacit and explicit knowledge.

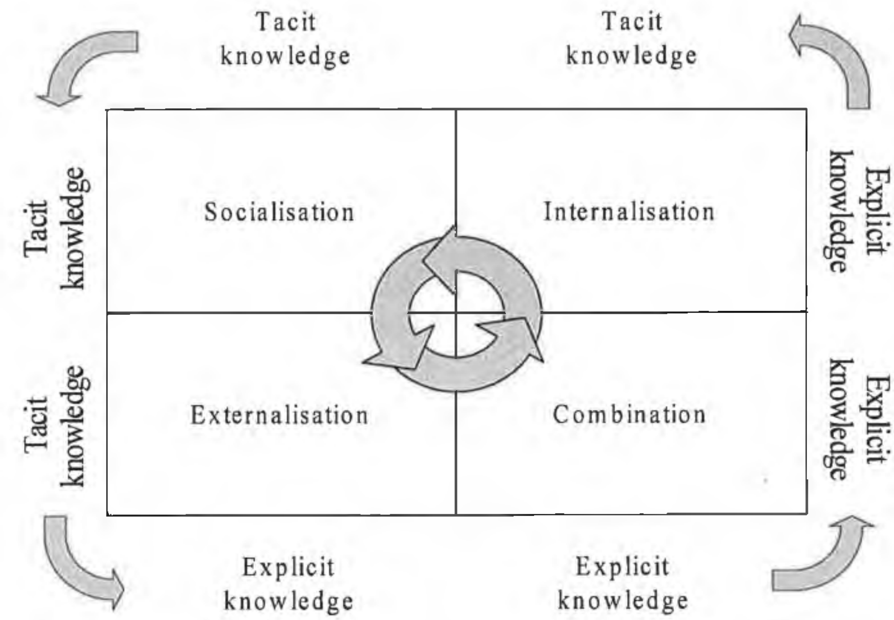
4.4.1 Knowledge Creation through Social Interaction and Transactive Memory

The generation of new knowledge as well as the deployment of already existing knowledge are based on processes of interaction (Schneider, 1996; Argyris, 1993). Knowledge is either transformed within one single person or among a group of people, created through a process of individual interpretation and personal construction.

Nonaka and Takeuchi (1995) are at the forefront of how knowledge is acquired in organisations. They hold that new knowledge is created through iterative social interaction among individuals, where knowledge originates with individuals and becomes group and organisational knowledge as a result of community interaction. Knowledge creation is achieved through recognition of the synergistic relationship between tacit and explicit knowledge (Choo, 1998).

In their model for knowledge creation Nonaka and Takeuchi (1995, p.65) posit four modes of knowledge conversion which can be seen in Figure 4.1.

Figure 4.1 Four Modes of Knowledge Conversion



Knowledge conversion is achieved through social interaction and there are four modes: socialisation (tacit - tacit), externalisation (tacit - explicit), combination (explicit – explicit), and internalisation (explicit – tacit). Socialisation (tacit - tacit) is concerned with sharing tacit knowledge within individuals' face-to-face interactions. This new tacit knowledge takes the form of shared mental models. To convert tacit knowledge to explicit (externalisation), iteration and reflection is used. Reflection involves codification of this knowledge through the use of metaphor and analogies. Combination (explicit – explicit) is simply concerned with the combination of discrete pieces of explicit knowledge to allow the generation of a new piece of explicit knowledge. Internalisation (explicit – tacit) of explicit knowledge to tacit knowledge flows from the experience gained through individuals using newly formed explicit knowledge. Thus, the cycle can begin again if necessary, building upon the existing field of knowledge.

Underlying Nonaka and Takeuchi's perspective is the 'conduit metaphor of communication' (Tsoukas, 1997, 2003), which is the view of ideas as objects which can be extracted from people and transmitted to others over a conduit. According to Tsoukas (2003):

Tacit knowledge cannot be 'captured', 'translated', or 'converted' but only displayed or manifested in what we do. New knowledge comes about not when the tacit becomes explicit, but when our skilled performance – our praxis - is punctuated in new ways through social interaction (p.426).

Cook and Brown (1999) argue that Nonaka and Takeuchi's account of the knowledge creation spiral has afforded tacit knowledge a lower status than explicit knowledge, because it is difficult to codify. These authors, like Yates and Orlikowski (1992, 1994), forward the term "organisational genre" to define group tacit knowledge. They found that different communication methods (e.g. email) became used for purposes other than for the purpose they were originally intended, without the rules for use being made explicit.

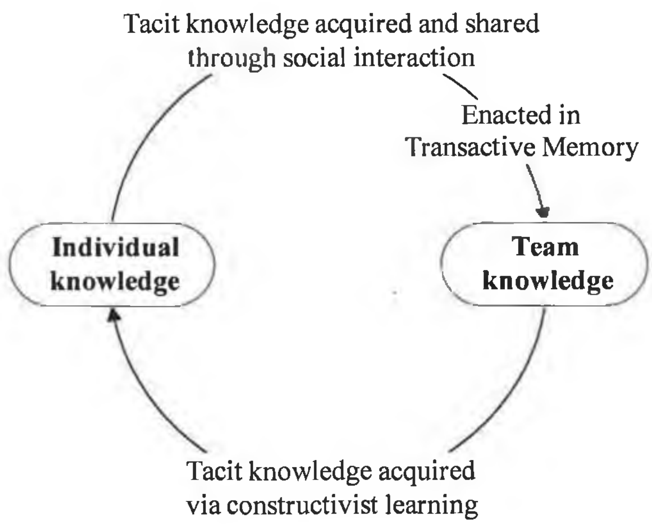
4.4.2 Linking Social Interaction, Tacit Knowledge and Transactive Memory

In Chapter 2 social interaction was defined as referring to informal, face-to-face, goal tied, communication where a distinction was made between quality and quantity of the interaction. Social interaction was seen as necessary for the development of transactive memory systems (Lewis, 2003). Social interaction is also related to tacit knowledge, where face-to-face interaction is considered to be the richest medium for transferring knowledge because it allows for immediate feedback and the embodiment of tacit knowledge cues (Koskinen et al. 2003). Face-to-face conversation is best suited to transmitting knowledge that is fundamentally tacit, because it can use a much wider variety of metaphors than conversation through information technology (Tsuchiya, 1998). Furthermore, Granovetter (1973) from his studies using SNA, stated that strong ties, identified by close relationships (among other things), are ideal for the sharing of tacit, complex knowledge.

Social interaction is, therefore, the primary means by which tacit knowledge is shared (Nonaka & Takeuchi,1995; Edmondson, et al. 2003). However it is not merely social interaction alone, this interaction leads to the development of a TMS. TMSs are important for the acquisition and sharing of team tacit knowledge, since they enact 'collective minds' of teams. Tacit knowledge is shared through social interaction, and these interactions contribute to the development of transactive memory. Interaction is important because knowledge is stored in communities and groups and a repository on its own does not support these communities (Lesser & Prusak, 2000). The more social interaction in work groups and teams, the more tacit knowledge is shared, then the better use is made of transactive memory.

In Figure 4.2, a graphical illustration of the proposed link between social interaction, transactive memory and tacit knowledge for the acquisition and sharing of tacit knowledge in teams, is proposed.

Figure 4.2 The Acquisition and Sharing of Tacit Knowledge in Groups



This figure represents the process by which tacit knowledge is shared between individuals in a group and from the group to the individual, where it becomes re-integrated. It is a dynamic, reciprocal process, which relies on constructivist, situated learning. As individuals interact, tacit knowledge is acquired and shared, which leads to the development of a transactive memory system. This is because through iterative social interaction, the tacit knowledge is acquired and shared leading to the development of a TMS, where the knowledge is stored and shared. TMSs are therefore both dynamic and static.

Knowledge acquisition and sharing are interdependent activities that occur between members of teams and may be seen in their interactions with one-another. Social interactions are therefore essential to the acquisition of team tacit knowledge. These relationships between tacit knowledge, social interaction and transactive memory are based on anecdotal evidence and not empirical studies. It is therefore important to test these claims, which lead to the following hypotheses:

Hypothesis 9

Team tacit knowledge will be positively related to social interaction (quality and quantity).

Hypothesis 10

Team tacit knowledge will be positively related to transactive memory.

Hypothesis 11

Social interaction (quality and quantity) and team tacit knowledge will be mediated by the development of a transactive memory system.

4.5 Factors Affecting Tacit Knowledge Sharing

Social interaction is an important factor in the acquisition and sharing of tacit knowledge. Several factors are thought to affect social interaction, and therefore acquisition and sharing of tacit knowledge, development of transactive memory and subsequent team performance. Two main factors influence the amount and quality of social interaction. The first is team climate, that encourages interaction. In the present study this team climate is adjudged to be psychological safety. The second is structural aspects of the team, which also influences social interaction, namely, team size, proximity and diversity. Each of these factors will be described, and some initial studies providing empirical evidence for the relationships among them will be outlined. More specific studies related to software development teams are detailed in Chapter 5.

4.5.1 Psychological Safety

Team psychological safety is defined by Edmondson (1999) as:

> a shared belief that the team is safe for interpersonal risk taking. For the most part, this belief tends to be tacit - taken for granted and not given direct attention either by individuals or by the team as a whole. Although tacit beliefs about interpersonal norms are sometimes explicitly discussed in a team, their being made explicit does not alter the essence of team psychological safety (p. 354).

In a study of 51 work teams in a manufacturing company, which examined the relationship between psychological safety and well-designed teams, Edmondson (1999), developed and tested, a new seven-item survey measure of team psychological safety. Analysis of the individual-level survey data (n=427) demonstrated the convergence of team members' perceptions of psychological safety. Edmondson (1999) concluded that, in groups with high psychological safety, group members are confident that the group would not embarrass, reject, or punish someone for speaking out or for bringing a different perspective to the task.

4.5.2 Empirical Studies of Social Interaction, Team Performance and Psychological Safety

Gorla and Lam (2004) investigated social interaction, as measured by the degree of extroversion on the Myers-Briggs Type Indicator (MBTI), and team performance in 20, Hong Kong development teams, consisting of 92 IS professionals. These researchers found that social interaction was strongly related to team performance, teams with extroverted programmers outperformed those with introverted types. The authors explain that this may be because programmers in small organisations must take on several roles and interact with many people.

Mu and Gnyawali (2003) in a study of 132 senior business students in the US, in groups of 4-6 people, investigated social interaction, task conflict, psychological safety as predictors of Synergistic Knowledge Development (SKD) and subsequent perceptions of group performance. SKD is a 'process by which a group constructively integrates diverse perspectives of individual group members' (p.690). Students analysed a case study individually at first, and then in groups. This process took place over several weeks, to allow the development of a collective understanding. Social interaction was measured using two-item, self-report, seven-point Likert scale. Mu and Gnyawali (2003) found that team psychological safety had the most influence on SKD, followed by task conflict and social interaction had the least influence on SKD. In addition, these authors found that SKD significantly contributes to students' perception of group performance. SKD is a similar construct to transactive memory. On the basis of this, the following predictions are made:

Hypothesis 12

There will be a positive relationship between social interaction (quality and quantity) and psychological safety.

Hypothesis 13

Transactive memory will be positively related to psychological safety.

Hypothesis 14

The relationship between social interaction (quality and quantity) and transactive memory will be mediated by psychological safety.

4.5.3 Team Structural Factors affecting Social Interaction

4.5.3.1 Social interaction and Team Size

Hare (1981) reviewed existing research on team size conducted since 1898. One consistent theme is that larger teams are marked by less average participation by individual members (Hare, 1981). In a study by Solomon (1960) participation rates in 3-person groups and 10-person groups were compared. Solomon concluded that the least active member in a 3-person group was over twice as active as the least active member in a 10-person group. According to the group dynamics literature, increasing the size of a group introduces opposing forces that affect group performance differently (Shaw, 1981). On the one hand, a larger group has greater cognitive resources at its disposal, resources that may contribute to improved group knowledge, creativity, and performance (Haleblian & Finkelstein, 1993). On the other hand, the larger group may suffer from problems related to control and coordination, with the net result that performance declines. This dynamic tension is also noted in the organization theory literature, in the observation that organizations become more control-oriented as they grow (Mintzberg, 1979).

A general rule when researching team size, is that a larger team adversely affects communication and coordination (e.g. Bantel, 1994; Wiersema & Bantel, 1992; Zenger & Lawrence, 1989) Rentsch and Klimoski (2001) investigated possible antecedents including team size, of team member schema agreement in 41 work teams. Teams ranged in size from 2-27 people and it was found that team size was negatively associated with schema agreement. These authors reasoned that team size and schema agreement may be mediated by team member interaction, in that size dictates interaction opportunity. Finally, Wagner, et al. (1984) argued that the communication processes in large groups are more structured and constrained than in small groups.

Hypothesis 15

Social interaction (quality and quantity) will vary according to team size, where the smaller the team the better the quality of the interaction and the greater the quantity of interaction.

4.5.3.2 Social interaction and Diversity

Diversity in this study refers to cross-functional groups which consist of members from different functional areas or different functional backgrounds. Professional or job diversity is the area of interest, rather than demographic or individual differences. A consistent finding in the cross-functional literature is that, although diverse groups can have positive outcomes, e.g. produce better-quality products more quickly and at lower cost (Lutz, 1994), their members also tend to have lower group cohesiveness and job satisfaction and higher turnover and job stressors than do members of homogeneous groups (Harrison et al. 1998; Jackson, et al. 1991; Lau & Murnighan, 1998; Milliken & Martins, 1996). Reduced communication among group members, moreover, can be harmful to internal social relationships and group cohesiveness (Harrison et al., 1998; Tsui et al., 1995). The following is therefore predicted:

Hypothesis 16

There will be a negative relationship between social interaction (quality and quantity) and diversity.

4.5.3.3 Social interaction and Proximity

According to Cramton (2001) people react more strongly to people they come into physical contact with which enhances group cohesion and leads to the building of better relationships over time. Distant people communicate less frequently, leading to less diffusion of task information (*ibid*). Proximity may be seen in the distance between people in a team.

The further away people are, who have to communicate, the less they will talk to each other. A distance of 30 metres is considered truly remote (Allen, 1977). This reduction in communication will have a negative relationship to the development of shared mental models (Levesque et al. 2000), in particular transactive memory. Others such as Kraut et al. (1990) have also shown that distance affects communication between team members.

In a field study in the US, conducted at a leading Fortune 100 company, they examined how having development teams reside in their own large room (an arrangement called radical collocation), affected system development. The collocated teams had significantly higher productivity and shorter schedules than both the industry benchmarks and the performance of past similar projects within the firm. The teams reported high satisfaction about their process, and both customers and project sponsors were similarly highly satisfied. The analysis of questionnaire, interview, and observational data from these teams showed that being 'at hand,' both visibly and being available, helped them coordinate their work better and learn from each other. Team members coordinate their actions around various artefacts and arrangements of people in space and so is related to distributed cognition (Hutchins, 1991; Suchman, 1987). Sawyer found that team rooms helped focus the activities of the work group and isolated them from interruptions (Sawyer et al. 1997). Therefore, proximity is of importance in social interaction. The following hypothesis is forwarded:

Hypothesis 17

Proximity will be positively related to social interaction

4.6 Summary

This chapter explored the issues surrounding the nature of the acquisition and sharing of tacit knowledge in groups. Tacit knowledge is acquired at the individual level through expertise, through the development of expert knowledge and skill learning, either implicitly or explicitly. The acquisition of tacit knowledge at the individual level may be seen in expert performance. The acquisition and sharing of tacit knowledge at the group level involves social interaction and the development of TMMs, specifically transactive memory. Several hypotheses were forwarded predicting the relationships between, tacit knowledge, social interaction and transactive memory. In addition several predictions were made regarding the factors that influences social interaction and thus tacit knowledge acquisition and sharing.

In Chapter 5 the model for the acquisition and sharing of tacit knowledge in software development teams is described and all hypotheses pertinent to this study listed.

Chapter 5

Model for the Acquisition and Sharing of Tacit Knowledge in Software Development Teams

5.1 Introduction

This chapter completes the review of the literature and involves the integration and application of theories to software development teams. The chapter opens with a description of the processes or methods used in developing software followed by the structure of software development teams. The members of software development teams are considered to be experts and knowledge workers and because they work with intangible processes, require more abstract criteria to determine project success. The theory behind the acquisition and sharing of tacit knowledge developed in Chapters 3 and 4 are applied to software teams with particular emphasis on social interaction, coordination of knowledge and factors that affect team performance. This chapter also outlines the factors that affect project success and issues for the management of software development teams. The chapter concludes with a model for the acquisition and sharing of tacit knowledge in software development teams.

5.2 What is Software Engineering?

According to Chau, et al. (2003),'[S]oftware engineering is a knowledge intensive process encompassing requirements gathering, design, development, testing, deployment, maintenance, and project coordination and management activities' (p.1). Software engineering is therefore not just concerned with the technical process of software development but also with activities such as software project management and the development of tools, methods and theories to support software production.

5.2.1 Software Development Processes

The development of software involves processes and methods. According to Sommerville (2004, p.64) '[A] software process is the set of activities that leads to the production of a software product'. Software processes are complex and like all intellectual and creative processes, rely on people making decisions and judgements. Because of the need for judgement and creativity, attempts to automate software processes have met with limited success. Computer-aided software engineering (CASE) tools can support some process activities, but is limited. One reason for this limitation is due to the immense diversity of software processes. There is no one best process, and many organisations have developed their own approach to software development. According to Sommerville (2004) there are four fundamental process activities regardless of the process used. These are:

1. *Software specification* where the engineers and the customers define the software to be produced.
2. *Software development* where software is designed and processed.
3. *Software validation* where the software is checked to ensure that it is what the customer requires.
4. *Software evolution* where the software is modified to adapted to changing customer requirements and market.

The improvement of the quality of software processes have the greatest relevance to the management aspects of the software engineering profession rather than to the technical aspects (Edwards, 2003), in that, 'if improvements are left solely to the technical level, then the best that is likely to be achieved will be isolated "islands of knowledge"' (p.8).

5.2.2 Software Development Process Models

Certification standard process models include the Capability Maturity Model Integration (CMMI) and ISO 15504 (SPICE) series of international standards which are intended to improve software product and process quality. CMMI is a widely used framework that looks at the extent of organisational process capability (Paulk et al. 1995). It is argued that effective knowledge management is one of the hallmarks distinguishing the higher levels of capability maturity (Edwards, 2003).

There is no ideal software process or method, and different methods have different areas where they are applicable. It has been argued that traditional methods may be too mechanistic to be used in detail (Nandhakumar & Avison, 1999) or represent unattainable ideals (Truex et al. 2000). From these criticisms a new set of methods has emerged called '*Agile*' methods. The introduction of the eXtreme Programming (XP) by Beck in 1999, is considered the starting point for various agile software development approaches (Abrahamsson et al. 2002). The boundaries between traditional methods and agile methods have yet to be established. According to Highsmith and Cockburn (2001) 'what is new about agile methods is not the practices they use, but their recognition of people as the primary drivers of project success, coupled with an intense focus on effectiveness and maneuverability [*sic*]. This yields a new combination of values and principles that define an *agile* world view' (p. 122).

5.3 Structure and Activities of Software Development Teams in Large and Small Organisations

The activities common to all software processes, as outlined by Sommerville (2004) give rise to different members of the development team. Teams unlike groups have differentiated responsibilities and roles (Cannon-Bowers et al. 1993) and there is a division of labour enabling teams to tackle complex tasks but requiring coordination. According to Gorla and Lam (2004), most research in software development teams have been conducted in large multi-national organisations (MNCs). However, software engineering is not only done by large companies like Microsoft, Nokia or Siemens, that belong to the world's largest software development organizations. A considerable amount of software is produced world-wide by small and medium-sized enterprises (von Wangenheim et al. 2003). The organisation sizes of interest, in the present study are Small to Medium Enterprises (SMEs).

According to Comission, the official journal of the European Union (2003) the category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding €50 million and/or an annual balance sheet total not exceeding €43 million. Within the SME category, a small enterprise is defined as an enterprise which employs fewer than 50 persons and whose annual turnover and/or annual balance sheet total does not exceed €10 million. A micro-enterprise is defined as an enterprise employs fewer than 10 persons and whose annual turnover and/or annual balance sheet does not exceed €2 million.

Large organisations differ from small ones along several dimensions of bureaucratic structure including formalisation, centralisation, complexity, and personnel ratios (Daft, 2004). Routine technologies are associated with a *mechanistic* structure and processes and non-routine technologies with an *organic* structure and processes (Daft, 2004). Formal rules and centralised management apply to routine units. When work is non-routine, departmental administration is more organic and free flowing. Smaller, non-routine organisations typically are characterised by *organic* structures and processes: low formalization, low centralization, employees rather than management having power, employees having extensive training and experience, moderate-narrow span of control, horizontal communication rather than vertical, coordination by group meetings and norms, and quality rather than quantity production emphasis. Routine departments typically should be opposite in their more *mechanistic* structures and processes (Daft, 2004).

It can be concluded therefore, that software development in SMEs uses nonroutine technology, implying that the structure of software SMEs is organic, involving experts with horizontal communication where coordination is more informal than in large organisations. In general, descriptions of software processes and methods refer to large organisations and teams in smaller organisations may behave in a different manner.

5.3.1 Structure of an Ideal Team in a Large Organisation

According to Sommerville (2004) members of software development teams have roles which correspond to the activities of software development process. Requirements analysts elicit and communicate what the customer wants, and work with designers to produce a system-level prescription for the system. Designers work with programmers describing the system so that programmers can write the code. After the code is produced, it is tested, firstly by programmers then by a group of testers. The code is then integrated, where testers work with an implementation team to verify that the system is built properly. When the functionality and quality of the system is approved by the development team, then together with the customer, it is compared to the initial requirements to verify that it is actually what the customer wants. Trainers show end users how to use the system and maintenance continues to support the customer. In addition, if the requirements change then the system must also. Depending on the customer, system size and complexity; the need for documentation and maintenance may also be large. Several others may become involved with the development team and remain throughout (Sommerville, 2004).

The activities involved in the large organisation team may be extrapolated to small organisations. As a general rule, software engineering project groups should have no more than eight members. Large teams are usually split into sub-groups, developing different parts of the system teams. Teams in small organisations, will tend to have role overlap. Sommerville (2004) argues that, in small projects, two or three people may share all the roles. In larger projects the development team is separated into distinct groups, based on their function. Small projects may occur in large organisations and large projects in small organisations. However, it is more likely that large projects are conducted in large organisations.

5.4 Factors Affecting Software Project Success

There are highly publicised failures in software development practice, associated with safety, cost overruns and schedule delays (Linberg, 1999). The Standish Group International Report of 2001, reports that 23% of all corporate software development were cancelled before completion with 49% costing 45% over their original estimates. Although these figures appear bleak they are a significant improvement on the original 1995 report, when 31% failed, cost overruns were 189% of original cost estimates and 53% of projects were challenged. The definition of project failure by the Standish group refers to projects that have been cancelled or do not meet budget, delivery and business objectives. According to Jiang et al. (2002) 'Information System (IS) success is usually defined as a composite of efficiency performance measures including cost, time and savings (p.17). However, few systems are completed on time and within budget, and are therefore deemed failures upon delivery (Ambler, 1999; Hayes, 1997; Meyer, 1998).

According to Garrety et al. (2004, p.351), '[T]he success of complex technology development projects depends heavily on the ability of team members to interact productively so that relevant knowledge can be acquired, generated and circulated in a timely and cost-effective fashion' (Garrety et al. 2004 p.351). The Standish group (2001) identify 'The CHAOS Ten' factors that lead to project success. These are presented in Table 5.1.

Table 5.1 The CHAOS Ten

Factor	Weight*
Executive Support	18
User Involvement	16
Experienced Project Manager	14
Clear Business Objectives	12
Minimized Scope	10
Standard Software Infrastructure	8
Firm Basic Requirements	6
Formal Methodology	6
Reliable Estimates	5
Other	5

**The more points, the lower the project's risk.*

Curtis, et al. (1988) in a study of 17 large projects looked at problem solving, in relation to process models. In particular, they looked at the behavioural and organisational factors that affect project outcomes. Curtis et al. (1988) concluded that the effects of tools and methods are small, variability across designers is high and success at design requires more than technical expertise. This finding indicates that the continuing search for the technological/methodological 'silver bullet' (Brooks, 1987) is not likely to achieve the goal of project success. Other research by Button and Sharrock (1995) found that software engineers did not follow prescribed structured methods in day-to-day practice, but developed intuitive ways of working. In addition, the introduction of structured methods (CASE tools) has been found to have a negative effect on established situated practices (Waterson et al. 1997; McChesney & Gallagher, 2004). Research has shown that human factors affecting team performance may be the key to project success (Faraj & Sproull, 2000; Guinan, et al. 1998; Kraut & Streeter, 1995).

5.5 Factors Affecting Team Performance in Software Development

Team performance on software development projects is dependent on many different and interacting factors. The two main factors, with most empirical support, are social interaction (or communication) and coordination. In addition, several other factors are thought to affect ream performance and are described under the framework forwarded by Guinan et al. (1998).

Team performance in software development may be divided into two parts: efficiency and effectiveness (Ancona & Caldwell, 1992; Faraj & Sproull, 2000; Henderson & Lee, 1992). Efficiency usually refers to the budget and schedule of the project (Boehm, 1981). Effectiveness, refers to the achievement of project goals (Daft, 2004). Unrealistic schedules and underestimated effort estimates typically result in extreme workload pressure (Boehm, 1981; Brooks, 1995). When there is a perception that the schedule or effort estimates are unrealistic, software developers may not strive for quality solutions or may not fully commit to the goals of the project (Glass, 1992). Therefore the following is predicted:

Hypothesis 18

There will be a positive relationship between efficiency and effectiveness.

5.5.1 The Role of Social Interaction

In large software development projects communication 'bottlenecks' and 'breakdowns' are very common (Curtis et al. 1988). Projects benefit from the integration of expertise from different specialist areas (Brusoni et al. 2001). A problem occurs in trying to coordinate these diverse individuals. People from different functional backgrounds have very different beliefs and expectations.

Team size is also a factor in coordination. The number of one-way communication links is n* (n-1), where n= group size. In a group with 7 or 8 members some will rarely communicate with one another (Sommerville, 2004).

Kraut and Streeter (1995) investigated communication and coordination in 65 projects in a large software company in the United States These authors outlined the four interacting factors that affect communication and coordination in software development. The factors were scale, uncertainty, interdependence and communication type and are discussed in turn.

In terms of scale, the larger the project, the more division of labour and the higher the need for coordination. Knowledge is often lost from requirements to specifications (Kraut & Streeter, 1995). Software is uncertain because different subgroups have different beliefs of what it should do and how it should do it. For example, in requirements the software engineer will be dealing with end-users, designers and programmers, all of whom have differing beliefs.

Software may be built from thousands of modules developed by different teams, that must mesh with each other perfectly for the system to operate. Thus, it is an interdependent process, requiring good coordination among groups. Communication in software development may be formal or informal. Formal communication is useful for coordinating routine transactions within teams, but it often fails in uncertainty (Kraut & Streeter, 1995). In software informal communication may be needed for coordination (Van de Ven et al. 1976). Physical proximity may be a constraint when acquiring work related information (Allen, 1977). In the face of uncertainty in research tasks, coordinating information through informal, interpersonal communication is valuable for both individuals and their organisations (Pelz & Andrews, 1966; Tushman, 1977).

Kraut and Streeter (1995) measured software productivity and software quality based on software metric data. Projects that produced many lines of code (LOC) also produced code of good quality (i.e. fewer errors, faults and shorter time to fix faults). They also found that older, smaller and less inter-organisationally dependent teams were better coordinated. Kraut and Streeter (1995) concluded that 'while much of the recent attention in software engineering has been on methods for formalizing communication among specialists, the data from this study suggest that, to be successful, these methods must at least be supplemented with interpersonal communication' (p.79).

In another study by Hoegl (1998; cited in Lechler, 2001), 147 software teams were analysed within four large international companies. Hoegl found that teamwork quality had a significant impact on project success. The quality of teamwork was defined as the collaboration within teams.

It has already been posited, in Chapter 2, that informal social interaction will aid the development of transactive memory, which involves coordination of expertise and thus will lead to improved team performance. In order to account for the role formal communication, which is thought to be useful in the coordination of routine transactions, in software development team performance, the following prediction is made:

Hypothesis 19

Team performance (efficiency and effectiveness) will be positively related to the presence of a formal knowledge sharing system.

5.5.2 The Role of Expertise Coordination

Other research into software teams has also found that performance is connected to team coordination. In an observation study by Walz et al. (1993), breakdown in coordination and knowledge sharing, as well as knowledge integration problems were identified as key factors which hindered project outcomes.

Faraj and Sproull (2000) in a quantitative study of 69 software development teams in one site, posited that it is not merely the presence of expertise but its coordination that leads to effectiveness in team performance. These researchers made a distinction between administrative coordination and expertise coordination, where administrative coordination is seen as sufficient for routine non-intellectual tasks, and expertise coordination is necessary for more complex tasks which involve the management of knowledge and skill dependencies, to identify where expertise is located, needed and accessed. These researchers define expertise as 'the specialized skills and knowledge that an individual brings to the team's task' (p.1555), and coordination as 'team-situated interactions aimed at managing resources and expertise dependencies' (p.1555). They also investigated administrative coordination, usually embedded in software tools. Administrative coordination was defined as 'formal or prespecified mechanisms used to assign tasks, allocate physical and economic resources, manage resource dependencies, and integrate outputs' (Faraj & Sproull, 2000, p.1557) and involves budgets, staffing, milestones, review meetings, inspections and critical path analysis etc. These authors found that conventional team factors: presence of expertise, professional experience, use of software development methods and administrative coordination were not found to be associated with team effectiveness but were found to be associated with team efficiency. In addition, expertise coordination was found to be associated with team effectiveness above and beyond conventional factors. This leads to the following hypothesis:

Hypothesis 20

Team performance (efficiency and effectiveness) will be positively related to administrative coordination.

To conclude from sections 5.5.1 and 5.5.2, the following hypothesis is forwarded:

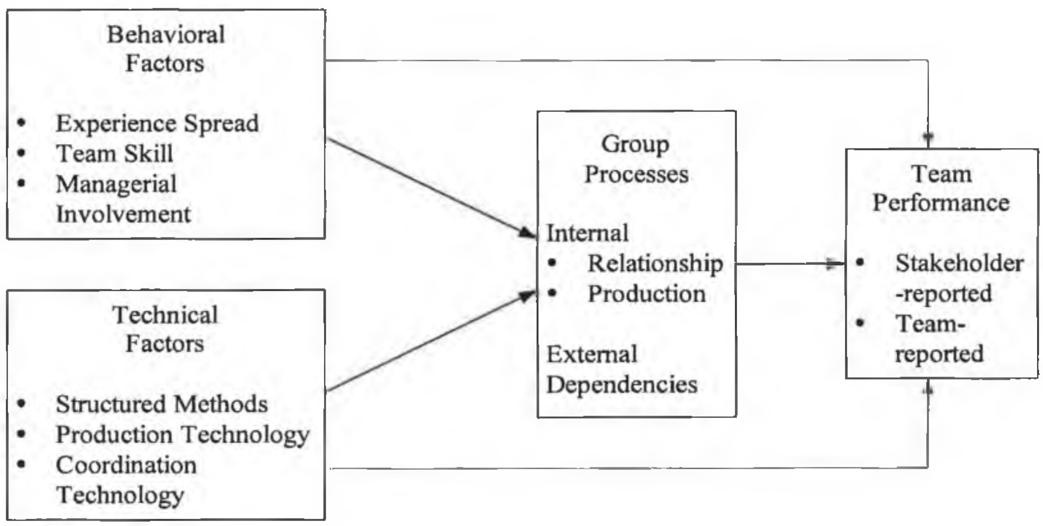
Hypothesis 21

Administrative coordination and the presence of a formal knowledge sharing system will predict team performance (efficiency and effectiveness).

5.5.3 General Framework for Factors that Affect Team Performance

Guinan et al. (1998) studied 66 software development teams in one site at the requirements stage using a framework to classify factors affecting team performance. This framework is depicted in Figure 5.1.

Figure 5.1 Framework for Factors Affecting Team Performance



This classification framework consisted of internal and external group processes and their antecedents, which were divided into two world views: *behavioural factors* and *technical factors*. Internal group processes include relationship processes and production processes, where relationship processes refer to the emotional well-being of the team, cooperation, motivation, atmosphere of sharing, trust, and working toward a common goal which is similar to the cohesive 'jelled' team, forwarded by DeMarco and Lister (1987). Team production processes are concerned with processes such as team schedule, effective coordination, problem identification and team size with smaller teams having less communication problems than larger teams (Brooks, 1995). Goal alignment is also an important production process because 'when a team is fulfilling its purpose team members are more effective because they are more directed' (DeMarco & Lister, 1987, p.18). The schedule needs to be realistic, as tight deadlines can be demotivating, 'people under time pressure don't work better they just work faster' (*ibid*, p.18). External group processes are concerned with external dependencies (Katz & Tushman, 1981) in the form of communication across departments, where the necessity to communicate with individuals who are not formal team mates across boundaries is critical to team success.

The two types of antecedents identified by Guinan et al. (1998) were *behavioural factors* dealing with experience spread, team skill and managerial involvement, and *technical factors* covering structured methods, production technology, and coordination. Experience spread is essentially demographic diversity. On the one hand, this diversity is thought to increase conflict and has a negative effect on internal communications, cohesion and coordination (Kiesler, 1978). On the other hand diverse teams when well managed have the ability to look beyond their boundaries for help in problem solving (Guinan, et al. 1998). This suggests that managerial involvement is directly related to increased performance (Guinan, et al. 1998). It is also argued that the leader should be distinct, and responsible, with everyone knowing where the buck stops (O'Connell, 2001; Henderson & Lee, 1992). Teams need to be highly skilled for optimum performance, because there is a chasm between the productivity of the most effective performers and the least effective, a ratio of 10:1 (Brooks, 1995, DeMarco & Lister, 1987). Guinan et al. (1998) concluded that relationship process was more important than production technology in optimising team performance. They concluded that effective plans, good communication, clear goals and procedures were critical and that behavioural factors were more consequential than technical factors such as structured methods and the use of CASE tools in influencing team performance. They also found that teams with the ability to communicate across department boundaries were also more successful.

5.6 Issues for the Management of Software Development Teams

Edwards (2003) argues that 'software engineering is knowledge work, and hence knowledge management is of high importance in software engineering' (p.11). Issues of KM were addressed in Chapter 3, where the confusion between knowledge and information was outlined, corresponding broadly to the management of personalised (tacit) and codified (explicit) knowledge respectively. This has implications for the management of knowledge in software development. There are technological, people and process-based solutions to the management of software developers and their knowledge. According to Edwards (2003), the best approach is a combination of all three within one overall knowledge management strategy that includes both personalization and codification elements (Hansen et al. 1999).

The software project manager's job is to ensure that the software project meets the schedule and budget constraints and delivers software that contributes to business goals including meeting user needs. According to Sommerville (2004), good management cannot guarantee project success, but poor management usually results in project failure.

The discourse of knowledge management is becoming more evident in the project management literature. Turner (1999) observes that project teams consist of 'knowledge workers'. Knowledge workers are characterised as individuals who have high levels of education and specialist skills combined with the ability to apply these skills to identify and solve problems (Drucker, 1993). Members of software development teams represent intellectual capital and software managers need to ensure that the organisation gets the best possible return on its investment in people. Knowledge workers have specific individual expertise characterised by their job title, but there is also a cross-over of knowledge boundaries and 'because software development is knowledge work, its most important resource is expertise' (Faraj & Sproull, 2001, p.1554). Researchers have determined that software developers have much higher achievement needs than the general population (Couger & Zawacki, 1980; Couger, 1988).

According to Edwards (2003), managers need to abandon traditional methods of managing these workers, since knowledge workers enjoy greater power and autonomy at the workplace because their expertise is both more difficult to control and more marketable to other employers. Furthermore, management approaches from other disciplines are not appropriate for managing software projects (Sommerville, 2004). Software engineering is distinct from other types of engineering because the product is intangible, progress is not explicit, and team members rely on the documentation of others to review progress. In addition, there are no standard processes, which makes it difficult to predict which process will cause development problems.

5.6.2 Managing the Development of New Software Products

New Product Development (NPD) has been described by many researchers as a knowledge-intensive activity (e.g. Davenport & Prusak, 1998; Iansiti & MacCormack 1997; Nonaka & Takeuchi, 1995; Ramesh & Tiwana, 1999) and knowledge as a competitive resource 'fuels continuous innovation which in turn leads to competitive advantage' (Nonaka & Takeuchi, 1995, p.6); where innovation and speed to market that are essential for business success (Davenport & Prusak, 1988). This 'continuous innovation' actually refers to incremental development of products (Ramesh & Tiwana, 1999). Software development is slightly different to most new product development, in that the process of development is intangible, resulting in a tangible product. 'Unlike much manufacturing software development is a nonroutine activity' (Kraut & Streeter, 1995, p.70) and involves uncertainty in that many projects are unique with no precedent prototype and with changing specifications (Brooks, 1995; Curtis et al. 1988).

According to Ramesh and Tiwana (1999), products and technologies become increasingly complex, NPD requires effective collaboration and synergistically integrated skills of several individuals. Ramesh and Tiwana (1999) posit that most product development is moving towards team-based structures, since teams are believed to increase individual commitment and performance. As Galegher et al. (1990) found, teams are more effective in bringing a new product to the market in a short time-frame.

NPD is associated with speed to market which helps garner competitive advantage. This development of new products is associated with well integrated teams who perform well. On the basis of this discussion, the following hypotheses are forwarded:

Hypothesis 22

New product development capability will vary according to team performance as measured by efficiency and effectiveness.

Hypothesis 23

Team performance (efficiency and effectiveness) will predict new product development capability.

5.7 Acquiring and Sharing of Tacit Knowledge in Software Development Teams

In Chapter 3, tacit knowledge was defined at the team and articulated level of abstraction. In Chapter 4 it was argued that tacit knowledge is acquired through social interaction and through the development of a transactive memory system. Learning implies acquiring both tacit and explicit knowledge and in small and medium sized software companies the tacit part is probably the most important (Dyba et al. 2004). In addition, Chapter 4 outlined the importance of the right culture or climate for the acquisition and sharing of tacit knowledge. This climate is one that embodies psychological safety (Edmondson, 1999).

An insight into how these theories may be applied to the domain of software development is provided by theoretical and empirical studies regarding the agile method approach to developing software. This agile approach provides an understanding as to how tacit knowledge is acquired and shared in software development teams. In addition, other studies in the software development field, investigating concepts related to tacit knowledge, transactive memory and social interaction provide evidence for the manner in which, the concepts under study are related to one another and to team performance. The agile approach and related studies are now outlined.

5.7.1 Agile Methods and Tacit Knowledge Sharing

According to Chau et al. (2003) it is unlikely that all members of a development team possess all the knowledge required for the activities of software development. Therefore different people will possess different aspects of knowledge, as posited by transactive memory and TMM theory. According to Chau et al. (2003) this underlines the need for knowledge sharing to enable software organisations to

1. effectively share domain expertise between the customer and the development team;
2. identify the requirements of the software system;
3. capture non-externalised knowledge of the development team members;
4. bring together knowledge from distributed individuals to form a repository of organisational knowledge;
5. retain knowledge that would otherwise be lost due to the loss of experienced staff; and
6. improve organisational knowledge dissemination.

Chau et al. (2003) argue that traditional approaches to software development are 'plan driven' or 'task-based' and promote knowledge sharing through documentation. These authors refer to this approach as 'Tayloristic' and contend that agile methods place emphasis on individuals and their interactions rather than on the process. Agile methods suggest that most written documentation can be replaced by informal communications among team members internally and between team and the customers with a stronger emphasis on tacit knowledge rather than explicit knowledge. Chau et al. (2004) cite the example of pair programming as used in XP (Beck, 1999). Pair programming, is a social process and involves two developers working in front of a single computer designing, coding, and testing the software together. During a pair programming session, some explicit but mostly tacit knowledge, is shared between the pair. The knowledge shared includes task-related knowledge, contextual knowledge, and social resources. Chau et al. (2004) conclude that 'for this reason, the social nature of pair programming made it a great facilitator for eliciting and sharing tacit knowledge'(p.4).

According to Melnik and Maurer (2004) '[A]gile methods consider face-to-face interactions (with the customer and among the development team members), "clean code that works", and suites of test drivers as the primary devices for knowledge sharing' (p.1). These authors argue that the knowledge is socially constructed and socially held and conducted a study to demonstrate the importance of face-to-face interaction in sharing abstract or complex knowledge. The sample consisted of small teams of 6-9 graduate students and twenty eight computer professionals who were attending a conference on Agile methods (formed into four teams, which consisted of people from the same company who knew each other well). In all ninety seven people took part, with fourteen teams formed. The teams had to complete a task where they could only use written documentation to specify a sample drawing to be reproduced. The resulting reproduced drawings with their inaccuracies, demonstrate the ineffectiveness of traditional or Tayloristic knowledge sharing when complex cognitive artefacts are used. The authors concluded that the higher the complexity, the more is the need for interactive knowledge sharing via direct verbal communication. Citing the richness of face-to-face communication in providing information through physical cues and voice inflection, which are important when there is ambiguity (Melnik & Maurer, 2004).

Tacit knowledge, like the abstract knowledge discussed in the Agile approach, is undocumented, complex and shared through iterative social interaction, therefore, Agile methods appear to promote the sharing of tacit knowledge.

5.7.2 Transactive memory and Tacit Coordination in Software Teams

Transactive memory systems emphasise members' expertise and mental representations of that expertise, but not other mental representations that team members might share about the team, task, or situation. It is this specific emphasis on expertise, however, that makes the transactive memory system construct especially relevant for understanding how knowledge-worker teams develop, share, integrate, and leverage distributed expertise (Lewis, 2003).

Two studies in the domain of software development, into the related concepts of expertise coordination and mutual knowledge, provide further evidence for the use and development of transactive memory in software development teams. In the expertise coordination study, (already discussed in section 5.5.3) Faraj and Sproull (2000) found 'that for expertise coordination to be effective, processes that are distributed, heedful and emergent have to occur' (p.1556). An empirical investigation into the similar concept of 'mutual knowledge', was conducted by McChesney and Gallagher (2004). These authors posit that 'mutual knowledge' consists not only of specific pieces of information, but also the awareness that the other knows this information. This view sees the team as a distributed cognitive system, highlighting issues of team design and development. These two concepts are very similar to transactive memory. Furthermore, in both studies the coordination of expertise and mutual knowledge was tacit.

McChesney and Gallagher (2004) investigated coordination activities in two software engineering projects using a qualitative interpretive approach. They highlighted a comprehensive set of unspecified and tacit work activities which are critical to the effective coordination and operation of a successful software project. These coordination mechanisms are not defined in standard software engineering process models and are tacit in that they are part of the situated, day-to-day problem solving strategies that software engineers use.

An example of a tacit coordination mechanism was keeping people in the loop through the copying of emails, where there were no formal rules for who should be copied any given communication but engineers just knew who to include. They also found that these communication activities actually maintain the coherence of project activity and describe them as the 'glue which holds the project together' (p. 485).

Transactive memory is a factor in successful team performance and is enacted in tacit knowing of the location and awareness of team member expertise. Therefore software development teams with a well-developed transactive memory system will have higher levels of team tacit knowledge than teams with less developed transactive memory systems.

5.8 Conclusions and Central Hypotheses

Software development is part of the discipline of software engineering, and the process and methods used to develop software need to be managed differently to other engineering projects (Sommerville, 2004). Software developers are knowledge workers who work in teams. There are two main types of knowledge that need to be managed in software development, codified and tacit, roughly corresponding to technical and non-technical factors. A growing body of research in software development has indicated that human non-technical factors affect team performance and project success more than technical factors. Communication and particularly informal communication in software development teams has been associated with successful projects and team performance (Guinan et al. 1998; Kraut & Streeter, 1995). Communication in teams needs to be coordinated tacitly through transactive memory or explicitly through administrative coordination.

Transactive memory develops as a result of social interactions particularly informal interactions. However, social interaction is also the means by which tacit knowledge is acquired and shared in software development teams, where social interaction refers to quality and quantity of informal interactions. Social interactions are deemed more important to the acquisition and sharing of tacit knowledge. Therefore the following prediction is made:

Hypothesis 24

Social interaction (quality and quantity) will predict tacit knowledge above and beyond transactive memory.

Finally, team tacit knowledge is thought to be an important factor in team performance as measured by efficiency and effectiveness. Team tacit knowledge is developed through social interactions and transactive memory, where social interaction and transactive memory are not thought to affect team performance directly (*hypotheses 22 and 23*).

Hypothesis 25

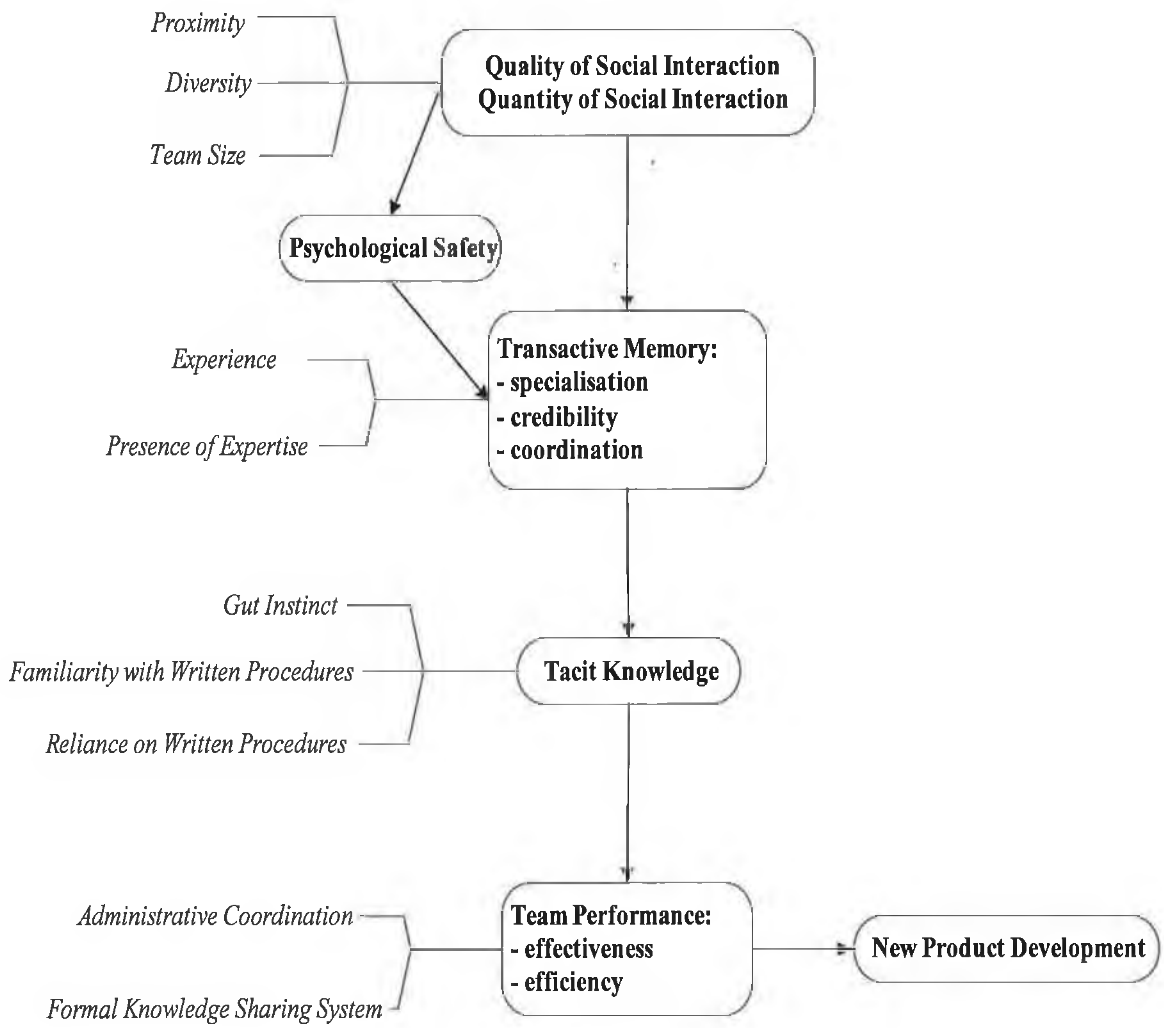
Tacit knowledge will predict team performance (efficiency and effectiveness) above and beyond quality of social interaction, quantity of social interaction and transactive memory.

5.9 Model for the Acquisition and Sharing of Tacit Knowledge in Software Development Teams

The aim of this literature review was to assess the factors influencing the acquisition and sharing of tacit knowledge in software development teams and to propose a theoretical model to be tested based on omissions in, and extensions of, previous research. The model proposed in Figure 5.2 summarises and integrates the hypotheses generated in Chapters 2, 3, 4 and 5. A summary of all the hypotheses is provided in Table 5.2. Before describing the model it is necessary to emphasise the position taken in the present study with respect to tacit knowledge. In Chapter 3, tacit knowledge was defined at the articulated level of abstraction (Sternberg, et al. 2000, Busch & Richards, 2003), which is really implicit knowledge. Tacit knowledge may be conceptualised at an individual or team level and both levels are important. However, as teams are the focus of interest in this study, the model will refer to team tacit knowledge, that must coordinated among team members. In addition, tacit knowledge was operationalised at the articulated level of abstraction.

The model described in Figure 5.2, deals with relationships and predictions surrounding four main variables, which represent the 'Main Model' to be tested. These variables are as follows: Social interaction (quality and quantity), transactive memory (consisting of three first order factors, specialisation, credibility and coordination), team tacit knowledge and team performance. The model will be described in terms of the main model and four 'Minor Models'. Each minor model will deal in turn, with relationships and predictions among factors related to each of the main model variables.

Figure 5.2 Model for the Acquisition and Sharing of Tacit Knowledge in Software Development Teams



The main thrust of the model, following the central line, deals with four main variables: Social interaction, transactive memory, team tacit knowledge and team performance. The left hand side of the model incorporates other factors that are thought to affect the main variables.

5.9.1 The Main Model

The central set of predictions in this model correspond to *hypotheses 24* and *25*, which deal with the predictive relationships among these four variables. It is also hypothesised that social interaction (quality and quantity) will predict tacit knowledge above and beyond transactive memory (*hypothesis 24*) and that team tacit knowledge will predict team performance (effectiveness and efficiency) above and beyond social interaction and transactive memory (*hypothesis 25*).

In addition to the main predictions, seven further relationships are hypothesised for the main model. Social interactions in the proposed model are informal and include quality and quantity, which are related to one another (*hypothesis 1*). Individual tacit knowledge becomes group tacit knowledge through social interaction (Nonaka & Takeuchi, 1995), which is also the means by which tacit knowledge is acquired in teams (Edmondson et al. 2003) referring to *hypothesis 9*. The development of a transactive memory system, is a consequence of the social interactions in laboratory groups (Moreland, 1999) and in high technology teams (Lewis, 2003, *hypothesis 5*). In addition the transactive memory system is another way in which team tacit knowledge is shared (*hypothesis 10*). Tacit knowledge at the team level is expected to be related to team performance (*hypothesis 8*) and transactive memory is also predicted to be positively related to team performance (*hypothesis 4*). Finally, it is predicted that there is a positive relationship between efficiency and effectiveness (*hypothesis 18*).
Other relationships among the four main variables and among the other hypothesised factors in the model are now outlined.

5.9.2 Minor Model 1: Social Interaction

In Chapter 2 it was argued that social interactions between team members are key to understanding how tacit knowledge is acquired, shared and leads to successful performance in software development teams. The quality and quantity of social interaction are affected by several influences, specifically, team psychological safety, team size, team diversity, and proximity referring to *hypotheses 12*, *15, 16* and *17*, respectively. A further hypothesis is now proposed:

Hypothesis 26

Proximity, team size, team diversity, psychological safety will predict social interaction (quality and quantity).

5.9.3 Minor Model 2: Transactive Memory

Presence of expertise, experience, and psychological safety are related to the development of the transactive memory system, incorporating *hypotheses 2, 3*, and *13,* respectively. In addition to these relationships, a further predictive hypothesis is forwarded:

Hypothesis 27

Team psychological safety, experience and presence of expertise will predict transactive memory.

5.9.4 Minor Model 3: Team Tacit Knowledge

Team tacit knowledge may be unrelated to explicit job knowledge as measured by familiarity with and reliance on written procedures but similar to gut instinct, as predicted in *hypotheses 6* and *7*, respectively. The variables in this model are included to provide convergent and discriminant validity check for the team tacit knowledge construct. This model is correlational; a predictive model is not forwarded here.

5.9.5 Minor Model 4: Team Performance

Team performance as measured by effectiveness and efficiency will be related to presence of a formal knowledge sharing system (*hypothesis 19*) and administrative coordination (*hypothesis 20*). Administrative coordination and presence of a formal knowledge sharing system will predict team performance (*hypothesis 21*). Finally, team performance will be related to new product development capability (*hypothesis 22*) and team performance will predict new product development capability (*hypothesis 23*).

5.9.6 Mediation hypotheses

Two mediation hypotheses are forwarded, in this study. It is predicted that transactive memory will act as a mediator between social interaction (quality and quantity) and team tacit knowledge (*hypothesis 11*) and that psychological safety will be a mediator between social interaction (quality and quantity) and transactive memory (*hypothesis 14*). A mediator is the causal pathway through which one variable exerts its influence on another variable.

5.10 Summary

This chapter investigated the issues surrounding the acquisition and sharing of tacit knowledge in software development teams. Theoretical discussion from previous chapters were integrated and applied to the domain of software development. Members of software development teams were described as knowledge workers, who work with intangible cognitive processes, which are mainly tacit. Coordination is important in such teams and may lead to competitive advantage. Furthermore, factors that contribute to success or failure in software development projects were found to be mainly human and related to the manner in which software is developed. Software development involves non-routine technology, and in SMEs and small teams there will be overlap of task roles.

Table 5.2 Summary of Hypotheses

#	*Hypotheses*
1	There will be a positive relationship between quality and quantity of social interaction.
2	Transactive memory will be positively related to the presence of expertise.
3	Transactive memory will be positively related to experience
4	Transactive memory will be positively related to team performance as measured by efficiency and effectiveness.
5	Social interaction (quality and quantity) will vary according to transactive memory.
6	There will be a positivecorrelation between team tacit knowledge and explicit job knowledge as measured by familiarity with written job procedures and reliance on these written procedures.
7	Tacit knowledge at the team level will be related to gut instinct.
8	Tacit knowledge at the team level will be related to efficiency and effectiveness.
9	Team tacit knowledge will be positively related to social interaction (quality and quantity).
10	Team tacit knowledge will be positively related to transactive memory.
11	Social interaction (quality and quantity) and team tacit knowledge will be mediated by the development of a transactive memory system.
12	There will be a positive relationship between social interaction (quality and quantity) and psychological safety.
13	Transactive memory will be positively related to psychological safety.
14	The relationship between social interaction (quality and quantity) and transactive memory will be mediated by psychological safety.
15	Social interaction (quality and quantity) will vary according to team size, where the smaller the team the better the quality of the interaction and the greater the quantity of interaction.
16	There will be a negative relationship between social interaction (quality and quantity) and diversity.
17	Proximity will be positively related to social interaction.

#	*Hypotheses*
18	There will be a positive relationship between efficiency and effectiveness.
19	Team performance (efficiency and effectiveness) will be positively related to the presence of a formal knowledge sharing system.
20	Team performance (efficiency and effectiveness) will be positively related to administrative coordination
21	Administrative coordination and the presence of a formal knowledge sharing system will predict team performance (efficiency and effectiveness).
22	New product development capability will vary according to team performance as measured by efficiency and effectiveness.
23	Team performance (efficiency and effectiveness) will predict new product development capability.
24	Social interaction (quality and quantity) will predict tacit knowledge above and beyond transactive memory.
25	Tacit knowledge will predict team performance (efficiency and effectiveness) above and beyond quality of social interaction, quantity of social interaction and transactive memory.
26	Proximity, team size, team diversity, psychological safety will predict social interaction (quality and quantity).
27	Team psychological safety, experience and presence of expertise will predict transactive memory.

Chapter 6
Research Methodology

6.1 Introduction

This chapter provides an overview of the design employed in the present study to investigate the hypotheses described in the previous chapter. The way in which research is conducted may be conceived in terms of the research philosophy subscribed to, the research strategy employed, the research instruments used and developed in pursuit of research goals and the search for the solution to a problem posed by the research questions in Chapter 1. The focus of this chapter is on the selection of the appropriate techniques to assess tacit knowledge and social interaction in software development teams. The principles of research are described and the factors influencing the choice of research design are identified. Beginning with a brief analysis of the philosophical and epistemological paradigms that exist within the social sciences and software engineering research and concluding with the rationale for the research design chosen.

6.2 Research Paradigms

Philosophical assumptions underpin the research process which dispose social scientists towards different research paradigms and methodologies (Burrell & Morgan, 1979; Giddens, 1975). This statement also holds true for software engineering researchers. Kuhn (1962) described a paradigm as an 'entire constellation of beliefs, values, techniques, and so on, shared by members of a given community' (p.162). Paradigms may shift over time, suggesting that paradigms are only as good as the evidence supporting them and the respect in which they are held within the research community.

The principle paradigm adopted by a researcher will largely depend on the ontological, epistemological and methodological assumptions held within their research community. The two research paradigms that have received most attention in the literature can be broadly labelled as positivist and phenomenological (Reichardt & Cook, 1979) or positivist and interpretivist (Bryman, 2001).

According to Guba and Lincoln (1994) positivism may be considered naively realistic and has an objective epistemology with the aim of finding universal truths. Positivism, has its roots in empiricism and is concerned with deductive logic where hypotheses derived from theory seek to determine associations or causality. Phenomenology assumes that reality is socially constructed where epistemologically, the researcher is 'immersed in the phenomenon of interest' (Firestone, 1987, p.17).

6.3 Methods and Paradigms

The most commonly used terms to differentiate these paradigms with respect to their associated methods and techniques, are quantitative and qualitative respectively (Creswell, 2003). Quantitative methods are based on the positivist paradigm while qualitative methods are built on a phenomenological world view (Firestone, 1987). According to Myers (1999) these 'paradigms' or epistemologies have been the subject of considerable disagreement as to whether they can be accommodated within the one study. Some social science researchers (Lincoln & Guba, 1985; Denzin & Lincoln, 2000) perceive qualitative and quantitative approaches as incompatible and mutually exclusive. Others, such as Patton, (1990) and Reichardt and Cook, (1979) argue that the skilled researcher can successfully combine approaches.

6.3.1 Research Methods in Social Science and Software Engineering

The epistemological basis of much research in the social sciences has been positivism, thus from an ontological perspective this research tends to adopt a realistic focus and is concerned with explaining and predicting 'what happens in the social world by searching for regularities and causal relationships between its constituent elements' (Legge, 1995, p.308). The term 'social science' incorporates both psychological and organisational approaches to research. However, in management and organisational studies, qualitative approaches have been used since their inception some 90 years ago. In the more defined field of industrial and organisational (I-O) psychology, researchers have more recently turned their attention to the possibilities for inquiry based on these approaches (Locke & Golden-Biddle, 2002).

Researching in software engineering is more appropriately placed in the domain of information systems (IS) (sometimes called or referred under Information Technology System (ITS) or Management Information Systems (MIS)). IS research is the formal study of information systems within an organisation. Software engineering differs from the field of IS, in that, IS takes social and organisational aspects into account

(Abrahamsson et al. 2002). This inclusion of social and organisational aspects is where the overlap with KM is evident. IS research is now to be found in the KM literature, and the terms are sometimes used interchangeably, where knowledge is treated as object and/or as subject (see Bouthillier & Shearer, 2002, for a discussion on the differences between KM and Information Management (IM)). According to Edwards (2003) there are relatively few 'mainstream' articles about KM in software engineering although they are becoming more common.

Galliers (1991, p.149) identified methodologies used in IS research and classified them according to scientific or interpretivist, which correspond to quantitative and qualitative methods (see Table 6.1). This taxonomy is also relevant to social sciences with the exception of theorem proof, forecasting and futures research.

Table 6.1 Taxonomy of Research Methodologies

Scientific	Interpretivist
Laboratory experiments	Subjective / argumentative
Field experiments	Reviews
Surveys	Action research
Case studies	Descriptive / Interpretive
Theorem proof	Futures research
Forecasting	Role / Game playing
Simulation	

Chen and Hirschheim (2004) assessed the trends in IS research in a study of 1,893 published articles in eight major IS publications outlets between 1991 to 2001 and found that positivist research dominates constituting 81% of published empirical research. In terms of research design survey research is the most widely used method constituting 41% followed by case study, laboratory experiment, action research and field experiment accounting for 36%, 18%, 3% and 2% respectively In addition quantitative research accounts for 60%, qualitative 30% and combination methods 10% of all approaches.

Based on the preceding discussion, it may be concluded that although, both social sciences and software engineering has now taken into account phenomenological perspective, most research is consistent with a positivist paradigm, relying on experimentation, survey method and questionnaire design.

6.3.2 Combining Methods and Paradigms: Triangulation and Mixed Methods

The combination of qualitative and quantitative methods has been referred to as *triangulation* (Denzin, 1970) or as *mixed methods* (Cresswell, 2003). Denzin (1970) defined triangulation as 'the combination of methodologies in the study of the same phenomenon' (p.297). The mixed method approach opts for pluralism or pragmatism rather than philosophical purity. It assumes that the research problem rather than a particular philosophical position should dictate choice of methods and procedures (Creswell, 2003).

Denzin (1989) differentiates between four different types of triangulation: triangulation of data, investigators, theories and methodologies. The triangulation type of interest for the present study is *investigator triangulation* which is concerned with the use of multiple, rather than single observers. It is suggested that by using triangulation any bias present whether relating to the researcher, the data sources or the methods employed, will be neutralised when used in conjunction with other researchers, data sources or methods (Mathison, 1988).

According to Creswell (2003) the mixed methods approach involves three elements: implementation, priority and integration. Implementation of quantitative and qualitative methods involves data collection that may be sequential or concurrent, with priority given to one approach over the other or both having equal status. The two types of data are integrated at several stages in the process of research: the data collection, the data analysis, interpretation or some combination of places (Creswell, 2003). Creswell (2003) outlines six mixed method strategies, three sequential and three concurrent as follows: sequential explanatory strategy, sequential exploratory strategy, sequential transformative strategy, concurrent triangulation strategy, concurrent nested strategy, concurrent transformative strategy.

The mixed method strategy of interest in the present study is the *sequential exploratory strategy*, which is especially advantageous for building a new instrument. In this approach, priority is given to qualitative data. This means that qualitative data are collected and analysed first and then quantitative data are collected. Integration occurs during the interpretation phase. Quantitative data are used to examine the possible generality of qualitative findings or to determine the distribution of a phenomenon within a chosen population.

Both investigator triangulation and the sequential exploratory strategy were employed in developing the sub-measure of tacit knowledge in Chapter 8.

6.4 Determining an Appropriate Research Framework for the Present Study

Creswell (2003) suggests that the choice of paradigm adopted by researchers will depend on the 'worldview' that exists within their discipline. The paradigm chosen will also largely depend on the way in which previous research has addressed similar problems, existing theories in the area, known variables, the research questions and the extent to which measures have been developed and validated. In addition, pragmatic reasons such as the time, resources and access available are also necessary conditions.

6.4.1 Previous Methods used in Addressing Similar Research Problems

A variety of paradigms and methods have been employed in investigating research problems similar to those addressed in the present study. Examples of methods used in related research studies variously investigating tacit knowledge, social interaction, knowledge sharing and team performance are now outlined.

Tacit knowledge has been measured quantitatively using a survey method (Sternberg, et al. 2000), and experimental methods (e.g. Cleeremans, 1993; Perruchet & Pacteau, 1990; Reber, 1967, 1993; Reed, et al. 1983). In addition, the qualitative case studies have also been applied in tacit knowledge sharing (e.g. Desouza, 2003; Stotts, et al. 2003), tacit coordination and adaptive learning in teams (Hutchins 1991; Weick & Roberts 1993), tacit knowledge and collective learning (Edmondson, 2002). A mixed method approach to investigating tacit knowledge flows was employed by Busch, et al. (2003). These researchers initially used a survey method but applied a formal concept analysis to visually represent results and Social Network Analysis (SNA) to map the tacit knowledge flows between individuals, to provide qualitative interpretation.

Studies linking knowledge, shared mental models and team performance have used qualitative interpretive approach (McChesney & Gallagher, 2004) and quantitative approaches (Levseque et al. 2001; Faraj & Sproull, 2000). Finally, social interaction has been measured both quantitatively using self report questionnaires (Chiu, et al. 1995; Levesque et al. 2001) or observation tools (Bales, 1950) and qualitatively using SNA (Busch et al. 2003). Team performance has been measured quantitatively using statistically validated scales (e.g. Faraj & Sproull, 2000; Kraut & Streeter, 1995).

6.5 The Research Framework and Design for the Present Study

6.5.1 The Research Framework

To determine the research design of the present study, the degree of fit between research questions and methodological choices available to the researcher were considered. Since the aim of the study is to find principles that may be applied to software development teams, qualitative, idiographic approaches do not allow for generalisation. Furthermore, in order to make direct comparisons with existing studies, it is better to be consistent, for the most part, with the methodology of a positivist framework. Therefore, the framework chosen was positivist, however within this framework a sub-measure of tacit knowledge was developed using a mixed method approach.

6.5.2 The Research Design: Quantitative Survey with Mixed Method Sub-measure

A survey design was chosen to measure the variables of interest in the present study. This design incorporates the positivist paradigm and a concomitant quantitative method. The survey method employs a number of instruments to collect data on all the variables of interest and provides a quantitative description of a sample population of software development teams through the use of self-report measures. Findings from the survey method can be generalised to the population of software development teams as a whole (Babbie, 2001). In addition, the survey was developed for completion online. An online survey was used because this distribution method best addressed the questions under study and suited the IT informed, time limited, participants. The survey developed in the present study, consists of a variety of both previously validated instruments and measures developed specifically for the present research. Investigator triangulation and the mixed method approach employing a sequential exploratory strategy were used to develop the team tacit knowledge sub-measure. All measures, in the survey, involve self-report perceptions where participants quantify how often or how intensely they experience the phenomena under study enabling comparisons across teams. The choice of survey items and the development of the tacit knowledge measure are detailed in Chapters 7 and 8, respectively.

6.5.3 The Survey Design: Benefits and Limitations

There are a number of benefits and limitations associated with the survey method (Fowler, 1988; Kerlinger, 1986). The cost associated with administering surveys is relatively low, respondents have time to think about their answer, they promote anonymity, provide access to widely dispersed respondents and the potential for interviewer bias is minimised. Questionnaires can be standardised, tested and validated, producing large amounts of data from sample populations. These can be subjected to rigorous and sophisticated statistical analyses and inferences can then be made for a wider population. Although survey research information is regarded as relatively accurate (Kerlinger, 1986), a number of limitations have been associated with their used. Postal surveys are liable to poor response rates, lack of opportunities to probe (Kidder, 1981) and the lack of interviewer control (Fowler, 1988).

One of the main problems with self-report measures is *mono-method bias* or *common method variance* (Campbell & Fiske, 1959; Fiske, 1982). Common method variance is 'variance that is attributable to the measurement method rather than to the constructs the measures represent' (Podsakoff et al. 2003, p.879). Examples of method variance are consistency of response (Podsakoff & Organ, 1986; Podsakoff et al. 2003), acquiescence with response set (Podsakoff & Organ, 1986; Podsakoff et al. 2003; Winkle, et al. 1982) and social desirability of response (Spector, 1987). These limitations are more commonly associated with the use of single items or poorly designed scales (Harrison & McLaughlin, 1993; Spector, 1987). For a comprehensive review of the biases and remedies associated with common method variance, see Podsakoff, et al. (2003).

Podsakoff et al. (2003) recommend two ways to control common method bias, through the study's procedures and/or statistical controls. Researchers may design a study so that, measures of the independent and dependent variables are obtained from different sources. When this is not possible then researchers should separate the measure of the independent and dependent variables which are presented at different times (temporal) or under different conditions (proximal or methodological). A further procedural remedy is to ensure anonymity and to reduce evaluation apprehension. In addition, the question order may be counterbalanced, such that dependent measures are presented prior to independent constructs. This is carried out in an attempt to control response consistencies (Harrison et al. 1996). Finally, scale items can be improved by avoiding ambiguity, double-barrelled questions and vagaries. In addition using different scale endpoints and bipolar numerical scales (Tourangeau et al. 2000).

Statistical remedies can also be used, in particular Harman's single factor test is one of the most common tests available for examining common method bias (Podsakoff & Organ, 1986; Podsakoff et al. 2003). According this test, all variables are hypothesised to load on a single factor representing the common method.

There are, in addition to common method variance, several sources of bias such as the possibly self-selecting nature of respondents, the point in time when the survey is conducted and in the researcher him/herself through the design of the survey itself (Galliers, 1991).

6.5.4 Issues in Online Surveying

According to Rogelberg et al. (2002), the internet is promising for survey researchers. The benefits include reduced research costs (no postage), ease of distribution of the survey to a wide geographic and large population, enhanced interactivity of research materials and adaptability of research materials (e.g. early responses on the survey can be used to customise the content (Ellis et al. 1998; Morrow & McKee, 1998). A further advantage is that they allow for speedy completion and response. Faught et al. (2004), posit that the problem with instantaneous communication is more an issue of volume than speed and that '[T]he Internet could serve as the ideal medium for sending and receiving surveys, potentially surpassing the use of mail and telephone surveys' (p.26). Technical issues are the main topics discussed in the Internet survey literature. Online surveys should be visually stimulating, easy to use and fit onto the respondents computer screens (Dillman, 2000). Issues also refer to the use of ID numbers to minimise the possibility of people not from the sampling frame responding and of respondents submitting more than one survey (Dillman, 2002; Rogelberg et al. 2002). Non-technical, people issues have also received attention, but are similar to issues related to phone and mail questionnaires. Issues of confidentiality and anonymity cannot be guaranteed; survey responses may be inadvertently cached on the client computer (Rogelberg et al. 2002). In addition, due to the ease of conducting internet surveys, there may be 'oversurveying' from being inundated with surveys (Rogelberg, et al. 2002). Rogelberg et al. (2002) postulate that this may be more to do with respondents' attitudes to surveys in general.

Two sets of research studies by Stanton and Rogelberg (2001) examined the results from 15 studies published between 1989 and 2000 and failed to find substantial differences in methodological issues related to administration of paper-and-pencil surveys and Internet surveys, and stated that few substantive conclusions were affected by them. These results were echoed in the work of Church and Waclawski (2000). Comparison of equivalent methodologies is how validity for Internet surveys has been demonstrated, (Faught et al. 2004). In particular, the comparison of response rates between mail surveys and Internet surveys. Low response rates are a concern for researchers, since answers from survey respondents may differ substantially from those of non-respondents, resulting in a biased estimate of the characteristics of the population (Bean & Roszkowski, 1995).

6.5.3.1 Response Rates

Internet survey response rates vary widely and are consistently lower than mail survey response rates. In a meta-analysis of 56 online surveys by Cook et al. (2000), an average response rate of 34.6% was recorded. Cook et al. (2000) concluded that this was mediated by the number of contacts, personalised contacts, pre-contacts and survey salience. For university faculty response rates of 58% (Schaefer & Dillman, 1998) and 24.54% (Green, Medlin, & Whitten, 2001) were recorded. Green, Medlin and Medlin (2001), recorded response rate of 8.5% from human resource managers and response rates of 3.7% and 1.9% for marketers and general management population respectively. Higher response rates result from more focussed populations (Green et al. 2001). In a paper-and-pencil survey of the Irish software industry a response rate of 8.7% was obtained by Reed and Kelly (2002), which they argue that while low, is typical of the software industry.

In general, email surveys have demonstrated superiority over postal surveys in terms of response speed and cost efficiency. Sheehan and McMillan (1999) estimated that, in studies where both mail and email were used to deliver surveys, mail surveys took 11.8

days to return and e-mail surveys were returned in 7.6 days. Email provides an easier and more immediate means of response (Flaherty et al. 1998). The cost benefits of e-mail have also been highlighted by researchers, with the cost of an email survey estimated to be between 5% and 20% of a paper survey (Sheehan & Hoy, 1999; Weible & Wallace, 1998). The cost savings are derived primarily from the reduction and/or elimination of paper and mailing costs in an email survey. Watt (1999) provided evidence that the costs of email and internet surveys decrease significantly as the sample sizes increase.

6.6 Summary

The choice of research design for the present study was based mainly on the positivist paradigm employing the survey method. A mixed method approach involving a sequential exploratory strategy and triangulation were used to develop the measure of tacit knowledge for teams, which formed just one sub-measure in the survey. Chapter 7 describes the survey and its sub-measures and Chapter 8 outlines the development of the tacit knowledge measure.

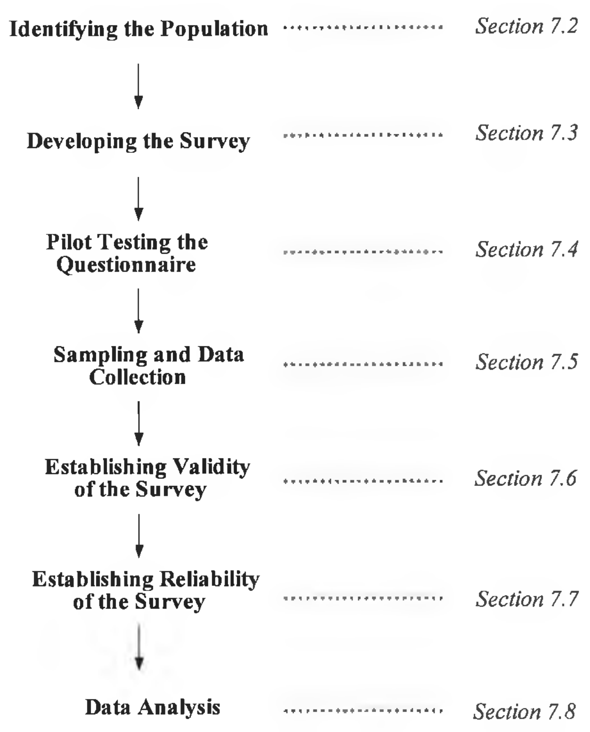
Chapter 7

The Research Process

7.1 Introduction

This chapter details the selection and development of measures for the main model variables of transactive memory, quality and quantity of social interaction, and team performance. In addition, measures for the subsidiary variables of knowledge sharing system, diversity, proximity, presence of expertise, administration coordination, product performance, implicit and explicit job, knowledge were selected. Following a thorough review of previous research where attempts had been made to operationalise these variables, a number of scales and methods were identified as the most appropriate for adoption. The research process involves various stages of data collection. Figure 7.1 outlines the stages of the research process and the associated sections, of this chapter in which they are described. All constructs considered in this investigation refer to the team as the unit of analysis. Accordingly, all measures were specified on the team level asking respondents to make team level assessments of the variables in consideration, or related to each individual in the team.

Figure 7.1 Stages of the Research Process



7.2 Identification of the Population

The population of interest in the present study were software development teams in Irish and UK software SMEs. The Irish and UK software industries share several commonalities, both countries are dominated by international companies with indigenous companies emphasising vertical or niche market. The Irish software industry has a greater proportional share of the Gross Domestic Product (GDP) than does the UK software industry. Both industries are now outlined in turn.

7.2.1 Irish Software Industry

Ireland is the largest exporter of software in the world with 40% of all PC packaged software sold in Europe, including 60% of business software is produced in Ireland. The Irish software sector is responsible for 11% of GDP and 10% of Irish Exports. According to the National Software Directorate (NSD), at the end of 2003, it was estimated that the Irish software industry consisted of more than 900 companies, 140 of them foreign, employing 24,000 people and exporting over €14bn worth of products and services. Irish companies account for almost €1.1bn of that (NSD, 2004). Employment in the industry which had grown at an annual rate of up to 20% in recent years, has contracted in 2003 for the second year in a row, growth was down by 14%. In Ireland the market is typically niche (or vertical) with emphasis on quality. Changes are likely to occur in the localisation of software. The Irish software industry has applied imported technologies rather than creating its own Irish owned companies and MNC's have developed side-by-side but with little interaction. The Irish Software Industry has a dual structure. The large dichotomy between MNCs and Indigenous companies, is manifested in revenue per employee.

7.2.2 UK Software Industry

At £32.9 billion (€47.7 billion) in 2003, the U.K. software and computer services sector is the largest in Western Europe. In the UK, there are 100,000 companies in software and computer services, employing 325,000 people directly and 600,000 in related industries. In 2002 it represented 8% of global consumption, 3% of U.K. GDP (DTI, 2004).

Similar to the Irish context, in the U.K., supply is dominated by multinational companies with the top 20 providers having 54% of the market, with only four U.K.

companies among them. Of the largest U.K. software companies, half are vertical applications providers, with a primary focus on financial services.

The U.K. like Ireland, suffers from two fundamental barriers to improving productivity performance in the software sector: too few large indigenous companies and the relatively poor productivity performance of all size bands, driven by a preponderance of companies focused on domestic vertical niches.

7.3 Developing the Survey

In order to develop the questionnaire, relevant measures for all the variables in the study were sourced and assessed for existing reliability and validity. Each measure is described in the following sections along with reasons for choosing them.

7.3.1 Tacit Knowledge Measure

There was no appropriate measure for tacit knowledge at the team level. It was necessary to develop this measure. The details for the development of this measure called the Team Tacit Knowledge Measure (TTKM) outlined in Chapter 8. Briefly however, the TTKM is a 14 item bipolar, Situational Judgement Test (SJT) where participants indicate the degree to which they feel each of the 14 factors affect team performance on successful software development projects. The 14 factors were randomised to eliminate order effects and to form a scale, where the participants were asked 'What factors influence team performance on successful software development project?' The 14 items are answered on a 5 point semantic differential type scale. An example of one of the bipolar constructs is 'Innovative project <----> Mundane/Everyday type project.' Respondents rated the constructs by selecting closest to the statement pole they felt described the factors that influence team performance on successful projects. The tacit knowledge measure was scored by comparing the individual score on each of the 14 items with an expert profile.

7.3.2 Quality of Social Interaction

Social interaction has been measured quantitatively using self report questionnaires for quality (Chiu, et al. 1995) and quantity (Levesque et al. 2001). In the present study the Quality of Social Interaction (QSI) was assessed by a self-report questionnaire regarding two perceived outcomes of social interactions across team members, resulting in an index of social interaction. This measure was adapted from Chiu et al. (1995) in which participants were asked to recall the most recent instance where they spent more than 15 minutes alone interacting face-to-face with 4 different people (social situations). The two perceived outcomes referred to whether the interactions fostered (a) attainment of personal goals and (b) promoted positive feelings among participants. For each of the social situations participants were asked (a) to indicate on a 3 point, scale whether they had attained their goal in the interaction (where 1 = 'no', 2 = 'to some extent' and 3 = 'yes'), and (b) to indicate the degree of change in their relationship with the other person after the interaction, also on a 3 point scale where 1 = 'got worse', 2 = 'remained the same' and 3 = 'got better'. For each of the four situations, the responses were multiplied to form an interaction quality index for that interaction, for that situation. The four interaction quality indices were averaged to form an overall index of perceived interaction quality. Chiu et al. (1995) found that of a possible range of 1 to 9, the overall index of perceived interaction quality ranged from 2.33 to 9 (N= 95, mean = 5.80, SD 1.09) for college students. In addition, convergent and discriminant validity were also established.

This measure was adapted for software development teams, where the four social situations were changed to 'team members', and so the number of social situations will vary from person to person and from team to team, depending on the number of members each respondent perceives to be in their team. In the present study there were 4 categories of response for both questions where an extra category (1 = 'not applicable') was added. This category was included to allow for the presence of a team member with whom the respondent does not have informal interaction. The value for 'not applicable' was not '0' since this number has to be multiplied to form the interaction index, a '0' would have indicated a non-response. Therefore the possible range was from 1 – 16. For each interaction the responses to these two questions were multiplied to form an interaction quality index for that social interaction. All of the interaction quality indexes were averaged to form an overall index of perceived interaction quality for each team. This measure was deemed adequate as it allowed for the interaction quality for each team to be assessed and lent itself to an online interactive survey method.

In order to compare to the original study of Chiu et al. (1995), which had a maximum score of 9 the Chiu et al. mean score is transformed by dividing by 9 and multiplying by 16, the new mean is 10.31 and the new SD is 1.94.

7.3.3 Quantity of Social Interaction

Quantity of social interaction was measured using the method by Levesque, et al. (2001) in 62 student software development project teams. Each person rated how much they had worked with each other member of their team, using a 6 point scale that ranged from 0 = 'not at all' to 5 = 'a lot'. The total interaction score was calculated by dividing the actual amount of interaction by the total possible interactions with other members of the team. A team interaction score was calculated for each team by taking the mean of its members' interaction scores. For Levesque et al. (2001) the team interaction score ranged from 0.28 to 0.81, with a mean interaction score of 0.54, on a scale of 0 to 1.00. This method was used because it was valid for software development teams and was appropriate for use in an online survey. These measures are more specific than general questionnaire measures because each individual is asked to rate each other team member, rather than just a general perception of team interaction.

7.3.4 Explicit Knowledge and Intuition

Two self report items were developed to measure perceived explicit knowledge which was operationalised as official job knowledge. Explicit knowledge was assessed by asking respondents their perceived levels of familiarity with official written procedures rated on a 5-point scale from 1 = 'not at all familiar' to 5 = 'very familiar' and their degree of reliance on official written procedures involved in carrying out their work also rated on a 5-point scale from 1 = 'I mostly rely on written procedures' to 5 = 'I never rely of written procedures' (reverse scored). These two items were then multiplied to form an index of explicit job knowledge with a possible range from 1- 25. Individual scores were averaged to team level. In addition team, members' intuition was assessed. Respondents were asked the extent to which they rely on their 'gut instinct' in doing their job. The term gut instinct was used rather than intuition as project managers expressed a preference for this terminology. However, the term 'gut instinct' is only nominal, and actually refers to intuition which was defined as implicit subjective procedures and standards that are difficult to articulate but can be seen in practice. The respondents rated gut instinct on a 5-point scale from 1 = 'I mostly rely on my gut instinct' to 'I never rely on my gut instinct'. Scores on this measure were averaged over each team.

7.3.5 Transactive Memory

As discussed in Chapter 2, transactive memory has been measured in the laboratory, however, Lewis (2003) developed a 15 item field measure of transactive memory where the TMS is a second order factor (transactive memory systems), indicated by three first-order factors (specialisation, credibility, coordination), each of which was indicated by five items. Reliabilities for the TMS and the three first-order factors were investigated in three separate studies. Study 1 comprised 124 teams of students, study 2 consisted of 64 MBA consulting teams and finally study 3 consisted of 27 high technology teams. Individual scores were aggregated to team level for all three factors and intra-group agreement (r_{wg}) was established. The TMS is a team level measure where individual responses are aggregated to team level.

Table 7.1 Reliabilities, Means and Standard Deviations for Transactive Memory

	Study 1 (N = 124)			Study 2 (N = 64)			Study 3 (N = 27)		
	α	$\bar{x}$	SD	α	$\bar{x}$	SD	α	$\bar{x}$	SD
Specialisation	0.84	15.24	2.53	0.86	18.06	2.47	0.76	20.30	2.37
Credibility	0.81	19.85	1.44	0.88	19.59	2.01	0.79	20.49	1.60
Coordination	0.83	19.07	2.36	0.91	17.94	2.86	0.82	18.58	2.14
Total Score	0.86	54.16	4.91	0.92	55.59	6.16	0.82	23.12*	1.98

*The TMS total in study 3 was weighted sum of subscale items

Lewis (2003) used weighted composite for study 3, because the sample size was too small to use structured equation modelling. This scale was used to measure transactive memory because it is a team level measure and the only field measure of this construct, and is deemed valid and reliable. Respondents were asked to 'think of the last project or milestone that this team completed' and then respond to each item on a scale of 1 to 5 where 1 = 'strongly disagree' and 5 = 'strongly agree'. Items (a) to (e), items (f) to (j) and items (k) to (o) represent the measures of specialisation, credibility and coordination respectively. In the original TMS two items measuring credibility (items (i) and (j)) and two items measuring coordination (items (m) and (o)) were reverse coded. Lewis (2003) concluded that the reverse coding introduced a significant amount of error in the TMS measurement model and recommended that further research should modify these items to be consistent with the rest of the scale items. In a personal communication with Lewis in January 20, 2003, we debated and agreed upon rewordings of the four items in Table 7.2.

Table 7.2 Reworded items for TMS measure

Item	Original	Reworded
(i)	When other members gave information, I wanted to double-check it for myself.	When other members gave information, I rarely wanted to double-check it for myself
(j)	I did not have much faith in other members' "expertise."	I had a lot of faith in other members' "expertise."
(m)	Our team needed to backtrack and start over a lot.	Our team did not need to backtrack and start over a lot.
(o)	There was much confusion about how we would accomplish the task.	There was **not** a lot of confusion about how we would accomplish the task.

In the present study, individual scores for each of the three factors underlying TMS and the total TMS scores were obtained by weighting the scores for each factor, to yield the total TMS score (see Chapter 9).

7.3.6 Presence of Expertise

According to Faraj and Sproull (2000), there are three dimensions of expertise associated with software development, these are:

1. Technical expertise (knowledge about a specialist technical area)
2. Design Expertise (knowledge about software design principles and architecture)
3. Domain expertise (knowledge about the application domain area and client operations)

Faraj and Sproull (2000) developed a measure of the presence of expertise by asking members of software development teams to evaluate each of the three dimensions in terms of the percentage of necessary expertise that is located inside the team (0% to 100%). The construct the presence of expertise is the mean percentage response to the three dimensions. This measure was averaged to team level where Faraj and Sproull (2000) found a reliability at the team level of $\alpha = 0.88$ ($N = 69$; mean = 78.3%, $SD = 12.7$). This measure was therefore deemed reliable and valid for software development teams.

7.3.7 Professional Experience

Number of years experience in the software development field is usually a proxy for domain knowledge and technical capability in software development (Boehm, 1987, Brooks, 1987) and therefore expert knowledge. This measure was also used by Faraj and Sproull in their study of 69 software development teams (mean 11.9, SD = 3.6).

7.3.8 Administrative Coordination

Formal communication system was operationalised by administrative coordination which 'refers to formal mechanisms to manage schedules, documents, and communication in which the team engages to accomplish its task' (Faraj & Sproull, 2000, p.1559). In order to measure this construct, the present research study used the six-item measure for formal and interpersonal administrative coordination measures developed by Kraut and Streeter (1995), who used it on software development teams. This measure refers to the extent of use on the project of: (a) formal policies and procedures for coordinating team's work, (b) project milestones and delivery schedules, (c) project documents and memos, (d) regularly scheduled team meetings, (e) requirements/design review meetings, (f) design inspections. Participants were asked to rate the extent on a 5-point Likert scale where 1= 'to a small extent' and 5 = 'to a great extent'). The responses were averaged over individuals and then averaged over the team where Faraj and Sproull (2000) found a reliability of Cronbach's $\alpha = 0.82$ (N= 69, mean = 3.49, SD = 0.56) in software teams.

7.3.9 Formal Knowledge Sharing System

A second measure of formal communication refers to the presence of a formal knowledge sharing system, which was assessed using three items taken from a six item measure of attitudes to knowledge sharing, by Hunter and Beaumont (2002). Individuals were asked to respond on a 5-point Likert scale their agreement with each item, where 1 = 'strongly disagree ' to 5 = 'strongly agree'. The three items ask individuals if their company has a well–organised system for sharing knowledge within and across departments as well as being part of the organisation's culture.

7.3.10 Team Performance

Two dimensions of performance for knowledge teams consisting of effectiveness and efficiency were measured using a self report measure (Faraj & Sproull, 2000). Self report measures were chosen because objective measures of performance present difficulties in the IS field (Henderson & Lee, 1992; Kemerer, 1989) since 'using objective measures assumes comparability across software projects or unique situations constraints, and this raises a new set of methodological measurement issues' (Faraj & Sproull, 2000, p.1560).

The effectiveness measure constituted five items and asked how well teams performed, in relation to other software development teams they have known, on dimensions of work quality, team operations, ability to meet project goals, extent of meeting design objectives and reputation of work excellence. The efficiency measure had two items and dealt with adherence to schedule and budget. Responses for both effectiveness and efficiency were rated on a 1 to 5 likert-type scale from 'not very good' to 'excellent'. The five items of effectiveness and the two items for efficiency were averaged over individuals and then teams to develop a measure of team effectiveness and efficiency, respectively. These measures were developed by Faraj and Sproull (2000), who found reliabilities for stakeholder ratings of software development teams for the effectiveness measure of alpha = 0.86 (mean = 4.07; SD = 0.48) and for the efficiency measure of alpha = 0.74 (mean = 3.85; SD = 0.77).

Using self-assessment of performance rather than stakeholder assessment was deemed appropriate in this context, for practical issues related to confidentiality and to maximise response rates. In addition, research by Wall et al. (2004) in three separate industrial samples in the UK found convergent, discriminant and construct validity between subjective and objective measures of company performance. This is consistent with findings by Bommer et al. (1995) who argue that there are no significant relationship differences between subjective and objective measures of performance.

7.3.11 Proximity

The further away people are physically from one another the less they communicate. Proximity in this study is defined as the distance relation between individuals in the team. A measure of proximity was developed where respondents were asked to indicate how close they were in physical distance (metres) to each person in their team by selecting from a 5-point scale where1= 'Between 0 and 5 metres' and 5 = 'Different building'.

This scale was deemed an appropriate measure of physical distance for software teams since, the increments in distance go from 25 metres square, to 100 metres square to 900 metres square to different office same building to different building. A cubicle bay of around 4 people would fit approximately into 25 metres square. The first two measurement categories would be appropriate sizes for small to medium offices and teams and the final two indicate extreme remoteness as there is a physical barrier between the team members as well as distance. This measure is categorical in nature, and the modal proximity of each team was chosen as the team level measure.

7.3.12 Diversity

Diversity within a team should lead to more varied knowledge. Diversity in this study is defined as being qualified in another job domain. Respondents were asked to respond to a forced choice yes/no in answer to the question to ascertain if they were fully trained/qualified in another job domain NOT software development. If respondents answered 'yes' they were filtered to the next question and asked to state which domain. The percentage of domain diversity was then assessed within each team. Those with higher diversity are represented by higher percentage. In addition, a qualitative analysis of the other job domains was undertaken, by placing the job domains into categories.

7.3.13 Team Size

Team size was ascertained by asking team members to list the initials of each person in their team, including their own. Teams were identified by matching the initials. Team size was defined as the average of the perceived team size of each respondent in the team. Since some members may perceive more members in their team than others.

7.3.14 Psychological Safety

Psychological safety was measured using the scale developed by Edmondson (1999) and outlined in Chapter 4. In this measure respondents are asked to indicate the accuracy of the seven statements in relation to the atmosphere or climate in their team e.g. 'If you make a mistake on this team it is often held against you' (reverse scored). This scale consists of seven items scored on a 7 point likert scale where 1 = 'very inaccurate' and 7 = 'very accurate'. These scores were then aggregated to team level. Scores on items 1, 3, and 5 were reverse scored. In a sample of 51 teams Edmondson (1999) demonstrated internal consistency of $\alpha = 0.82$, (mean =5.25 and SD =1.03). This measure has been used on different types of teams and has established reliabilities and validities and was therefore deemed appropriate for use in the present study.

7.3.15 New Product Development Capability

This measure was used to assess the competitiveness of the software product and is based on the measure of trans-national new product development capability developed by Subranmaniam and Venkatraman (2001). This measure asks respondents with respect to key competitors, to rate how their product category currently fares on 6 dimensions. This measure which integrates key indicators for competitiveness from previous related studies. For example, the frequency of new product introductions (Nobeoka & Cusumano, 1997). The original measure by Subranmaniam and Venkatraman (2001), was developed for assessing the global strategy of transnational new product capability and contained 6 items measured on a scale from 1 – 7 where 1 = 'much worse than competition' and 7 = 'much better than competition.' In the present study this measure was modified to remove the emphasis on the transnational aspect and to measure new product capability in relation to key competitors, therefore national and transnational were not specified. Three of the original items in the transnational scale were re-worded to remove the international emphasis: The modifications are as follows:

The word 'global was removed from 'Frequency of new global product introductions' and the word 'overseas' was removed from 'Ability to penetrate new overseas markets'. Finally the item measuring 'Ability to respond to unique requirements of different countries' the word 'countries' was changed to 'customers'. The item 'Ability to introduce new versions simultaneously in several markets' was removed resulting in a 5-item scale. This scale was completed by managers only.

7.3.16 Stage of Development Cycle

Team leaders/managers were asked to indicate phase in the development cycle of the team. There were four phases to choose from: (a) requirements/ planning, (b) beginning phase of development, (c) middle phase of development, and (d) final phase of development.

7.3.17 Demographic Details

A number of demographic details were included in the questionnaire: sex, job title, educational level and age. Respondents indicated their sex and age. There were six age categories from ages 18-24 to 61+. Participants also indicated their highest educational qualification from a choice of six categories. Finally respondents stated their current job title.

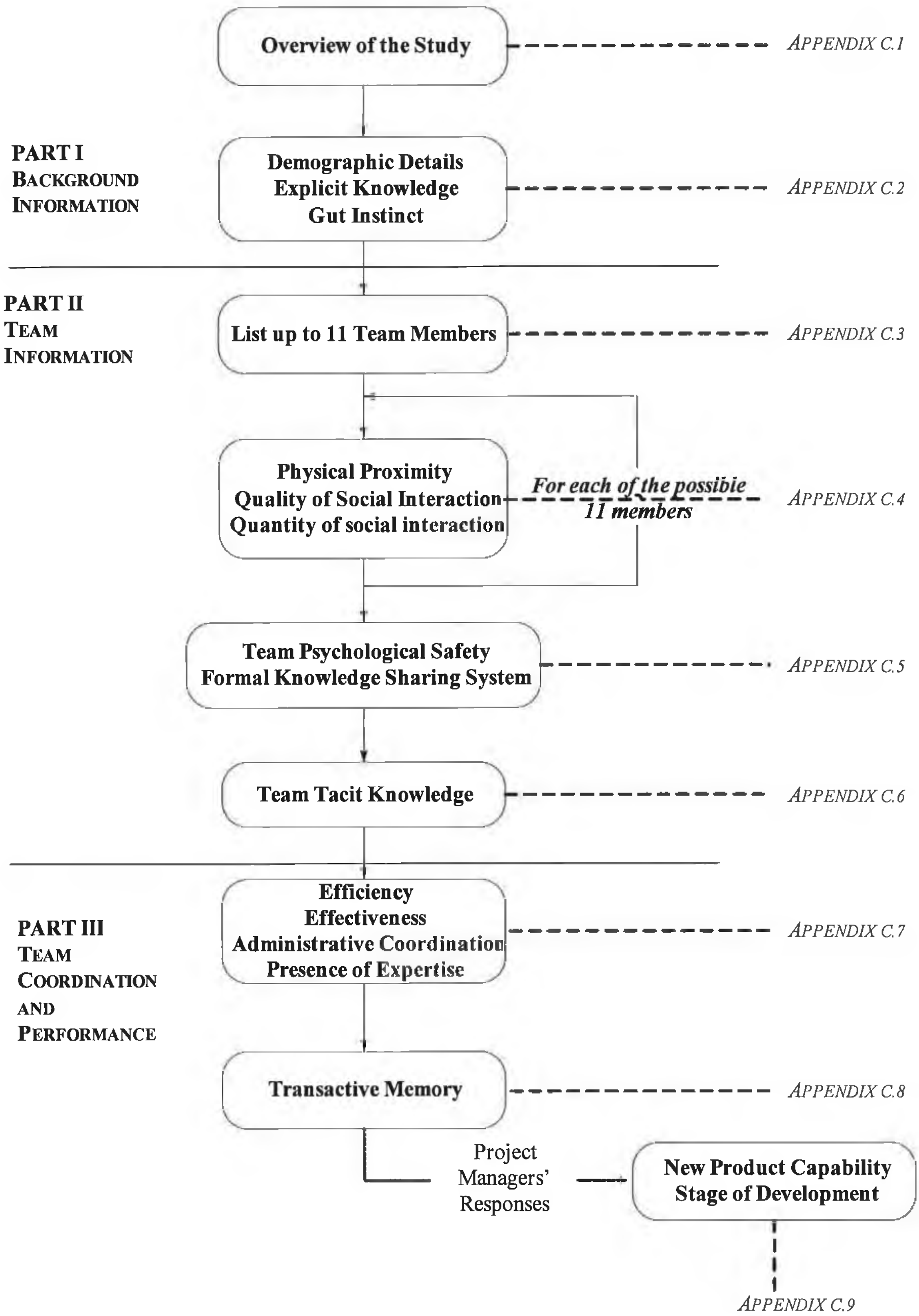
7.3.18 Structure of the Questionnaire

The structure of the questionnaire is depicted in Figure 7.2 along with the associated section of Appendix C where screen shots of the online survey are located. The survey was structured for ease of use and to minimise as far as possible, the effects of common method bias. Respondents were assured anonymity and the independent and dependent measured were counterbalanced, where the team performance measures were presented before transactive memory. In addition, negative wording of items was eliminated where possible and different scales and endpoints were used.

The survey was presented in three parts. The first part gave an overview of the study and assessed demographic details, explicit job knowledge and gut instinct and ensured anonymity. In Part II, the respondents were asked to complete a table of the initials, of the members of their team (up to 11). Before listing all members, they had first to include their own initials. This was to enable team identification later. Quality of social interaction, quantity of social interaction and proximity, were assessed interactively, for each respondent in relation to each other team member that they had listed. Following this interactive stage, individual perceptions of psychological safety, presence of a formal knowledge sharing system and tacit knowledge were measured.

Part III measured individual perceptions of team coordination, using the administrative coordination, presence of expertise and transactive memory measures. Finally, dependent variables of team performance, team effectiveness and team efficiency were assessed. At this stage, team members were invited to give an email address to be sent results of the study. Team leaders and managers were directed to complete a further measure, while other team members submitted their responses. Team leaders or managers completed the NPD questionnaire and indicated the stage of the development of the project. Finally, a page appeared to thank respondents for their participation.

Figure 7.2 Structure of the Questionnaire



7.3.19 Deploying the Survey Online

It was decided to develop an on-line interactive survey using dynamically changing pages. Since these advanced types of feature were needed, Java Server Pages (JSP) were used to create the survey forms. The data received from the online survey were captured and processed using the JSP session bean. The session bean controls:

1. The presentation of 'dynamic' page content (e.g. presentation of previously entered responses on new pages).
2. Collection and storage of data during questionnaire session
3. 'Wrapping' and emailing of survey data

Finally, an internet server for posting materials and processing incoming data running Apache Tomcat Java environment was used to host the survey. Before going 'live' the online grid was tested on different browsers (Netscape and Internet Explorer). In addition, the online survey was pilot tested.

7.4 The Pilot Study

Pre-testing of a questionnaire is necessary to ensure that errors – which may only be apparent to the population concerned are identified (Reynolds et al. 1993). These errors may relate to specific words or meanings contained within the questionnaire. A pilot study of two software development teams (N= 3, N=8) was undertaken to ensure that the data obtained was acceptable. The questionnaires were emailed to the two teams and respondents were asked to comment on the way the items were worded and scales presented. They were also asked to communicate difficulties experienced during completion. Participants reported that the items were clear, relevant and there were no apparent difficulties completing the questionnaire. One respondent felt that one aspect of the measure for quality of social interaction was 'a bit economic', specifically 'did you attain your personal goal in the interaction?' As this was a matter of opinion and as it was inherent to the survey, it was decided to keep the item. As a result of this pilot study, no amendments were made.

7.5 Sampling and Data Collection

Data were collected over a 6 month period from June 2003 until November 2003. The samples were chosen from two databases. The Irish sample was obtained from the National Software Directorate's (NSD, 2003) listing of over 700 Irish based software companies. The UK sample was obtained from the Kellysearch directory (2003) of over

3,000 UK software companies. In order to maximise response rates the following criteria were used to eliminate organisations from the sample frame:

If the target organisation

(a) did not provide an email address,

(b) did not develop software in teams,

(c) conducted software development 'offshore',

(d) were software re-sellers,

(e) were involved in software production maintenance,

(f) were involved in computer training, consulting or web design.

In all, 263, Irish, small to medium enterprises (SMEs) were contacted (29 emails were incorrect or returned by anti-spamming tool) yielding 234 usable contacts. The UK sample frame consisted of 382 SMEs (48 emails were incorrect or returned by anti-spamming tool). To further maximise response rates, where possible, the company CEO or COO names were obtained and all were contacted by email (see Appendix B). The email explained the study and asked the recipient to forward it to the relevant project manager, who was asked to deploy the attached link to all team members. In addition, the email advised of anonymity of responses and offered a summary of the key findings of the study customised to each participating company.

7.5.1 Power Analysis

When conducting survey research a recurring issue refers to the appropriate number of respondents required to draw meaningful conclusions from the data. (Cohen, 1988; Keppel, 1991). The identification of the correct sample size is achieved by applying a technique called statistical power analysis (Cohen, 1988). Statistical power ($1-\beta$) is concerned with determining *a priori* the probability of correctly rejecting the null hypotheses (reducing type II errors). To use power analysis to calculate the sample size requirement the following pieces of information are needed: the significance criterion or alpha level, the effect size (ES) and the appropriate level of power (Miles & Shevlin, 2001). The alpha is the level of significance used as the criterion to determine whether there is a significant effect and by convention is set a 0.05. The ES represents the degree to which the phenomenon is present in the population (i.e. that the null hypothesis is false). Power is the probability of finding a result given that the effect does exist in the population, and by convention is set a 0.80 (Cohen, 1988). This gives an 80% chance of finding a significant result if there is an effect of the specified size in the population from which the sample was taken. In multiple regression the ES is equal to $R^2$and the larger the ES the greater chance we have of finding it.

In the present study, the commonly specified power level of 0.8 and alpha value of 0.05 was used to derive a required sample size. The theoretical model was assumed to generate an ES or R^2 level of 0.26, which is reasonable for organisational and sociological studies (Cohen, 1988, p.414) and in line with similar team-level studies (Faraj & Sproull, 2001; Kraut & Streeter, 1995, Guinan et al. 1998). Thus, the required sample size was derived to be 46 for the main model which contains 6 independent variables (Chapter 5, Figure 5.2).

7.5.2 Sample Selection and Demographic Characteristics

Overall 181 people, constituting 48 teams in 46 organisations in Ireland and the UK completed the survey consisting of 75% (N=121) males and 25% (N=60) females. Most (47%) were in the 31-40 age bracket with an average of 11.64 years of experience (SD 4.97). The modal highest educational qualification was the 'college degree', constituting 50% of the sample. The percentage breakdown for age and qualification can be seen in Table 7.3.

Table 7.3 Percentage of Total Sample in Each Category for Age and Education Level

Age		Highest Qualification	
Category	Percentage of sample	Category	Percentage of sample
18-24	0%	School leaving certificate (or equivalent)	3%
25-30	34%	College diploma	5%
31-40	47%	College Degree	50%
41-50	11%	Higher Diploma	11%
51-60	6%	Master's degree/PhD	28%
61+	2%	Other	3%

The majority of respondents (81%) were between 25 and 40 years of age and are highly educated with 89% having a college degree or higher.

Respondents were also asked if they were qualified in a job domain that was not software development. Thirty four percent of the sample indicated that they were fully qualified in another area, while 66% were not. The overall sample was therefore not very diverse in domain background. The job titles forwarded by respondents were classified into five categories. The percentage of participants in each job title category is illustrated in Table 7.4.

Table 7.4 Percentage of Total Sample in each Category for Job Title

Job Title Category	Percentage of Sample
Business Management	6%
Team/Tech/Project Management	34%
Analyst/Tech Consultant/Software Architect	17%
Developer/Programmer/Software Engineer	41%
Miscellaneous	2%

Finally, in relation to the stage the project was in the development cycle, no project was in the requirements stage, the majority of projects (50%) were in the middle phase of development, 39.6% were in the final phase of development and 10.4% were in the beginning phase.

7.5.2.1 Organisation Level Response Rates

The organisational level response rates across the two samples are summarised in Table 7.5. It was deemed that non-response bias was not a pervasive threat to the validity of the study, since, some non-participating organisations returned emails giving reasons for not taking part. These reasons included: lack of time, software development was not team based or they were not software developers. Given the challenges associated with getting teams to respond, the overall response rate of 9.15% compares favourably to email studies and to studies involving software developers (Reed & Kelly, 2002).

Table 7.5 Organisation level Response rates for Ireland and the UK

	UK Sample	Irish Sample	Total Sample
Valid initial sample	334	234	568
Respondents	27	25	52
Response rate	8.08%	10.68%	9.15%

Six teams from six organisations were not used because only one person responded. In all 48 teams were used in the final analysis. This exceeds the sample size set by the power analysis and so no further data collection was deemed necessary.

7.5.2.2 Team Size and Within-Team Response Rate

Team size varied from 2 to 12+, with the mean team size being 4.91 and an average within team response rate of 81.86%, which was deemed acceptable. However, it is pertinent to note here, how these figures were calculated, since alternative sizes and response rates may also have been used.

7.5.2.3 Alternative Calculations for Team Size and Within-Team Response Rate

Firstly, team size was calculated using the perceived team size based on the social interaction responses. Respondents listed the initials of members they perceived to be in their team, therefore some team members perceived themselves to be part of smaller or larger teams than other team members. The mean team size was 4.91 calculated according using Equations 1 and 2 (EQ1, EQ2) in Appendix D.

However, team size may also be calculated based on overall sample response according to Equation 3 (EQ3) in Appendix D. The mean team size using this equation was 5.71, however, this method was not in keeping with the calculations for social interaction and so the previous mean team size is reported.

The within team response rate was therefore calculated in two different ways firstly based on Equations 4 and 5 (EQ4, EQ5) in Appendix D. The total number of responses per team, divided by that team's mean size (calculated according to EQ2). This leads to a generous estimation of overall response rate, since some teams on average, underestimated their overall team size (and hence had response rates greater than 100%). The within team response rate may also be calculated based on overall response rate based on Equation 6 (EQ6). Using this equation a more conservative estimate of within team response rate of 66.06% can be reported.

7.6. Establishing Validity of the Measures in the Present Study

From a statistical perspective, in order to determine the validity of a scale i.e. the extent to which scales measure what they intend to measure, scale items (a) must be highly interrelated or internally consistent and (b) they must reflect a single underlying construct. These two conditions correspond to the reliability and validity of a scale. While the reliability of a measure contributes to its validity, it is not a sufficient condition for validity. This section seeks to describe the steps taken to establish the validity and reliability of the scales employed.

Validity can be defined as the agreement between a test score or measure and the quality it is believed to measure, i.e. does the test actually measure what it purports to measure (Anastasi & Urbina, 1997). There are two main approaches to validity, the traditional approach and Messick's (1995) unified approach. Both of these approaches are discussed in the next two sections.

7.6.1 Traditional Approach to Validity

The *construct validity* of a test is the extent to which the test may be said to measure a theoretical construct or trait. Campbell (1960) argued that in order to test construct validity, we must show that a test correlates highly with other variables with which it should theoretically correlate but also that it does not correlate significantly with variables from which it should differ. The former is known as *convergent* validation and the latter as *discriminant* validation (Campbell & Fiske, 1959).

Criterion Related validity indicates the effectiveness of a test in predicting an individual's performance in specified activity and incorporates predictive and concurrent validity (Anastasi & Urbina, 1997).

Factor analysis is particularly relevant to construct validation procedures. Tests can be characterised in terms of the major factors determining its scores, together with the weight loading of each factor and the correlation of the test with each factor. Such a correlation is sometimes reported as the factorial validity of a test. The factor analytic technique used in the present study was the maximum likelihood using VARIMAX rotation, which is a widely accepted technique for rotating data (Babbie & Halley, 1994). The cut-off point for factor loadings was 0.40 with an eigen value above 1. Factor analysis was used in the present study to confirm the primary structures of the scales employed, that had been previously validated by original authors. In addition the two scales: New product development capability, and Formal Knowledge sharing system were validated using factor analysis to confirm that each tapped into only one construct. Construct validity and predictive validity were employed in the present study as part of the validation process for the TTKM, incorporated under Messick's unified validity framework.

7.6.2 Messick's Unified Validity Framework

Messick (1995) argued that 'validity is an overall evaluative judgment of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of interpretations and actions based on test scores or other modes of assessment' (p.741). Messick's framework was used to validate the TTKM. This was based on the precedent set by Sternberg et al. (2000) who validated their tacit knowledge measures using this method. Sternberg et al. (2000) argue that tacit knowledge tests are not developed like other knowledge tests that use the factor analytic technique instead, both theoretical and empirical justifications outlined in Messick's (1995) framework are used to establish the validity of tacit knowledge tests (Sternberg et al. 2000). There are six aspects to Messick's (1995) framework, outlined as follows:

- *Content*: show evidence of content relevance and representativeness.
- *Substantive:* outline theoretical rationale.
- *Structural:* explain the fidelity of the scoring structure.
- *Generalisability*: explain scope of generalisations to populations.
- *External:* describe convergent and discriminant validity.
- *Consequential:* outline consequences of the assessment to the society.

7.7 Establishing Reliability for the Measures in the Present Study

Measurement error is common in all areas of science and tests that are relatively free of measurement error are considered to be reliable (Anastasi & Urbina, 1997). Cronbach's alpha coefficient is regarded as a reasonable indicator of the internal consistency of an instrument and is an appropriate reliability estimate for questionnaires using rating or Likert scales (Oppenheim, 1992). This coefficient takes into account both the number of times and the average correlation among items on a scale (Nunnally & Bernstein, 1994). A number of guidelines regarding the acceptable alpha level has been proposed within the literature. Though each method normally is expressed in terms of an index called the reliability coefficient. This index ranges from 0 to 1 with 0 meaning zero reliability and 1 meaning 100% reliability. Typically reliabilities above 0.6 are adequate where scores are used in development or to identify issues which need to be further assessed. Where scores are used in making high stakes decisions and for detailed individual assessment then values above 0.7 are sufficient and those above 0.8 would be considered good (British Psychological Society, 2003).

7.7.1 Reliability of Tacit Knowledge Measures

Tacit knowledge inventories and other situational judgement tests differ from conventional knowledge tests in that items may be poorly defined and are multidimensional in nature drawing on skills, knowledge and abilities (Hedlund et al., 2003). Across an inventory there are diverse areas of knowledge some acquired by the individual some not, therefore the complexities of the tacit knowledge measures reduces the likelihood of obtaining the same levels of internal consistency as for other traditional knowledge and ability tests. According to Legree (1995) expect to obtain alpha coefficients between 0 .5 and 0 .8.

7.8 Data Analysis

Data can be analysed in a number of ways depending on the goals of the research. The hypotheses presented in this study are relational in nature and consequently the overall design of the research is correlational. Statistical procedures that examine differences between means provide indirect indication of whether a relationship exists between variables. However, they do not indicate the magnitude or strength of a relationship, which is only possible through tests of correlation. The present study first explored differences between the two countries on all the variables. In addition, the hypothesised relationships between these variable were examined using correlational analyses. In particular regression analyses were conducted on the main variables in the model as well as regression analyse on the minor variables.

7.8.1 Analysing Means

The means for each of the key variables in the study were analysed according to UK or Ireland. A two-tailed independent t-test was used to ascertain if there were any mean differences between the two sets of samples. This procedure determines whether a set of scores comes from the same population.

7.8.2 Analysing Relationships

All of the hypotheses sought to investigate relationships. The relationships between all predicted relationships between minor variables, main variables and minor and main variables were conducted using a 'Pearson Product Moment Correlation Coefficient' (normally referred to in shorthand by the symbol 'r'). It is calculated as a number ranging between -1.00 and +1.00. A perfect negative correlation ($r = -1.00$) indicates that the two sets of numbers form a perfect inverse relationship and a correlation of 0.00 means there is no relationship between the variables.

7.8.3 Standard Multiple Regression, Hierarchical Regression and Dummy Coding

In addition to assessing relationships between variables, there were three sets of minor models predicting each main variable (except team tacit knowledge) and one main model predicting the relationship between the main variables in the model. Standard multiple regression was used to test the minor models and a variation of multiple regression called hierarchical multiple regression was used to test the main model. Multiple regression is used to account for (predict) the variance in an interval dependent, based on linear combinations of interval, dichotomous, or dummy independent variables (Miles & Shevlin, 2001). Multiple regression can establish that a set of independent variables explains a proportion of the variance in a dependent variable at a significant level (significance test of R^2), and can establish the relative predictive importance of the independent variables (comparing beta weights).

The predictors of quality and quantity of social interaction, transactive memory, team tacit knowledge and team performance, respectively, were examined using standard multiple regression. Standard multiple regression is where all predictors are entered into the model at one time (Miles & Shevlin, 2001).

For the analysis of the first two sets of minor models where quality of social interaction and quantity of social interaction respectively, were regressed on team size, proximity, diversity and psychological safety, the categorical variable of proximity was dummy coded in order to be able to use it in the regression analysis. Dummy coding is used to enter categorical variables with more than two levels. In dummy coding one group is considered the reference group and new dummy variables are created to identify which condition the other subjects are in. Proximity had five levels which were dummy coded into four binary variables.

For the analysis of the main model, hierarchical regressions were conducted on the variable (s) of interest (social interaction and team tacit knowledge, respectively) such that each will be predictive above and beyond a standard set of predictors.

7.8.4 Tests of Mediation

Mediated hierarchical regression was used to test two hypotheses. The mediation hypothesis reflects causal hypotheses about variables. In this approach, the relationship between an independent variable and a dependent variable is decomposed into direct and indirect (mediated). Two mediated analyses were undertaken. The first has psychological safety as a mediator between quality and quantity of social interaction and transactive memory, the second, has transactive memory as a mediator between social interaction and team tacit knowledge.

Baron and Kenny (1986) described four steps that had to be satisfied in order for a variable to be a true mediator: (1) the independent variable significantly predicts the dependent variable, (2) the independent variable predicts the proposed mediator, and (3) the mediator is a significant predictor of the dependent variable, when we control for the independent variable (4) If the mediator is a complete mediator of the relationship between the independent variable and the dependent variable, the effect of the independent variable when controlling for the mediator, should be zero (Baron & Kenny, 1986), or at least not significant (Miles & Shevlin, 2001). If the first three criteria fulfilled, but the final condition is violated, then the mediation is considered partial.

7.9 Aggregation Analysis

Before aggregating individual responses to the team level, it is necessary to statistically test the conformity of the level of measurement to the level of the theoretical analysis (Rousseau, 1985; Klein et al. 1994). The Inter-rater Agreement (IRA) r_{wg} was used to assess within –team agreement for each team separately (James et al. 1984). The IRA assesses reliability across respondents within a team by comparing convergence of responses from multiple respondents evaluating a single target. The range of inter-rater agreement is between 0 and 1, where 0 = no agreement and a score 1 = complete agreement. A strength of this method is that it compares the responses within a team without including any information from the other teams. This formula had been used by most team based studies cited in this thesis (e.g. Edmondson, 1999, Faraj & Sproull, 2000, Lewis, 2003).

However, Lindell et al. (1999) in a review of inter-rater agreement formula argued that the James et al. (1984) formula breaks down for mean observed variances greater than the variance of uniform distribution (yielding either negative values, or values greater than 1) and is non-linear with respect to the number of response categories especially if they exceed five. Lindell et al. (1999) suggest a test of agreement, but not reliability. Their measure is not only linear with respect to the number of measure response categories, but also holds for observed mean variances greater than the variance of the normal distribution. Furthermore, their measure incorporates weighting based on sample size, allowing for inter-group comparison of inter-rater agreement. The range of responses for the Lindell et al. (1999) formula is from -1 (total disagreement) to +1 (total agreement) for five response categories and between -3.5 to +1 where positive values indicate agreement and vice versa. The data remain linear with respect to the number of items in the measure. Comparisons between scales with 7 response categories and 5 response categories can only be made if both are > 0. The equations for both inter-rater agreements and the reasons Lindell et al. (1999) forward for the development of their formula are discussed in Appendix E. Both measures for inter-rater agreement were calculated and reported in Chapter 9.

7.10 Summary

In this chapter, the measures chosen for the model variables were described and evaluated, with reasons given for each choice. The manner in which the survey was administered was described along with the pilot study. The research context was then described in detail, along with demographic details of the sample. Issues related to response rates and the results of a power analysis was reported along with overall sample response rate and within team agreement. Following this, issues surrounding reliability and validity, statistical analyses used and methods for aggregation analysis were described. In Chapter 9 these methods are applied to the data and results obtained.

Chapter 8
Development of the Team Tacit Knowledge Measure

8.1 Introduction

Various approaches to measuring expert knowledge and tacit knowledge have been forwarded within different disciplines, some qualitative, some quantitative, mostly individual and all related to expertise. The main obstacle to overcome when measuring tacit knowledge is that it is tied to context, and cannot be articulated. Different approaches, in different disciplines account for this to varying degrees.

There was no existing direct measure of tacit knowledge at the team level for any domain including software development. It was therefore necessary to develop a questionnaire measure at the team level, in order to answer the research questions posed in the present study. This measure needed to be relevant to all members of the team and pertinent to the context of a software development. In this chapter previous approaches to measuring tacit knowledge in the disciplines of psychology, AI and IS are described. In addition, the rationale and procedure for the development and validation of the Team Tacit Knowledge Measure (TTKM) for software developers are outlined. In the present study a knowledge-based approach was taken, whereby 'experts' differ from novices in task performance relative to their domain of expertise.

8.2 Approaches to Measuring Tacit Knowledge

Tacit knowledge has been measured directly at the implicit level or articulated level of abstraction (Busch, et al. 2003; Sternberg, et al. 2000; Reber 1995; Reed et al. 1983), by proxy at the tacit team level (Berman et al. 2002; Edmondson et al. 2003) and using surrogate indicators at the department level (Roy & Nagpaul, 2000). In general expert knowledge forms the basis for tacit knowledge measures, since it is thought that tacit knowledge distinguishes novices from experts (Sternberg et al. 2000). In the software development arena Busch et al. (2003) operationalised tacit knowledge as 'implicit managerial knowledge about software development projects' and used proficiency as the level for obtaining expert knowledge.

The approach taken in AI and psychology to measuring tacit knowledge is methodologically individualistic, based on the information processing approach. In psychology, Artificial Grammar (AG) experiments (Reber, 1995; Cleeremans, 1997) and mental scanning (Reed et al. 1983), have occurred in the laboratory and have been developed largely to demonstrate the existence of implicit learning and tacit knowledge. The AI approaches are concerned with eliciting expert knowledge. However, these approaches have largely not accounted for the context specific nature of tacit knowledge and require the expert to articulate tacit knowledge through a knowledge engineer. Firstly, the measures used by AI researchers to elicit expert knowledge are outlined followed by the main psychological (Yale group) approach to measuring tacit knowledge. Indirect group level measures of tacit knowledge are then described.

8.2.1 AI Techniques for Eliciting Expert Knowledge

There are various techniques used in AI for knowledge acquisition. This is particularly important for knowledge engineers, as special techniques have to be used with an expert to try to elicit tacit knowledge, which is the hardest and often the most valuable knowledge to acquire (Shadbolt & Burton, 1995).

Shadbolt and Burton (1995) divide the techniques used with experts into two classes: natural techniques and contrived techniques. Natural techniques are those that the expert is familiar with as part of their area of expertise, and include interviews and on-the-job observation techniques. Contrived techniques have been developed in order to capture various types of knowledge that are either inefficient or impossible to acquire by using natural techniques. These contrived techniques generally involve special ways of representing knowledge and/or special tasks that the expert is set (Hoffman, et al. 1995).

Milton (2002) outlined the main techniques used in knowledge engineering for eliciting knowledge, moving from natural techniques (protocol-generation techniques) to contrived techniques (protocol-analysis, laddering, sorting, matrix based, repertory grid, constrained process and network based techniques). These are as follows:

- *Protocol-Generation Techniques* include interviewing reporting and observational techniques
- *Protocol Analysis Techniques* produce a protocol, i.e. record of behaviour, whether in audio, video or electronic media..

- *Laddering Techniques* involve the creation, reviewing and modification of ladders (i.e. hierarchies). Here the expert and knowledge engineer both refer to a ladder presented on paper or a computer screen, and add, delete, rename or re-classify nodes as appropriate.
- *Sorting Techniques* capture the way experts compare and order concepts, and can lead to the revelation of knowledge about classes, properties and priorities (Rugg & McGeorge, 1997).
- *Repertory grid and matrix techniques* involve the construction and filling-in of grids indicating such things as problems encountered against possible solutions. The repertory grid is a cognitive mapping technique used in many fields for eliciting and analysing knowledge and for requirements engineering (Gaines & Shaw, 1995), self-help and counselling purposes (Fransella & Bannister, 1977). The technique is essentially matrix-based although it is more complex than simply filling-in a matrix of elements.
- *Limited-Information and Constrained-Processing Task* techniques which either limit the time and/or information available to the expert when performing tasks that would normally require a lot of time and information to perform.
- *Network-Based Techniques* include the generation and use of network diagrams, such as concept maps, state transition networks and process maps (Berg-Cross & Price, 1989).

8.2.2 Direct Measures of Tacit Knowledge: The Yale Group Approach

The tacit knowledge approach is based on the critical incident technique where incidents from domain experts are identified, followed by judgements of those incidents. According to Flanagan (1954) a critical incident describes the behaviour, the setting in which the behaviour occurred and the consequences of the behaviour. Then domain experts provide examples of effective and ineffective behaviours (McClelland, 1976). The critical incidents are analysed qualitatively to determine the nature of the competencies that appear important for success in that domain. This technique has been used in a number of performance assessment tools (Smith & Kendall, 1963; Motowildo et al. 1990).

Situational Judgement Tests (SJTs) are low fidelity simulations (i.e. stimuli do not closely represent the actual situation) which present situations that are selected on the bases of critical incident analysis. Following each description is a set of strategies for solving the problem by rating the best (or worst) strategy and is scored by awarding points based on the correct choice of best or worst alternatives (Motowildo et al. 1990) or by percentage of experts who endorse the item (Chan & Schmitt, 1998). 'The set of ratings the individual generates for all the situations is used to assess the individual's tacit knowledge for that domain' (Sternberg et al. 2000, p.123).

Tacit knowledge tests are based on SJT's and are scored in the following three ways:

1. Correlating participant's responses with an index of group membership (expert, intermediate, novice).
2. By judging the degree to which participants' responses conform to professional rules of thumb.
3. Computing differences between participants' responses and an expert prototype.

The process of developing a tacit knowledge inventory in this way begins by eliciting experienced-based tacit knowledge from successful practitioners in a particular domain and finishing with a validated and revised instrument. The most promising items are selected, that will yield a measure of underlying domain relevant tacit knowledge in any domain (Sternberg et al. 2000).

Critics argue that Sternberg and the Yale group's tests of tacit knowledge do not demonstrate the strong empirical support they claim (Gottfredson, 2001). At least one research group sympathetic to the theory has concluded that the test is reliable but not a valid measure of success (Taub et al. 2001).

8.2.3 AI and KM Direct Approaches to Measuring Tacit Knowledge

Busch and Richards (2004) forwarded two methods for AI (KBS) and KM approaches to capturing tacit and explicit knowledge. In KBS these authors advocate a Ripple Down Rules (RDR) approach (Compton & Jansen, 1990) to capture both tacit and explicit knowledge in a dynamic knowledge base which is further analysed qualitatively using Formal Concept Analysis (FCA) to visually represent the results. The KM approach also uses mixed methods but employs the Yale group technique to measure tacit knowledge followed by the application of FCA to provide qualitative interpretation.

The KM approach was not concerned with knowledge capture but deals with tacit knowledge alone, whereas the KBS approach is concerned with the capture of both the tacit and explicit components of knowledge (Busch & Richards, 2004).

8.2.4 Indirect Proxy Measures of Tacit Knowledge at the Team and Department Level

Two proxy team measures and one department-level measure are discussed. The studies involving the proxy measure forwarded by Berman, et al. (2002) of tacit knowledge in basketball teams and the proxy measure proposed by Edmondson et al. (2003) for surgical teams, were described in detail in Chapter 3 (section 3.7). Proxy measures attempt to address the problem that tacit knowledge is unobservable and hold that tacit knowledge cannot be articulated, therefore, tacit knowledge needs to be measured by substitution. A further study of tacit knowledge, using a surrogate measure by Roy and Nagpaul (2000) is now outlined.

Roy and Nagpaul (2000) investigated tacit knowledge in 31 government laboratories in India. The rationale was that the scientific and technical personnel in the laboratories, are considered assets because they possess tacit knowledge resulting from working across different functional areas. Using correspondence analysis, as a graphical map, the structure of the multi-variate relationships between the laboratories and the functions performed by the scientific and technical personnel of these laboratories were explored, thereby illustrating the profiles of tacit knowledge in different laboratories.

In conclusion, several measures have been forwarded to measure tacit knowledge. The Yale group approach is a direct measure, based on the premise that novices and experts differ in the amount and organisation of domain specific knowledge and that tacit knowledge has an articulable level. Therefore the more expert like knowledge a person possess', the more tacit knowledge that individual has. Direct measures of tacit knowledge have all been individually based, using the Yale group approach. Indirect measures have included surrogate indicators for demonstrating tacit knowledge at in laboratories with different functioning individuals and team measures of tacit knowledge have been measured by proxy. Proxy measures do not agree that tacit knowledge has an articulated level of abstraction. There exists no direct measure of tacit knowledge at the team level. The next section outlines the rationale and development of a team measure of tacit knowledge for software development teams

8.3 Developing the Team Tacit Knowledge Measure

Developing a direct team level measure of tacit knowledge for software development teams needs to address a number of issues:

1. It should measure the tacit knowledge possessed by all software development team members, albeit to different degrees.
2. A team measure is not intended to be a definitive measure of all tacit knowledge possessed by teams, but tacit knowledge of a certain type, i.e. domain specific expert knowledge.
3. The direct measure can only deal with tacit knowledge at the articulable level of abstraction.

The development of the Team Tacit Knowledge Measure (TTKM) is based on Yale group's general framework of differentiating between novices and experts but applies the repertory grid technique rather than SJTs to measure tacit knowledge of experts. It was decided to use the repertory grid because it accounts for context and was less cumbersome to administer than the SJTs (Ryan & O'Connor, 2003). The context refers to the question posed to experts to elicit tacit knowledge, it is a brief or very short situation that is then construed. The repertory grid is based on Kelly's (1955/1991) personal construct theory which has generated a number of tools of psychological inquiry, the most notable of which is the repertory grid method. The grid method is an accepted research tool in psychology (Bannister, 1981) and in the management field is the preferred methodology for mapping cognitive constructs of individuals (Brown, 1992; Dutton et al. 1989; Reger, 1990). The repertory grid forwarded by Kelly is a simple technique for accessing tacit knowledge (Stewart & Stewart, 1981), and helps illuminate personal knowledge and gain access to private worlds (Kelly, 1955/1991). The repertory grid, therefore accesses tacit knowledge at the articulated level (Bannister & Fransella, 1989; Moynihan, 2002).

The TTKM was developed in five phases using the mixed method, sequential exploratory approach with qualitative data collected first, and analysed, followed by quantitative data collection. In addition, investigator triangulation was used when transforming the qualitative data into a quantitative measure. The five phases of development are as follows:

1. Unstructured interviews with domain experts were conducted to understand the process of software development and the nature of software teams.
2. Development and administration of an online interactive repertory grid to expert project managers.
3. Analysis of grids and development of 'supplied' grid.
4. Administration of supplied grid to novices and experts, for validation.
5. Inclusion of items for TTKM based on differences between novices and experts.

8.3.1 Phase 1 of TTKM Development: Unstructured Interviews

First unstructured interviews were conducted with a professor of software engineering who had extensive experience using the repertory grid and two project managers, to understand the process of software development and the nature of software teams. The result of these interviews was the development of an understanding of the language and context in which software engineering occurs. In addition, the 'context' or situation for experts to construe was decided.

8.3.2 Phase 2 of TTKM Development: Development and Administration of an Online Interactive Repertory Grid

There are three important aspects to the grid, elements, constructs and links (Easterby-Smith, 1980). The repertory grid provides a two-way classification of information in which relationships are uncovered between a persons' observations of the world (called elements) and how they construct or classify those observations (Moynihan, 2002). These constructs are bipolar, describing how some elements are similar and yet different from another, e.g. a team may be described as 'experienced <–> inexperienced'. The third component of the grid links the elements and constructs, where each element is rated on each construct. Experienced project managers were chosen as experts because they are responsible for planning and scheduling project development, should be technically competent, have experience of non-managerial team membership and are responsible for the supervision of work. Project managers should know to varying degrees all aspects of the development process and therefore their expert knowledge is invaluable to our understanding successful team performance (Ryan & O'Connor, 2003).

It was decided to develop the measure online because online questionnaires allow for interaction of previous items in a scale to form part of later items in a questionnaire, a feature necessary to the repertory grid. In addition, there would be little experimenter bias and can reach a wide geographic audience. Finally, the expert sample are busy people who use computers in their everyday work, therefore, an online questionnaire was deemed more appropriate to the sample than to conduct face-to-face interviews.

8.3.2.1 Online Interactive Repertory Grid

The repertory grid technique involves the elicitation of *constructs*. A construct is the way in which two or more things are alike, and thereby different from a third or more things. In the repertory grid these 'things' are referred to as *elements*. We can never affirm something without simultaneously denying something. Hence, constructs are bipolar: we make sense out of our world by noting likenesses and differences.

This study employs the repertory grid method to access implicit expert knowledge about factors that affect team performance. Interviews were done using a specially developed online interactive repertory grid designed for the software development context. It was decided to develop an on-line interactive repertory grid using dynamically changing pages. Since these advanced types of feature were needed, Java Server Pages (JSP) were used to create the survey forms. The data received from the online survey were captured and processed using the JSP session bean, following the same procedure outlined in Chapter 7 (section 7.3.19). In addition, the online repertory grid was pilot tested by the professor of software engineering and the two project managers from phase 1, some minor 'bugs' were found and rectified.

8.3.2.2 Participants

It was decided that the experts would be experienced and proficient project managers in software development field and a minimum of 10 managers was needed (Moynihan, 2002). Access to experts was gained through personal contact and 'snowball sampling'. The snowball sample developed as follows: The two expert project managers who were consulted on constructing the grid, provided this researcher with contact details of other suitable project managers and also forwarded an e-mail with a link to the repertory grid (Appendix F) to other managers they knew, who were experienced and had a reputation for excellence. In addition, a website address was provided to afford more information on the study. Thirteen project managers in software development from 7 different organisations in Ireland (N=6) and the UK (N=1) took part in the study. Most managers (N=8) were in the 31-40 age bracket, and from an organisation size of 1000+ (N=5). The mean number of years of experience 9.23 years (SD = 3.75) and consisted of 10 males and 3 females.

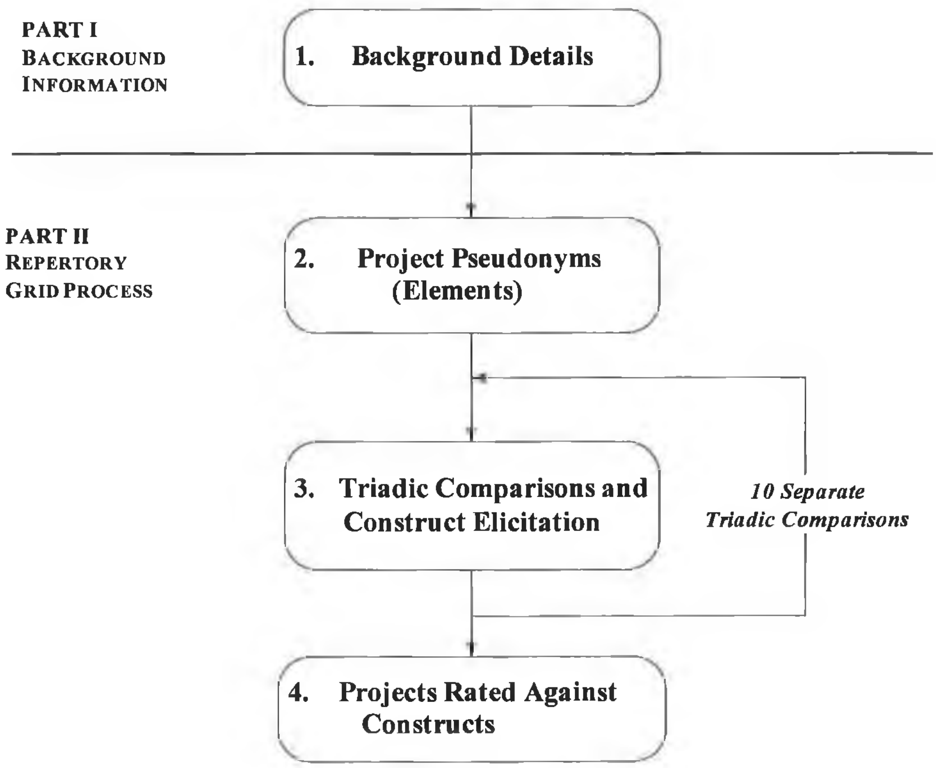
8.3.2.3 Repertory Grid Process

The Repertory grid process is outlined in steps 1-4, in the algorithm shown in Figure 8.1 and was in two parts, Part I referred to Background Details and Part II began with Step 2 in Figure 8.1, dealing with the repertory grid.

The respondents were e-mailed the repertory grid questionnaire. Appendix G contains screen shots of the questionnaire. The first screen detailed the study and ensured anonymity (Appendix G.1). Participants then completed the online repertory grid, which took about 15 minutes. When developing the grid the explicit context was decided as "*What situational factors do experienced project mangers in software development feel significantly influence their team's performance*?" This context was chosen because provides a general, broad rather than specific, narrow context, allowing managers scope to provide their own constructs and is based on the context provided by Moynihan (2002) in his study exploring risk factors in software development projects.

In *Step 1*, three categorical choice questions referring to respondent's background, age, sex and organisation size were obtained. In addition, a fourth question asked how many years of experience the respondents had in the software industry (Appendix G.2).

Figure 8.1 Algorithm of the Repertory Grid Process

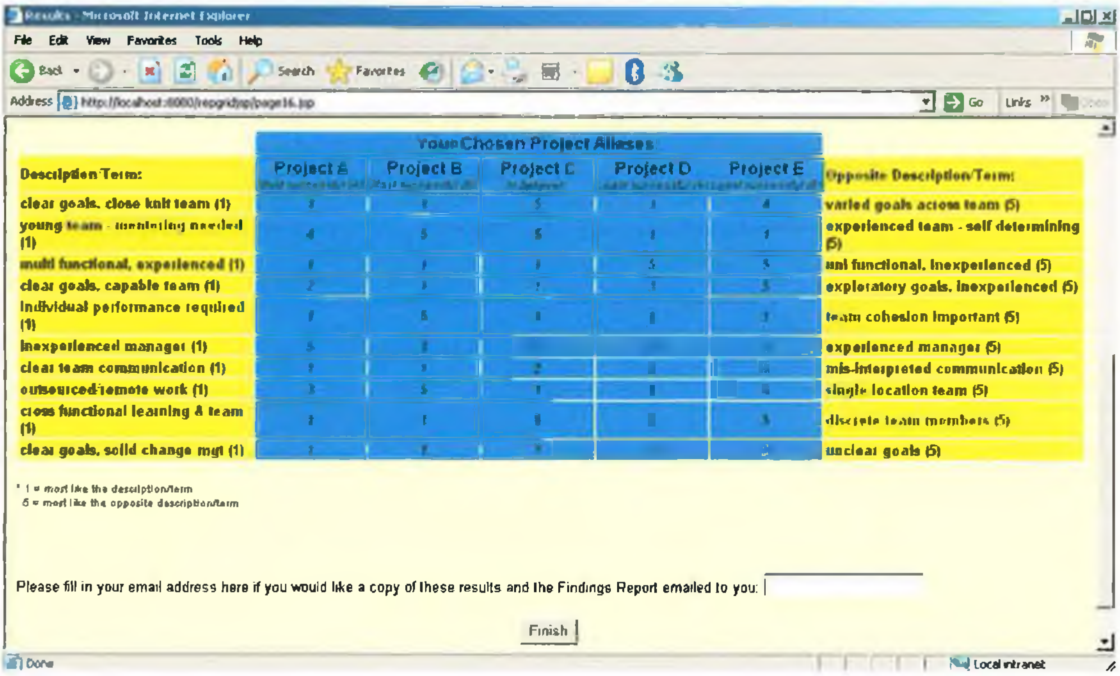


In Part II, Participants were asked to list elements, in this case, the elements were 5 software development projects they had managed (*Step 2*). Only 5 projects were chosen because, in a previous study by Moynihan (2002) it was found to be the average number of projects managers listed when no limits were applied. Using pseudonyms or aliases, project managers listed the two 'most successful', one 'in-between' and the two 'least successful' projects they had managed (Appendix G.3). These project types were given in order that comparisons could be made across project managers.

In *Step 3*, project managers were asked to think about the 5 projects in relation to situational factors that affect team performance. The elements (projects) were then presented in groups of three (triads) to produce both a similarity and a difference. Then the manager was asked to choose two projects that are similar and thereby different from the third resulting in a bipolar construct being elicited. This step was repeated 10 times without recurrence of any combination of triads and 10 bipolar constructs were elicited (Appendix G.4).

In *Step 4* (Figure 8.2) each of the five elements (projects) were rated on each of the 10 bipolar constructs on a scale of 1-5.

Figure 8.2 Elements Rated on Each of the 10 Bipolar Constructs.



As the repertory grid was administered online, all of the information required by the participants needed to be available. Each screen/page was designed to have a minimum of instructions, and where possible 'pop-up' menus provided explanations for concepts. The grid was then e-mailed automatically and anonymously to the researchers email and to the respondent.

8.4.3 Phase 3 of TTKM Development: Results and Analyses of Repertory Grids

The TTKM was therefore developed using a mixed methods, sequential exploratory approach, firstly the qualitative repertory grid was used to access articulated tacit knowledge, this was then analysed using a quantitative content analysis. In addition, triangulation of observer was utilised to perform the content analysis. The software package WebGrid III (Gaines & Shaw, 2003) was used to conduct a statistical principal components analysis of the repertory grids. WebGrid III is an implementation for the World Wide Web of Kelly's *repertory grid* technique for building conceptual models and provides variety of methods for modelling and visualizing the relations between constructs. Principal components analysis is to reduce the information in many measured variables into a smaller set of components. Finally, the measure was developed for teams by further analysing the data using the statistical package SPSS version 12.

The thirteen repertory grids yielded bipolar constructs which were compared and analysed using the generic approach to categorisation and content analysis outlined by Jankowicz (2003).

8.3.3.1 Categorisation and Content Analysis of Constructs

Content analysis is a technique in which constructs of all the interviewees are pooled and categorised according to the meaning they express. A 'bootstrapping' technique was used where constructs are looked at systematically and the themes they express are identified where each construct was the basic unit of analysis (Jankowicz, 2003). In all, 132 constructs were obtained (one manager had 2 extra constructs) and were numbered to prepare for categorisation. Each construct being categorised was compared to the others. If a construct was like the first construct, the two were placed together under a single category. Constructs that differed from the first category were put in separate categories. Each subsequent construct was compared to the growing body of categories and allocated to an existing category or a new category was created. This process continued until all 132 constructs were classified into 26 categories. Unclassifiable constructs were allocated to a 27^{th} category called 'other'. After the categories had been identified and all constructs allocated the results were tabulated and the category headings defined.

8.3.3.2 Reliability of the Category System

In order to counteract the obvious subjectivity of such a categorisation a second rater also classified the 132 constructs. This reliability check of the category system was based on Jankowicz (2003) who advocated that a second rater categorise the constructs into themes. In the present study, a slight variation was used where the 27 category names were supplied to the second rater, who placed the constructs under each category. The two raters' sets of categories were compared, the joint allocation of constructs were assessed and the extent of agreement was measured. There was an inter-rater reliability of 84.84%, with disagreement occurring on 20 constructs e.g. one rater categorised 'workflow' with constructs like 'short-term project' and the second rater placed it in the 'other' type constructs. The remaining constructs were debated and consensually placed into the categories.

The 27 themes and the number of managers having a construct under each theme can be seen in Table 8.1. All 132 individual constructs under each theme can be seen in Appendix H (Table H.1).

Table 8.1 Breakdown of Constructs under Each Theme

Factor No.	Theme	No of managers having at least one construct under the theme.	Total number of constructs under the theme
1.	Clear well-defined goals	7	21
2.	Team is motivated and capable	6	7
3.	Co-operative team	5	7
4.	Knowledge required for project is available within the team	5	5
5.	Clear procedures	4	6
6.	Innovative project	4	7
7.	Project length	4	4
8.	Experienced team	4	4
9.	Adequate resources	3	5
10.	Diverse team membership	3	5
11.	Project scope and importance	3	5
12.	Strict deadlines	3	4
13.	Third party is involved in the project	3	4
14.	Team size	3	4
15.	Clearly specified client requirements	3	3
16.	Managerial experience and control	3	3
17.	Management back up and support	2	6
18.	Morale	2	3
19.	On schedule and On budget	2	4
20.	Measure of Success Criteria in evidence	2	3
21.	Clear team communication	2	3
22.	Team challenges to management are welcome	2	2
23.	Competition within the team	2	2
24.	Clear non-competing roles	2	2
25.	Client's needs met	1	4
26.	Client from same organisation	1	2
27.	Other	3	7
	Total		**132**

Thirteen project managers demonstrated diminishing returns after the 9th elicitation session (manager) when no more new themes emerged (Table 8.2).

Table 8.2 Cumulative Number of Themes by Number of Elicitation Sessions

Number of sessions	1	2	3	4	5	6	7	8	9	10	11	12	13
Cumulative number of themes	8	12	13	18	19	23	25	26	27	27	27	27	27

There were clear differences among the constructs elicited. The constructs were of a similar level of abstraction with little 'emotive' language. All used the shared vocabulary of project management, using words such as 'clients', 'requirements', 'resources' and 'third party'. There was quite a bit of variation in the amount of themes elicited per manager, with the lowest being 2 and the highest being 10 (there was a maximum of 10 per manager, see Table 8.3).

Table 8.3 Number of Themes Elicited Per Manager

	Manager #												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
No. of themes per person	8	6	2	9	5	8	9	6	4	6	5	8	10

On visual inspection of the matrix, of the number of constructs per manager under each theme in Appendix I (Table I.1), it is evident that different managers focussed on different combinations of themes.

8.3.4 Phase 4 of TTKM Development: Development of Supplied Grid Questionnaire

In order to develop a team measure for tacit knowledge regarding the factors that influence team performance on successful software projects, a 'supplied grid' (Fransella & Bannister, 1977; Bell, 2001) was developed based on the 27 themes. It was decided to maintain as far as possible the integrity of the managers original constructs by representing each theme with a verbatim construct, so for example 'Co-operative team' is represented by the construct 'High co-operation'. Two researchers examined the constructs under each theme and consensually agreed representative constructs.

A principal components analysis of the 13 grids were analysed to ensure that all of the constructs that managers associated with 'successful projects' were included in the themes. Each participant's constructs were inputted for principal components analysis to WebGrid III to ascertain how they personally construed factors that affect team performance. WebGrid III, yields a cluster analysis and a PrinCom map of how a person has construed situational factors that affect team performance. These analyses are individualistic and personal to each participant. For an example of a personal grid analysis (Appendix J).

Two themes were not represented in the supplied grid, the theme 'other' was eliminated because it contained diverse highly idiosyncratic constructs, also, 'client from the same organisation' was not used because only one manager mentioned it and it was not closely associated on the PrinCom map with successful projects. However, 'clients needs met', although only mentioned by one manager was included because it was very close to successful projects. One theme was added pertaining to 'one clear decision maker/leader', since it is prominent in the literature but no manager used this particular construct. In all 25 themes were included in the supplied grid, with a response set of 5 options (see Appendix K).

8.3.5 Phase 5 of TTKM Development: Validation of 'Expert' Knowledge by Comparison with Novices

8.3.5.1 Administration of Supplied Grid to Experts and Novices

In order to ascertain which of the constructs elicited were truly expert and not mere common sense, a comparison was made between novice and expert construing. The supplied grid questionnaire consisting of the 25 constructs was put online and emailed back to ten experts who had already taken part (not all wanted to be contacted again), and emailed to a further 8 reputable project managers who were recommended by other project managers and initially contacted personally (by email and phone) and agreed to take part. Fourteen males and four females with a modal, age of 31 – 40 years and average years of experience of 9.44 years (SD = 3.41), completed the supplied grid. The questionnaire was also administered (without the 'years of experience' demographic question) to 124 final year students in Computer Applications or Computer Science at three different Third-level institutions (College 1, N = 21; College 2, N = 58; College 3, N = 45), whose modal age was 18 – 24 years, with 31 females and 93 males completing the questionnaire. Students were chosen to provide a baseline measure of 'novices'. All of the students had worked in a team, but had very little experience.

The 25 items are answered on a 5-point semantic differential type scale. An example of one of the bipolar constructs is 'Innovative project <----> Mundane/Everyday type project'. Respondents rated the constructs by selecting closest to the statement pole they felt described the factors that influence team performance on successful projects. The questionnaire included 3 demographic questions referring to age, sex and years of experience.

8.3.5.2 Analysis of Expert and Novice Responses

Using the Levene test for homogeneity of variance (with an alpha level of .05) data for novice group and the expert group, and were found to be heterogeneous on 7 factors (Appendix L, Table L.1).

Normality was checked on all factors for novices and experts by assessing skewness. Using the convention that the skewness statistic is not more than twice as large as its standard error then the data were not reliably different from normal. The novice data were skewed for most factors except 'short-term project', 'small project', 'big team' and 'third party is involved in the project' and therefore considered non-normal. To ascertain if this skewness was due to the pooling of the data, histograms for all three colleges were compared but still showed skewness. The expert data were not skewed except for the factor 'clear non-competing roles'. Taking into account the non-normal student sample and the unequal sample sizes between the novices and experts, it was decided to use a non-parametric test to ascertain which factors differentiated between the two groups. The non-parametric Mann-Whitney U test, equivalent of a t-test was performed, since t-tests are biased by unequal variances especially when sample sizes are unequal (Hsu, 1938; Overall et al. 1995; Rogan & Keselman, 1977). The results of the Mann-Whitney U test revealed 14 factors that significantly differentiate between novices and experts (Table 8.4). These 14 significant factors formed the tacit knowledge measure.

Table 8.4 Medians, Interquartile Range and Mann Whitney U for Novices and Experts

Factor No.	Left Pole of Bipolar Construct (scale value of left pole = 1)	Novice		Expert		Mann Whitney *U*
		Md	*IQR*	*Md*	*IQR*	
1.	Clear goals	1	(1 - 1)	1	(1 - 1)	864.00*
2.	Highly motivated team	1	(2 - 1)	2	(2 - 1)	799.00*
3.	Highly co-operative team	1	(1 - 1)	2	(2 - 1)	682.50**
4.	Knowledge required available within the team	2	(3 - 1)	3	(3 - 2)	708.00**
5.	Unclear Procedures	5	(5 - 4)	4	(5 - 3)	1053.00
6.	Innovative project	2	(2 - 1)	3	(4 - 2)	443.50***
7.	Short-term project	3	(3 - 2)	3	(3 - 2)	952.50
8.	Experienced team	2	(2 - 1)	2	(3 - 2)	777.00*
9.	Adequate resources	1	(1.75 - 1)	2	(3 - 1)	544.00***
10.	Diverse team membership	2	(3 - 2)	3	(3 - 3)	640.00**
11.	Small project	3	(3 - 2)	2	(3 - 2)	752.00*
12.	Strict deadlines	2	(3 - 2)	3	(3 - 2)	742.50*
13.	Third party is involved in the project	3	(4 - 2)	3	(4 - 3)	856.00
14.	Big Team	4	(4 - 3)	4	(3 - 1)	762.00*
15.	Inaccurate client requirements	5	(5 - 4)	5	(5 - 3.75)	1015.00
16.	Manager in control	2	(2 - 1)	2	(3 - 1)	1115.00
17.	Management back up and support	2	(2 - 1)	2	(2 - 1)	988.50
18.	Low morale	5	(5 - 4)	4	(5 - 4)	795.50*
19.	On schedule and On budget	2	(3 - 1)	2	(3 - 1)	1078.50
20.	Lack of measures of success	4	(5 - 3.25)	4	(5 - 3.75)	1048.00
21.	Clear team communication	1	(1 - 1)	1	(2 - 1)	929.00
22.	Management decisions challenged	2	(2 - 1)	2.5	(3 - 1)	989.50
23.	Internal competition	3	(3 - 2)	4	(5 - 3)	556.50***
24.	Clear non-competing roles	1	(2 - 1)	1	(3 - 1)	1085.50
25.	One clearly identified decision maker/leader	2	(3 - 1)	1	(2 - 1)	628.00**

* p<.05; **p<.01; ***p<.001

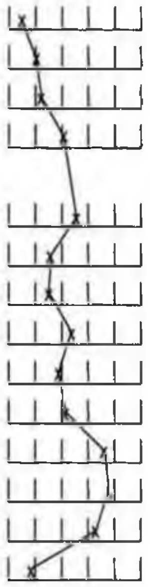
8.4 The TTKM

The TTKM is a 14 item bipolar, SJT where participants indicate the degree to which they feel each of the 14 factors affect team performance on successful software development projects on a 5-point semantic differential type scale. The 14 constructs are rated by selecting closest to the statement pole that best describes the factors that influence team performance on successful projects. There are no right or wrong answers on this questionnaire, just personal construing of factors that affect team performance on successful projects. In the main study, the 14 factors where randomised so as, to eliminate order effects. The expert responses for each of the 14 items were used to construct an expert profile using the expert mean. The expert means can be seen in Table 8.5 and the expert profile is illustrated in Figure 8.3.

Table 8.5 Expert Means and Standard deviations for 14 factors

Factor No.	Left Pole of Bipolar Construct (scale value of left pole = 1)	Mean	SD
1.	Clear goals	1.00	0.00
2.	Highly motivated team	1.56	0.51
3.	Highly co-operative team	1.72	0.75
4.	Knowledge required available within the team	2.56	0.92
5.	Innovative project	3.11	0.96
6.	Experienced team	2.16	0.62
7.	Adequate resources	2.00	0.77
8.	Diverse team membership	2.89	0.83
9.	Small project	2.44	0.51
10.	Strict deadlines	2.72	0.46
11.	Big Team	4.17	0.78
12.	Low morale	4.28	0.46
13.	Internal competition	3.83	1.09
14.	One clearly identified decision maker/leader	1.44	0.70

Figure 8.3 Expert Profile



1. Clear goals	Vague goals
2. Highly motivated team	Team is not motivated
3. Highly co-operative team	Uncooperative team
4. Knowledge required available within the team	Knowledge required is not totally available within the team
5. Innovative project	Mundane/everyday type project
6. Experienced team	Inexperienced team
7. Adequate resources	Inadequate resources
8. Diverse team membership	Uniform team membership
9. Small project	Extensive project
10. Strict deadlines	Widely variable deadlines
11. Big Team	Small Team
12. Low morale	High morale
13. Internal competition	No competition within the team
14. One clearly identified decision maker/leader	Unclear as to who makes the decisions

8.5 Establishing Validity of the TTKM

Validity for the TTKM was established using Messick's (1995) unified validity framework to show how tacit knowledge theory and the phases of test development contribute to knowledge of the validity of the TTKM. Messick's framework treats traditionally separate forms of validity as aspects of a more comprehensive type of construct validity involving content, substantive, structural, generalisable, external and consequential aspects of validity. Traditionally, validity is established using factor analysis, however, SJTs and knowledge tests of this type are usually multi-factorial in nature. Each element of Messick's (1995) framework is discussed in relation to the validity of the TTKM.

8.5.1 Content Relevance

According to Sternberg et al. (2000) the goal of construct relevance 'calls for tacit knowledge test questions that are sensitive to knowledge of the type specified by the focal construct and insensitive to knowledge that falls outside the focal construct' (p.138). In developing the TTKM measure, content relevance was established by content experts in this case expert project managers to determine boundaries of the construct domain, which was tacit knowledge regarding the factors that affect team performance on successful projects. Evidence of content relevance was established by using the repertory grid technique to access tacit knowledge. In addition, the selection of items for the final TTKM was based on the differences between novices and experts, and items that differentiated the two groups were retained for the final measure.

It is also important to attend to the representativeness of the tasks selected for assessment, which must be typical of the job domain. This was established by using job incumbents who are representative of people in software development i.e. project managers were from large and small companies, in Ireland and the UK and with varying years of experience. In addition, representativeness of items was established through content analysis where 'typical' or most frequently occurring items were used. Finally, care was taken to ensure that the domain chosen was one that was relevant to teams of software developers as well as experts, this was validated by the choice of context for the repertory grid which was based on initial interviews with two project managers and professor of software development. The TTKM allows aggregation to team level due to the validity of representativeness.

8.5.2 Substantive Theoretical Rationale

The substantive theoretical rationale for observed consistencies in test responses assessing tacit knowledge and its relationship to test performance was established. This is based on cognitive model in Chapter 3 which looks at individual representation of tacit knowledge. Figure 3.1 illustrated how tacit and procedural knowledge are acquired by individuals, leading to a performance advantage in people's ability to respond to contextualised mundane problems. The TTKM is also based on Sternberg et al's (2000) definition of tacit knowledge: acquired with little environmental support, is procedural and has practical value to the individual. The items for the TTKM were elicited from expert project managers, the context of situational factors that affect team performance was non-technical and knowledge acquired through experience or 'on one's own' (Sternberg et al. 2000; Hedlund et al. 2003), not through formal instruction. Obtaining the items that differentiated between novices and experts provided further validation. Expert knowledge about these situational factors was therefore procedural which is thought to guide action. Tacit knowledge, however, 'represents a subset of procedural knowledge that is not readily articulated in the form of explicit rules and procedures' (Hedlund et al. 2003). The items reflected the experienced based and action oriented aspects of Sternberg et al.'s (2000) definition which represents the practical value to the individual, i.e. learning through experience what factors affect team performance on successful projects.

8.5.3 Structural Aspect

The structural aspect refers to the fidelity of the scoring structure to structure of construct domain (Messick, 1995). This is related to representativeness, where experienced and reputable expert project managers construed the situation in terms of bipolar constructs, illuminating personal knowledge and gaining access into private worlds (Kelly, 1955/1991). The task structure is consistent with the construct domain, since, the internal structure of the 'supplied grid' was made up of a representative construct from each of 25 factors. Finally, the structure of the TTKM further reflected the domain since it is the result of the differences between expert and novice response on the items.

8.5.4 Generalisability Aspect

In terms of generalisability, Messick (1995) noted, 'the issue of generalizability [*sic*] of score inferences across tasks and contexts goes to the very heart of score meaning' (p. 746). Generalisation to the population and across populations. This includes test-retest reliabilities for repeated administration of the test across individuals Test-retest reliability was established over a two week interval, involving 49 final year students undertaking a class on software quality as part of their degree in Computer Applications, as participants. The result of a Pearson's correlation over the two administrations of the tests was $r = 0.73$ ($p < .05$). This coefficient is reasonable, considering the sample size and the potential for discrepancy between the test administrations, since it is likely that students had acquired expertise regarding factors that affect team performance, as they were attending a class in software quality.

8.5.5 External

The external aspect of construct validity essentially, refers to convergent and discriminant validity. A statistical validation of the tacit knowledge measure was undertaken to evaluate the discriminant validity of the TTKM relative to explicit knowledge; convergent validity in relation, intuition (gut instinct), social interaction and (criterion related) predictive validity in relation to team performance. The correlations may be seen in Chapter 9-Table 9.2. Convergent and discriminant validity were predicted in *hypotheses 6* and *7* (See Chapter 5, Minor Model 3)

Hypothesis 6 stated that team tacit knowledge will vary according to explicit job knowledge as measured by familiarity with written job procedures and by reliance on these written procedures and *hypothesis 7* predicted that tacit knowledge at the team level is related to gut instinct.

As predicted, tacit knowledge had a low non-significant relationship with explicit knowledge as measured by 'reliance on written procedures' and 'familiarity with written procedures', thus providing discriminant validity for the TTKM. The TTKM was not significantly related to intuition (gut instinct) but convergent validity was provided by a significant correlation between scores on the TTKM and quality of social interaction ($N = 48$, $r = 0.45$, $p<.01$) providing partial support for *hypothesis 9*, since the TTKM was not significantly related to quantity of social interaction. In terms of predictive validity, the TTKM was significantly related to the effectiveness component of team performance ($N = 48$, $r = 0.34$, $p<.05$) but not the efficiency aspect (*hypothesis 8*).In terms of predictive validity the TTKM was significantly related to the effectiveness component of team performance but not the efficiency aspect (*hypothesis 9*).

8.5.6 Consequential aspect

The consequential aspect refers to the intended and unintended consequences of score interpretation (Messick, 1995). The primary issue is that any negative impact should not be derived from any source of test invalidity. If an item may have an adverse impact or be at odds with an organisation culture then it should not be used (Sternberg et al. 2000). The pilot study of the entire survey, outlined in Chapter 7 did not uncover any negative consequences associated with items of the TTKM.

8.6 Summary of the Development of the TTKM

Previous measures of tacit knowledge either measured tacit knowledge at the individual articulated level or by proxy at the team level. There was no team level questionnaire based measure of tacit knowledge at the articulated level of abstraction. It was necessary to develop the TTKM in order test the hypotheses posed by the theoretical model in Chapter 5. The TTKM is based on the premise the novices and experts differ in the amount and organisation of tacit knowledge. The TTKM does not measure all tacit knowledge within a team but only one aspect, to do with factors that affect team performance on successful projects. The TTKM was developed using a sequential exploratory approach, using the repertory grid as the qualitative aspect and quantitative content analysis of the responses to those grids. Mixed methods was used to retain, as far as possible the context dependent aspects of tacit knowledge. The validity of this instrument was established using Messicks' (1995) framework and was deemed to be a valid measure. The reliability of the TTKM along with the other measures used the main study will be reported in Chapter 9.

In the next chapter the results of the main study are reported.

Chapter 9
Results and Analysis

9.1 Introduction

The data were analysed in two parts. In Part I, the data were prepared, checked for normality and reliabilities and validity for the measures used in this study were established. The data were analysed using SPSS version 12 and Microsoft Excel. In Part II the main model, minor models and their concomitant hypotheses were tested.

PART I: DATA PREPARATION

9.2 Data Preparation and Preliminary Analyses

The data were gathered from the email using a custom Java batch processing application and converted to a Microsoft Excel file. Preliminary data preparation and calculations were then undertaken. Firstly, the data were aggregated to team level. Following this, both individual level and team level data were transferred to SPSS version 12 for further analysis. The internal consistency of the measures was assessed along with the level of team agreement. The data were then checked for normality. After this initial data preparation, the data were described at team level in terms of means and standard deviations.

Inferential analyses were then carried out. A series of independent t-tests were performed to assess the differences, if any, between Ireland and the UK on responses on all measures.

9.2.1 Data Preparation

Normality was checked on all variables by assessing skewness and visually inspecting histograms. Using the conservative convention that the skewness statistic is not more than twice as large as its standard error (Tabachnik & Fidell, 2001) then the data were not reliably different from normal, for all variables except team size, familiarity with written procedures, and presence of expertise. Further analyses of these variables indicated that skewness was attributed to the presence of outliers. To check if these outliers posed a threat to the inferential analysis, the regression analyses were conducted with and without the outliers, which were found to exert no significant influence. It was decided to keep the outliers in the data. In addition, the data for these regressions were linear since the standard deviation for the dependent was more than the standard deviation for the residuals. In regression analysis in particular, skewness is only an issue if it relates to the dispersion of the residuals. For all regression analyses there were no outlying residuals i.e. points whose standardised residual is greater than 3.

The data met the conditions for regression. Inspection of standardised residual plots indicated homosecdasticity, where the residuals were dispersed randomly throughout the range of the estimated dependent. The correlations were all well below the 0.8 that would indicate high collinearity (Kennedy, 1985). In addition, further evidence to indicate that multicollinearity was not a problem, was apparent in the variance inflation factor (VIF) which was below 4.0 (which is the recommended cut-off point; Miles & Shevlin, 2001) for all variables in all regressions.

9.2.2 Transforming and Weighting Scores

In order to maintain consistency across variables, each score on the TTKM was subtracted from the maximum score, so that a higher the score on TTKM reflected more expert like responses. In addition, 'reliance on gut instinct' and 'reliance on written procedures' were subtracted from the maximum+1, in order that high scores were equal to high reliance.

In relation to the transactive memory system (TMS) measure, a weighted composite score was computed on the advice of Lewis the originator of the measure (personal communication, 2004). The technique, described more fully in Kim and Mueller (1978), essentially involves regressing the TMS factor on its sub-factors and items, while still taking into account the hypothesised measurement model. Scale weights are given by the regression coefficients. In this study the scale weights were as follows: specialisation: R^2 = 0.53, credibility: R^2 = 0.79, coordination:R^2 = 0 .67. The scores for each sub-factor were multiplied by their scale weight the three were added together to make the weighted composite.

9.3 Aggregation of Data across Countries and to Team Level

Scores on all measures were aggregated to team level. First, individual scores were calculated for most variables (except proximity, diversity, team size and new product development capability, which were collected at the team level), then, these were averaged for team level analysis. Criteria for scoring and averaging the test scores were outlined in Chapter 7.

A series of t-tests on the main variables indicated no significant differences between Ireland and the UK on any of the variables in this study (Appendix M, Table M.1). Country of origin was not an influencing factor in the present study, therefore the organisations were pooled into a single sample forming a combined sample size of 48 teams.

9.4 Adequacy of Measures

All constructs using multiple indicators were tested for their reliability at both the individual and team level. The validity of all measures, where relevant was established using factor analysis. However, the TTKM was tested for convergent and discriminant validity using Pearson's correlation coefficient.

The means and standard deviations for all measures are presented in Table 9.1, along with the Cronbach alpha reliabilities, at both the individual and team level. In addition, the reliabilities for the measures at the team level from the previous studies discussed in Chapter 8 are also presented. Finally, the two values for inter-rater agreement are reported: r_{wg} (James et al.1984) and R_{wg} (Lindell et al. 1999).

9.4.1 Internal Consistency of Measurements

The internal consistency for all measures at individual level are all above α = 0.68 (except for the TTKM) and above α = 0.67 at the team level. Therefore, the internal consistency of the measures is considered adequate at the team level. Internal consistency for the TTKM, as measured by Cronbach's coefficient alpha, was α =0.49 at the individual level and α = 0.71 at the team level, indicating a significant increase in the internal reliability of the measure at the team level, thus providing support for the premise that TTKM measures tacit knowledge at the team rather than individual level. Given that the obtained team level reliability falls within the range for other situational judgement tests and for those reliabilities obtained on previous measures of tacit knowledge (Hedlund et al. 2003). Then the internal consistency of the team level score is considered to be acceptable.

Table 9.1 Means, Standard Deviations, Reliability and Inter-Rater Agreement for All Measures

Variable	Mean	SD	Min	Max	alpha Ind.	alpha Team	alpha Prev.	r_{wg}	R_{wg}
1. Quality of SI	12.83	1.88	9.17	16.00	NA	NA	NA	NA	NA
2. Quantity of SI	64.60	17.06	10.00	100.00	NA	NA	NA	NA	NA
3. TMS (weighted composite)	41.94	4.38	31.83	47.76	.88	.92	.82	.98	.74
4. Credibility	21.64	2.34	15.00	25.00	.82	.88	.79	.96	.75
5. Specialisation	20.85	3.04	13.00	25.00	.88	.94	.76	.95	.72
6. Coordination	20.59	2.91	14.00	25.00	.88	.94	.82	.95	.73
7. Team Tacit Knowledge	5.49 (10.84)	2.48	0.00 (6.26)	10.08 (16.34)	.49	.71	NA	.96	.58
8. Effectiveness	3.69	0.55	2.40	4.60	.76	.88	.86	.90	.57
9. Efficiency	3.24	0.73	1.50	4.50	.68	.83	.74	.76	.59
10. Psychological Safety	5.62	0.64	4.31	6.57	.78	.82	.82	.93	.60
11. Team size	4.91	2.34	2.00	11.20	NA	NA	NA	NA	NA
12. Diversity	50.17	38.07	0.00	100.00	NA	NA	NA	NA	NA
13. Formal knowledge Sharing System	9.16	1.93	4.00	14.00	.78	.85	NA	.87	.40
14.Experience (years)	11.64	4.97	2.00	22.50	NA	NA	NA	NA	NA
15. Expertise Presence	80.00	13.11	33.33	98.33	.68	.67	.88	NA	NA
16. Reliance on Gut Instinct †	4.00 (2.00)	0.62	3.00	5.00	NA	NA	NA	NA	NA
17. Familiarity with Written Procedures†	4.07	0.76	1.00	5.00	NA	NA	NA	NA	NA
18. Reliance on Written Procedures†	3.01 (3.00)	0.95	1.00	5.00	NA	NA	NA	NA	NA
19. Administrative Coordination	3.13	0.72	1.00	4.50	.81	.89	.82	.80	.41
20. New Product Development	21.29	2.58	16.00	27.00	NA	.68	NA	NA	NA

() items in brackets are non-reverse coded.

† single item measures

The 5-item scale for 'new product development capability' initially had low reliability (α = 0.54), two items were removed increasing the reliability to α = 0.69. The items relating to 'ability to price competitively' and 'ability to penetrate new markets' were removed. Leaving three usable items for analysis in the scale, consisting of items a, b and c (see Appendix C.9).

The first set of inter-rater agreement values or $r_{wg,}$ are the values reported in all studies using the formula forwarded by James et al. (1984). The r_{wg} values range from 0.76 to 0.96 and thus reflect a high level of within-team agreement. Lindell et al.'s (1999) measure incorporates weighting based on sample size, allowing for inter-group comparison of inter-rater agreement (R_{wg}). The inter-rater agreement is significantly lower when this formula is applied, ranging from 0.40 to 0.75. This is because the scale range is from –1 to +1 for 5-item scales and from –3.5 to +1 for 7-item scales. Comparison between the 5 and 7 item scales can be made because all were positive. However, comparison cannot be made between James et al. (1984) and Lindell et al. (1999), since the formula are different. Hence, both inter-rater agreement scores are reported.

9.4.2 Statistical Validity of the Measures

Validation of the TTKM was established using Messick's (1995) framework, which was discussed in Chapter 8. Theoretical and statistical validities for all other scales had already been established (see Chapter 7) except for presence of a formal knowledge sharing system and new product development capability. Principal components analysis with varimax rotation, a cut-off criterion of .40 for factor loadings and eigen values of above 1.0 or above, was used to check the existing statistical validities, and to establish the validity of 'formal knowledge sharing system', and 'new product development capability'. These were all conducted on team level data.

The three items that make up the 'formal knowledge sharing system' loaded on one factor. These items were entered together with administrative coordination and two clear factors were revealed, providing discriminant validity for presence of a formal knowledge sharing system (see Table 9.2). The three items that constitute 'new product development capability' were entered into the analysis with the measures of efficiency and effectiveness and three distinct factors were elicited. Thus the two factors that constitute team performance were confirmed and discriminated from one another and from new product development capability. The results for these analyses are illustrated in Table 9.3.

Table 9.2 Factor Analysis for Formal Knowledge Sharing system and Administrative Coordination

Items	Administrative	Knowledge
Requirements/design review	.88	
Project milestones and delivery schedules	.87	
Project documents and memos	.85	
Regularly scheduled team meetings	.74	
Formal policies and procedures for coordinating teams work	.74	
Design inspections	.70	
This organisation has a well organised system for sharing knowledge		.96
This organisation has a well organised system for sharing knowledge across teams		.85
Sharing knowledge systematically is part of the organisation's culture		.79

Table 9.3 Factor Analysis for NPD Capability, Efficiency and Effectiveness

Items	Effectiveness	Efficiency	New product
Work quality	.89		
Reputation of work excellence	.79		
Extent of meeting design objectives	.74		
Ability to meet project goals	.67		
Team operations	.66		
Adherence to schedule		.90	
Adherence to budget		.83	
Ability to respond to the unique requirements of different customers.			.89
Being first in the marker with new product introductions			.83
Frequency of new product introduction			.48

Finally, factor analysis also confirmed the three first order factors for transactive memory as posited by (Lewis, 2003; see Table 9.4). In addition, the seven items constituting team psychological safety were consistent with Edmondson (1999; Table 9.5). Furthermore, the three components: technical, domain and design expertise, loaded on the single factor 'presence of expertise' as posited by Faraj and Sproull (2000), in Table 9.6.

Table 9.4 Factor Analysis for Specialisation, Coordination and Credibility

Items	Coordination	Specialisation	Credibility
There was not a lot of confusion about how we would accomplish the task.	.90		
Our team did not need to backtrack and start over a	.89		
Our team had very few misunderstandings about what to do.	.83		
We accomplished the task smoothly and efficiently	.81		
Our team worked together in a well-coordinated fashion.	.69		
Different team members are responsible for expertise in different areas.		.94	
I know which team members have expertise in specific areas.		.91	
The specialized knowledge of several different tean was needed to complete the project deliverables		.90	
Each team member has specialized knowledge of some aspect of our project.		.89	
I have knowledge about an aspect of the project that no other team member has		.79	
I was comfortable accepting procedural suggestions from other team members.			.85
I trusted that other members' knowledge about the project was credible			.81
When other members gave information, I rarely wanted to double-check it for myself.			.68
I was confident relying on the information that other team members brought to the discussion.			.58
I had a lot of faith in other members' "expertise."			.55

Table 9.5 Factor Analysis for Psychological Safety

Items	Psychological safety
Members of this team are able to bring up problems and tough issues	.854
People on this team sometimes reject others for being different.	.841
Working with members of this team, my unique skills and talents are valued and utilised.	.759
If you make a mistake on this team it is often held against you.	.656
No one on this team would deliberately act in a way that undermines my efforts.	.647
It is safe to take a risk on this team.	.625
It is difficult to ask other members of this team for help.	.548

Table 9.6 Factor Analysis for Presence of Expertise

Items	Presence of Expertise
Technical expertise	.869
Design expertise	.859
Domain expertise	.668

9.4.3 Test for mono-method bias

Harman's single factor test is one of the most common tests available for examining common method bias (Podsakoff & Organ, 1986; Podsakoff et al. 2003). The above factor analyses indicate that the items in the measures do not load on a single factor, therefore the team survey was not hampered by excessive common-method variance.

9.5 Summary of PART I

The data were prepared for the analyses of the predicted hypotheses. The measures were all deemed acceptable for use at the team level, with good inter-rater agreement and reliabilities. In addition, validities of the measures were established and the data were checked for mono-method bias. The data were deemed acceptable for further analysis.

PART II: HYPOTHESIS AND MODEL TESTING

In this section, the inferential analyses are conducted. Firstly, all the predicted relationships between variables in the main model and the minor models were calculated using Pearson's product moment correlation coefficient. In addition, some *post hoc,* non-hypothesised relationships are described. Regression analyses, both hierarchical and standard, were then conducted to test the two central predictions of the main model followed by minor model predictions. Mediation analyses were then undertaken. Furthermore, the regression analyses for the central predictions were re-run, *post hoc* with the TMS first-order factors, to ascertain how these factors influenced the outcome.

9.6 Analysing Relationships

Table 9.2 presents the inter-correlations for all the variables this study. One main model consisting of four sets of variables and four subsidiary models which predict and/or are related to each variable in the main model were tested. In this section the hypotheses related to the main model will be discussed first, followed by the four subsidiary models and their concomitant hypotheses.

9.6.1 Main Model Relationships

The main model variables for testing consisted of quality and quantity of social interaction, transactive memory (composite score), team tacit knowledge and team performance (efficiency and effectiveness). Firstly the relationships between all the variables in the main model were tested, corresponding to predicted hypotheses. These relationships and associated hypothesis numbers are graphically depicted in Figure 9.1.

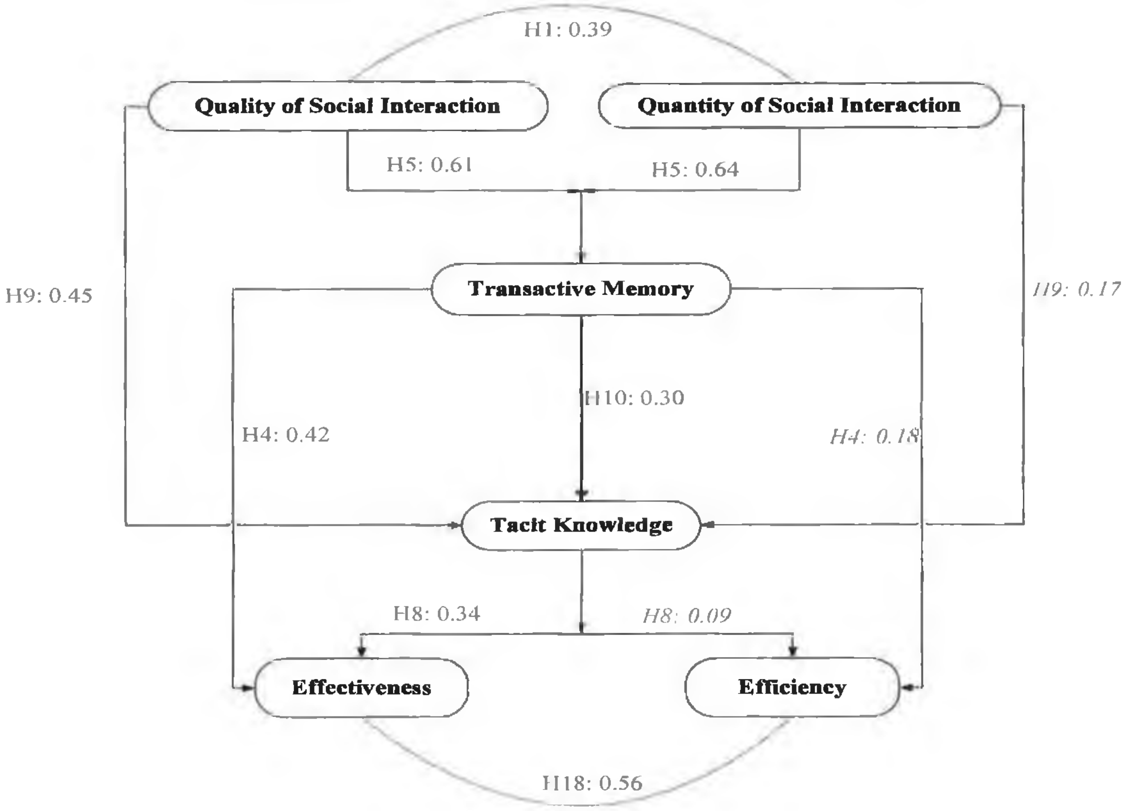
As predicted in *hypothesis 1* there is a significant positive relationship between quality and quantity of social interaction ($r=.39$, $p<.01$) suggesting that as quantity of social interaction increases so does quality of social interaction.

Hypothesis 4 stated that transactive memory would be positively related to team performance. Effectiveness was significantly and positively related to transactive memory composite score ($r=.42$, $p<.01$) but efficiency was not ($r=.18$, $p>.05$). In addition, both quality and quantity of social interaction were positively and significantly related to the development of a transactive memory system (as measured by the TMS composite score; $r=.61$ and $r=.64$, $p<.01$, respectively) providing support for *hypothesis 5*. Furthermore partial support for *hypothesis 8* was evidenced by a significant positive relationship between team tacit knowledge and effectiveness ($r=.34$, $p<.05$) but not efficiency ($r=.09$, $p>.05$), indicating that tacit knowledge is not related to schedule and budget.

A significant positive relationship was found between quality of social interaction and team tacit knowledge ($r=.45$, $p<.01$), but the relationship between quantity of social interaction and team tacit knowledge, while positive in direction, was not significant ($r=.17$, $p>.05$), providing partial support for *hypothesis 9*. This indicates that the nature and quality of the informal social interactions are related to the amount of tacit knowledge within a team, while the frequency of interaction is not.

It was found that team tacit knowledge was significantly and positively related to the composite score for transactive memory ($r=.30$, $p<.05$), providing support for *hypothesis 10*. Finally, *hypothesis 18* stated that there would be a positive relationship between efficiency and effectiveness. Efficiency and effectiveness were significantly and positively related to each other ($r=.56$, $p<.01$), suggesting that the more efficient a project is, the more effective it is also.

Figure 9.1 Main Model Correlation Coefficients and Associated Hypothesis Numbers



Note: Coefficients in blue are not significant.

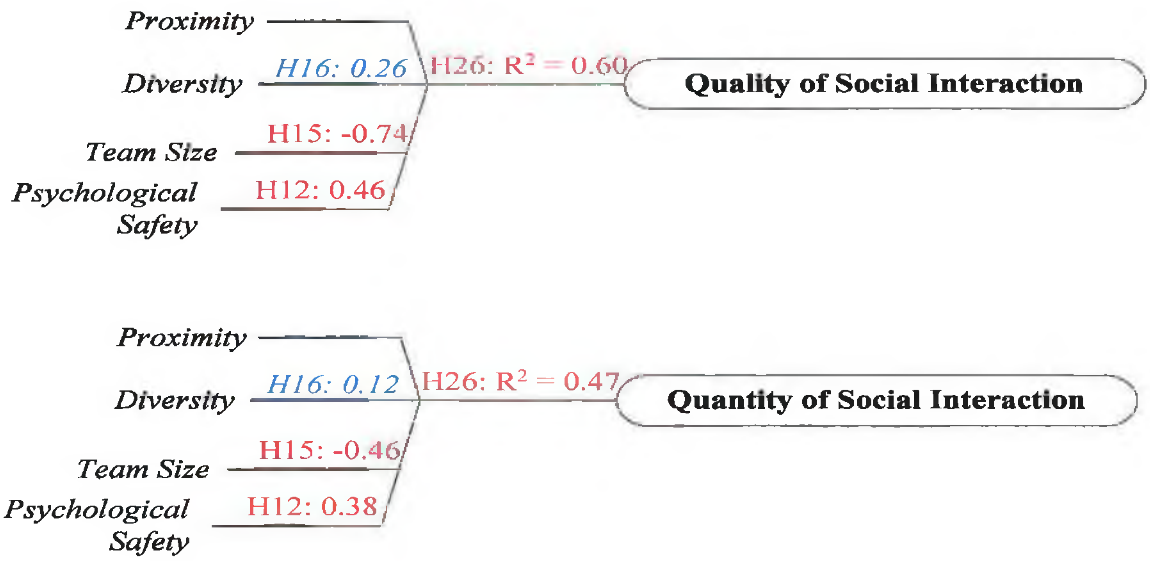
9.6.2 Minor Model 1: Relationships with Social Interaction

The predicted relationships between quality and quantity of social interaction and control variables thought to affect social interaction, i.e. diversity, team size, psychological safety and proximity are outlined below and illustrated in Figure 9.2 along with associated hypothesis numbers and the regression coefficients which are calculated in section 9.8.1.

Hypothesis 12 predicted that there would be a positive relationship between psychological safety and quality and quantity of social interaction ($r=.46$, and $r=.38$, $p<.01$, respectively). This hypothesis was supported by the data, where psychological safety increases as social interaction increases. *Hypothesis 16* predicted that there would be a negative relationship between social interaction (quality and quantity) and diversity. However, the relationships between quality of social interaction, quantity of social interaction and diversity ($r=.26$ and $r=.12$, $p>.05$) respectively, were positive and not significant The percentage diversity within the team has no influence on the quality and quantity of social interaction.

There were significant negative relationships between quality of social interaction, quantity of social interaction, respectively, and team size (r=-.74, and r=-.46, p<.01). Providing support for *hypothesis15*, that larger teams reduce the quality and quantity of social interaction. Finally, *Hypothesis 17* predicted that proximity would affect social interaction. This variable was not included in the analysis of relationships, since it is categorical in nature. Proximity is analysed in the regression analysis.

Figure 9.2 Correlation Coefficients, Regression Coefficients and Hypothesis Numbers for Minor Model 1.



Note: Coefficients in blue are not significant.

Table 9.7 Inter-correlations of all Variables in the Study

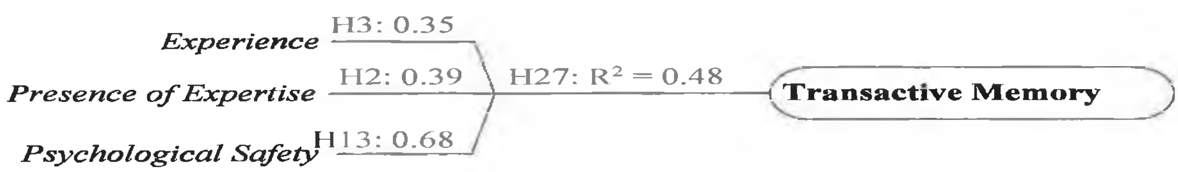
Variables	Correlation Coefficients																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Quality of SI	–																		
2. Quantity of SI	.39**	–																	
3. Specialisation	.21	.33*	–																
4. Credibility	.54**	.66**	.37**	–															
5. Coordination	.66**	.53**	.21	.75**	–														
6. TMS	.61**	.64**	.63**	.90**	.85**	–													
7. TTKM	.45**	.17	-.12	.36*	.42**	.30*	–												
8. Psychological safety	.46**	.38**	.36*	.57**	.69**	.68**	.25	–											
9. Experience	.49**	.13	.08	.35*	.37*	.35*	.23	.29*	–										
10. Familiarity with written procedures	.18	.02	.04	.13	.23	.18	.19	.14	.21	–									
11. Reliance on gut instinct	.26	.14	.27	.20	.31*	.33*	.04	.41**	51**	.02	–								
12. Reliance on written procedures	.20	-.19	.05	.00	.15	.09	.20	.07	.21	.48**	.17	–							
13. Team size	-.74**	-.46**	-.23	-.52**	-.55**	-.56**	-.24	-.47**	-.36*	-.03	-.37	.03	–						
14. Diversity	.26	.12	.27	.17	.19	.26	.18	.02	-.08	.27	-.04	.25	-.25	–					
15. Expertise presence	.29*	.16	.07	.43**	.40**	.39**	.18	.41**	.35*	.15	.09	.04	-.26	-.01	–				
16. Formal knowledge sharing system	.24	.25	-.07	.40**	.34*	.30*	.21	.29*	.19	.52**	.06	.18	-.15	.18	.37**	–			
17. Administrative coordination	-.18	-.19	-.05	.11	-.04	-.09	.08	-.00	-.12	.36*	-.01	.29*	.29*	.21	.05	.34*	–		
18. Effectiveness	.13	.15	.05	.32*	.44**	.42*	.34*	.42**	.24	.30*	.30*	.20	-.17	.15	.25	.24	.08	–	
19. Efficiency	-.03	-.08	.10	.10	.22	.18	.09	.28	-.01	.33*	.09	.15	.16	.02	.36*	.40**	.52**	.56**	–
20. New product development	-.12	-.08	.00	.05	.13	.08	.13	.04	-.04	.35*	.12	.13	.05	.02	.00	.17	.02	.48**	.38**

*p<.05, **p<.01

9.6.3 Minor Model 2: Relationships with Transactive Memory

As with previous models, the zero-order correlations between the variables in the model were explored in order to test the relevant hypotheses, in this case *hypotheses 2, 3* and *13* predicted that transactive memory would be positively related to presence of expertise, experience and psychological safety, respectively. Transactive memory was significantly and positively related to all three control variables. Suggesting that higher the levels of expertise (r=.39, p<.01), experience (r=.35, p<.05) and psychological safety (r=.68, p<.01) within a team, lead to a more developed transactive memory system. These correlation coefficients and associated hypothesis numbers are depicted, along with the regression coefficient (calculated in section 9.8.2) in Figure 9.3.

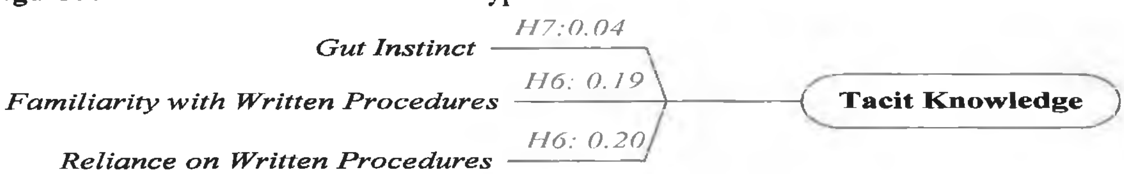
Figure 9.3 Correlation Coefficients, Regression Coefficient and Hypothesis Numbers for Minor Model 2



9.6.4 Minor Model 3: Relationships with Team Tacit Knowledge

Tacit knowledge at the team level was not related to intuition as measured by gut instinct, therefore *hypothesis 7* was not supported (r=.04, p>.05). This means that convergent validity was not provided by the 'gut instinct', variable. Discriminant validity was in evidence since, team tacit knowledge was not significantly related to explicit job knowledge as measured by 'familiarity with written job procedures' (r=.19, p>.05) and by 'reliance on these written procedures'(r=.20, p>.05) (*hypothesis 6).* These correlation coefficients along with associated hypothesis numbers are shown in Figure 9.4. A full discussion of the validity of the TTKM was presented in Chapter 8.

Figure 9.4 Correlation Coefficients and Hypothesis Numbers for Minor Model 3

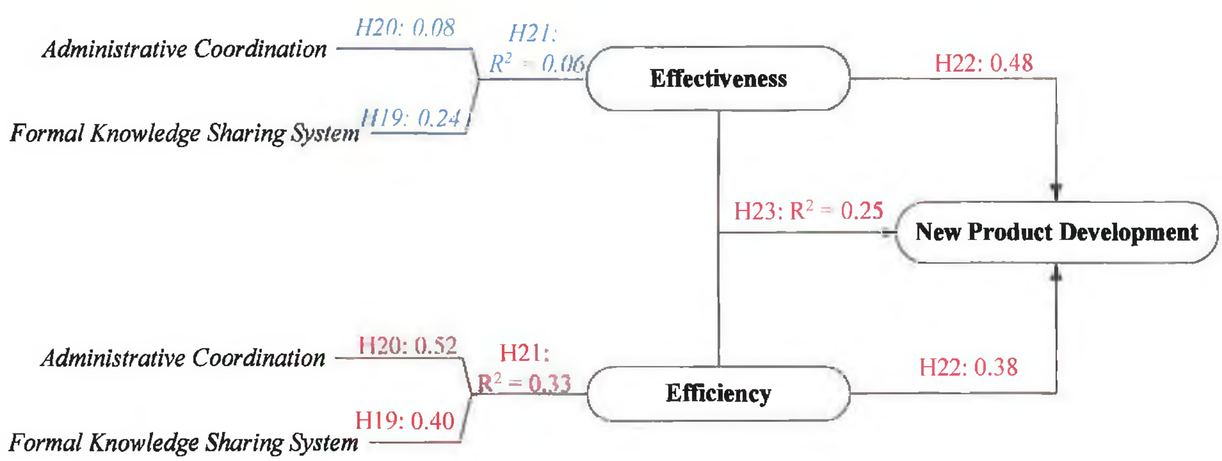


Note: Coefficients in blue are not significant.

9.6.5 Minor Model 4: Relationships with Team performance

Hypotheses 19 and 20 predicted the significant positive relationships between team performance as measured by efficiency and effectiveness and control variables thought to affect team performance i.e. presence of a formal knowledge sharing system and administrative coordination. It was found that both administrative coordination and presence of a formal knowledge sharing system were significantly and positively related to efficiency (r= .52, and r=.40, p<.01) respectively, but not effectiveness, (r= .08 and r=.24, p>.05, respectively), providing partial support for the hypotheses. This suggests that formal coordination and communication influences scheduling and budget but not the quality of the work. In addition, *hypothesis 22* predicted that team performance would be related to new product development capability. This hypothesis was supported by the data, where effectiveness and efficiency were positively related to NPD (r=.48 and r =.38, p<.01, respectively). This indicates that more effective and efficient teams have more competitive products. These correlation coefficients and associated hypothesis numbers are depicted, along with the regression coefficients (calculated in sections 9.8.3 and 9.8.4) in Figure 9.5.

Figure 9.5 Correlation Coefficients, Regression Coefficients and Hypothesis Numbers for Minor Model 4

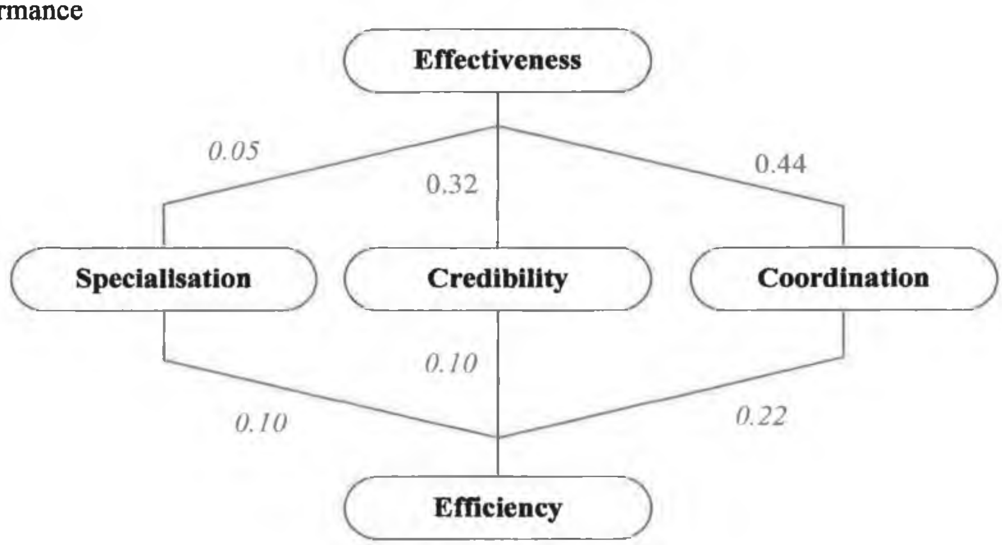


Note: Coefficients in blue are not significant.

9.6.6 Post hoc Relationships with Transactive Memory First Order Factors

In this section, all predicted relationships with transactive memory are examined in relation to the first order factors of credibility, coordination and specialisation. In the main model, *hypothesis 4* related transactive memory to team performance. Broken down to its component parts (first order factors), it was found that effectiveness was significantly related to the first order factors of credibility and coordination. This suggests that the more credibility and coordination in a team the more effective it is. However, effectiveness was not related to the specialisation in the team and none of the first order factors were related to efficiency (see Figure 9.6).

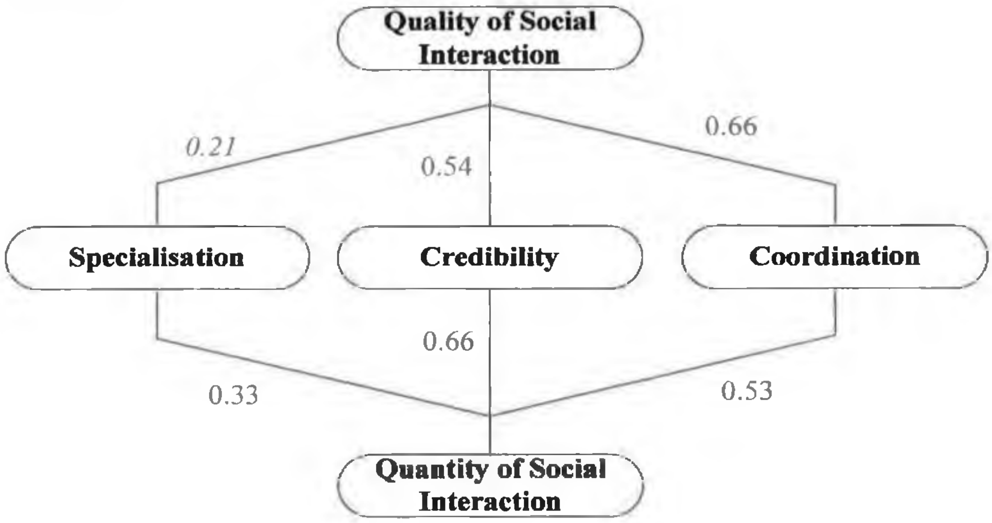
Figure 9.6 Correlation Coefficients for Transactive Memory First Order Factors and Team Performance



Note: Coefficients in blue are not significant.

Hypothesis 5 predicted that social interaction (quality and quantity) would vary according to transactive memory. Quality of social interaction was significantly, positively related to coordination and credibility, but not to specialisation. This suggests that specialisation or differentiated structure of team members' knowledge is not influenced by quality of social interaction. Quantity of social interaction was significantly, positively related to coordination, credibility, and specialisation (see Figure 9.7).

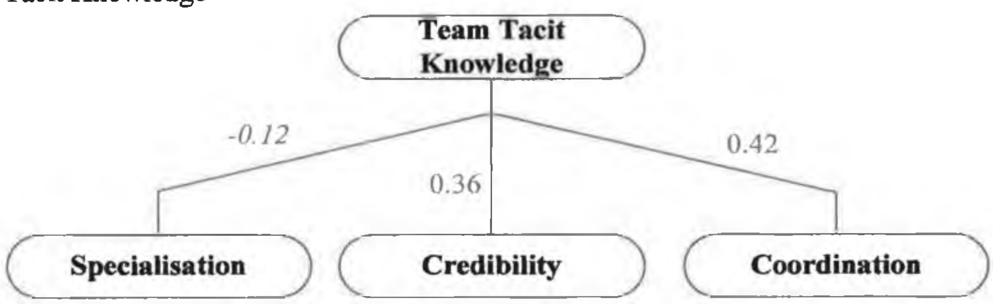
Figure 9.7 Correlation Coefficients for Transactive Memory First Order Factors and Social Interaction



Note: Coefficients in blue are not significant.

Hypothesis 10, posited a relationship between transactive memory and team tacit knowledge. When the TMS construct was separated into its first order factors, there were significant positive relationships between team tacit knowledge and credibility and coordination. However, team tacit knowledge was not significantly related to specialisation and the relationship between the two variables was negative (see Figure 9.8). Suggesting that, the more differentiated the structure of the team members' knowledge, the less team tacit knowledge that is present.

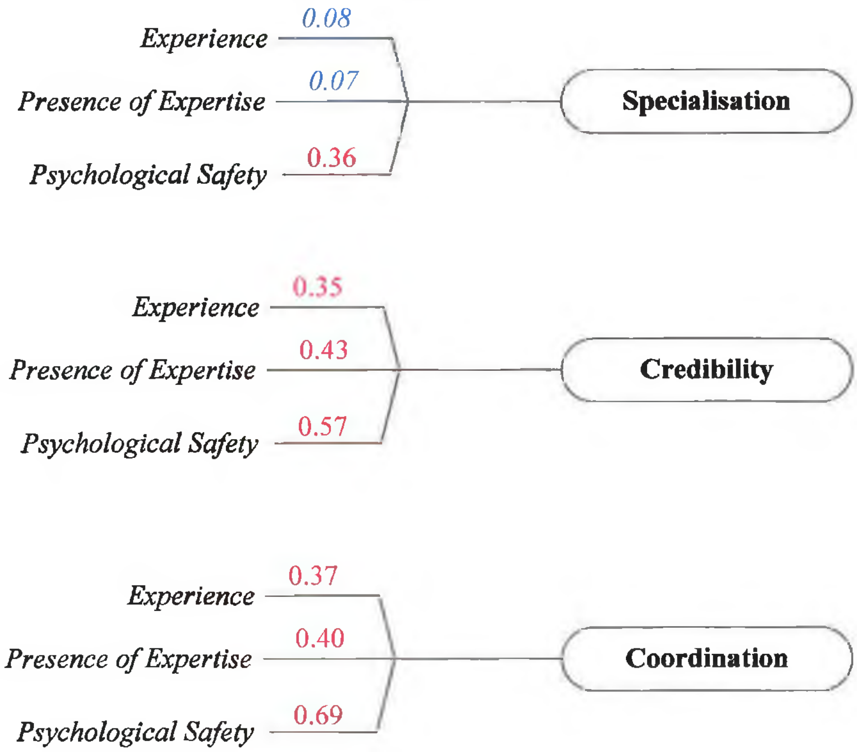
Figure 9.8 Correlation Coefficients for Transactive Memory First Order Factors and Team Tacit Knowledge



Note: Coefficients in blue are not significant.

In minor model 2, the first order factors credibility and coordination were significantly and positively related to psychological safety, presence of expertise and experience relating to *hypotheses 2, 3* and *13,* respectively as depicted in Figure 9.9. However, specialisation, was only significantly related to psychological safety and not to presence of expertise or experience (see Figure 9.9). This suggests that knowledge about the presence of differentiated knowledge in a team, is aided by an atmosphere of psychological safety.

Figure 9.9 Correlation Coefficients for Transactive Memory First Order Factors and Psychological Safety, Presence of Expertise and Experience



<u>Note:</u> Coefficients in blue are not significant.

9.6.7 Non-Hypothesised Relationships

A number of non-hypothesised significant relationships were found. Reliance on gut instinct was positively related to transactive memory, coordination, psychological safety, experience, and effectiveness. In addition, reliance on gut instinct was negatively related to team size. Suggesting that relying on gut instinct contributes to the development of a transactive memory system, and to the coordination of expertise. Teams with more experienced members also tended to rely on gut instinct and finally, the more individuals relied on gut instinct the more effective they were.

Experience and psychological safety were also related to presence of expertise. In addition psychological safety and transactive memory were associated with the presence of a formal knowledge sharing system and transactive memory was related to smaller teams, evidenced by the negative correlation coefficient with team size.

Furthermore, explicit job knowledge as measured by 'familiarity with written procedures' was directly related to presence of a knowledge sharing system, administrative coordination, efficiency, effectiveness and product performance. Indicating that explicit knowledge may be shared though formal sharing systems and is also implicated in successful performance and competition. Finally, explicit job knowledge as measured by 'reliance on written procedures' was related to administrative coordination, which in turn was positively related to team size, where the larger the team the more use of administrative coordination.

The most important non-hypothesised correlations are those that relate to team performance.

9.6.8 Summary of Relationships

Quality and quantity of social interaction were found to be interdependent, with only quality of social interaction indicating higher levels of tacit knowledge within the team. The greater the quality and quantity of social interaction, the better developed the overall transactive memory system and levels of psychological safety, however, the percentage diversity within the teams did not influence social interaction. It was also found that larger teams reduce the quality and quantity of social interaction.

To summarise transactive memory and team tacit knowledge, it was found that higher levels of expertise, experience and psychological safety were associated with a more developed transactive memory system and team tacit knowledge was not related to gut instinct, or explicit job knowledge.

In terms of team performance, team tacit knowledge and overall transactive memory were both associated with effectiveness but not efficiency. Formal coordination and communication influences scheduling and budget but not the quality of the work. In addition, more effective and efficient teams have a better 'new product development capability'.

In relation to the TMS first order factors, coordination and credibility were both associated with higher levels of team tacit knowledge and effectiveness. Specialisation within the team is not associated with team tacit knowledge or team performance. Finally, the most important non-hypothesised correlations are those that relate to team performance. Gut instinct was related to effectiveness and explicit job knowledge was related to effectiveness, efficiency and new product development capability, indicating that explicit knowledge is also important to team performance, but is possibly shared through different channels than tacit knowledge.

9.7 Predicting Relationships between Main Model Variables

9.7.1 Predicting Team Tacit Knowledge using Hierarchical Multiple Regression

Hypothesis 24 predicted that social interaction (quality and quantity) would predict team tacit knowledge above and beyond transactive memory. To test this hypothesis a hierarchical regression was conducted to ascertain the extent to which quality and quantity of social interaction in software development teams accounts for unique variance in team tacit knowledge ratings. Transactive memory was entered as a weighted composite score and the results of the hierarchical regression analysis for the 48 teams are presented in Table 9.8. Firstly, the weighted composite TMS score was entered as a control variable in step 1. Scores on the quality and quantity of social interaction were entered in step 2.

The results illustrated in Table 9.8 indicate that in step 1, transactive memory explains 9% of the variance and is statistically significant ($F_{1, 46} = 4.44$, $p<.05$). Around 20 % of the variance in team tacit knowledge is accounted for by all of the variables combined in the full model, which is statistically significant ($F_{3, 44} = 3.76$, $p<.05$). Quality and quantity of social interaction significantly describe 12% of variance in team tacit knowledge above and beyond transactive memory ($\Delta F = 3.20$, $p<.05$). The beta weight for transactive memory is significant in step 1, indicating that alone transactive memory is a significant predictor of team tacit knowledge.

Table 9.8 Hierarchical Regression of Team Tacit Knowledge on Transactive Memory and on Quality and Quantity of Social Interaction

Independent variables	**Standardised beta weights**				**Df**
	Step1		Step 2		
	B	t	B	t	
Step1: Control variables					1, 46
TMS composite score	.30	2.11*	.06	.31	
Step 2: Social interaction					3, 44
Quality			.43	2.52*	
Quantity			- .04	- .23	
R^2	.09		.20		
R^2_{adj}	.06		.15		
F	4.44*		3.76*		
ΔR^2			.12		
ΔF			3.20*		

*p<.05, **p<.01

However, in step 2, when quality and quantity of social interaction are input, only the beta weight for quality of social interaction is statistically significant (Beta = 0.43, t = 2.27, p<.01). This means that when other independent variables are held constant, quality of social interaction will increase team tacit knowledge by almost half a standard deviation. This highlights the unique importance of quality of social interaction in predicting team tacit knowledge relative to the other variables in the regression equation.

The quantity of social interaction score was positively, though not significantly correlated with the criterion variable (see Table 9.7) and was significantly related to transactive memory and to quality of social interaction. However, it is important to note that quantity of social interaction has a negative beta weight in the regression model. The 'sign' of the relationship has changed suggesting that this is a suppressor variable. This means that to include quantity of social interaction, serves to suppress or discount scores on quality of social interaction and transactive memory, of teams who had high scores on the team tacit knowledge measure because of quantity of social interaction rather than because of their quality of interaction or transactive memory. Thereby, leaving transactive memory and quality of social interaction as improved predictors of team tacit knowledge.

Therefore, *hypothesis 24* for quality of social interaction is supported, but not for quantity of social interaction. In addition, the combination of all the transactive memory, quality of social interaction and quantity of social interaction variables combined are significant predictors of team tacit knowledge (see Figure 9.10).

9.7.2 Predicting Team Performance

Hypothesis 25 predicted that team tacit knowledge will predict team performance (efficiency and effectiveness) above and beyond quality of social interaction, quantity of social interaction and transactive memory (weighted composite score). Two hierarchical regressions were conducted to test this hypothesis with effectiveness and efficiency, in turn acting as the dependent variable. The results of the two hierarchical regressions are presented in tables 9.9 and 9.10, respectively.

9.7.2.1 Predicting Effectiveness

Table 9.9 presents the results of the hierarchical regression analysis for the 48 teams. to ascertain the extent to which team tacit knowledge in software development teams accounts for unique variance in effectiveness ratings. In the hierarchical regression quality and quantity of social interaction and the composite score on transactive memory were entered as control variables in step 1. Scores on the team tacit knowledge and quantity of social interaction were entered in step 2.

Table 9.9 Hierarchical Regression of Effectiveness on Transactive Memory, Social Interaction and on Team Tacit Knowledge

Independent variables	Standardised beta weights				Df
	Step1		Step 2		
	B	t	B	t	
Step 1: Control variables					3, 44
TMS composite score	.52	2.46*	.50	2.46*	
Quality SI	- .13	- .73	- .27	-1.53	
Quantity SI	- .14	- .75	- .12	- .70	
Step 2: Team Tacit Knowledge					
Team tacit knowledge			.34	2.29*	4, 43
R^2	.15		.24		
R^2_{adj}	.09		.17		
F	2.50		3.37*		
ΔR^2			.10		
ΔF			5.25*		

*p<.05, **p<.01

The results in Table 9.9 show that the first model entered in step 1 indicates that transactive memory composite score, quality and quantity of social interaction explain 15 % of the variance in effectiveness and is statistically non-significant ($F_{3,\,44} = 2.50$, p>.05). Around 24 % of the variance in effectiveness is accounted for by all of the variables combined in the full model, which is statistically significant ($F_{4, 43} = 3.37$ $p<.05$). Team tacit knowledge describes 10% of variance in effectiveness above and beyond the transactive memory and quality and quantity of social interaction and is statistically significant ($\Delta F = 5.25$, $p<.05$). The ratio of beta weights is the estimated unique predictive importance of the independent variable.

However the beta weights for transactive memory and team tacit knowledge are statistically significant Beta = .50 and .34 respectively. Therefore with other variables held constant, effectiveness was positively related to transactive memory and team tacit knowledge, increasing by half a standard deviation for every one unit increase in transactive memory and by .30 of a standard deviation for every unit increase in team tacit knowledge. This suggests that transactive memory and team tacit knowledge have a greater influence on effectiveness, since their influence on effectiveness remains significant when all other independent variables are partialled out.

Quality and quantity of social interaction were not significantly correlated with the criterion variable. However, these two independent variables were significantly correlated with other independent variables in the model and have negative beta weights. Quality and quantity of social interaction act as suppressor variables.

Therefore *hypothesis 25* is supported for effectiveness, where team tacit knowledge predicts effectiveness above and beyond social interaction and transactive memory (see Figure 9.10).

9.7.2.2 Predicting Efficiency

Table 9.10 presents the results of the hierarchical regression analysis for the 48 teams to ascertain the extent to which team tacit knowledge in software development teams accounts for unique variance in efficiency ratings. Quality and quantity of social interaction and transactive memory weighted composite score were entered as the control variables in step 1 and scores for team tacit knowledge were entered in step 2.

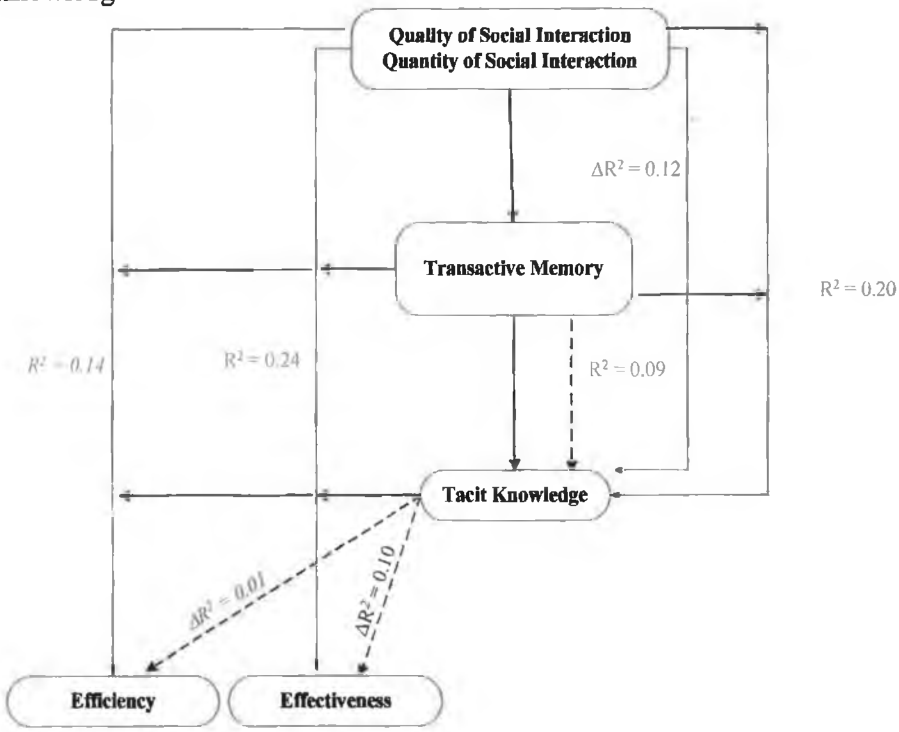
Table 9.10 Hierarchical Regression of Efficiency on Transactive Memory, Social Interaction and Team Tacit Knowledge

Independent variables	Standardised beta weights				Df
	Step1		Step 2		
	B	t	B	t	
Step 1: Control variables					3, 44
TMS composite score	.53	2.49*	.52	2.44*	
Quality SI	- .22	-1.25	- .27	-1.43	
Quantity SI	- .34	-1.85	- .33	-1.81	
Step 2: Team Tacit Knowledge					4 43
Team tacit knowledge			.12	.74	
R^2	.13		.14		
R^2_{adj}	.07		06		
F	2.19		1.76		
ΔR^2			.01		
ΔF			0.54		

*p<.05, **p<.01

The hierarchical regression in Table 9.10 is statistically non-significant for the full model ($F_{4, 43}$ = 1.76, p> .05) and for the hierarchical change (ΔF = 0.54, p> .05). This means that transactive memory, quality and quantity of social interaction and team tacit knowledge do not predict efficiency (see Figure 9.10). Moreover, team tacit knowledge does not predict efficiency above and beyond, transactive memory and quality and quantity of social interaction. However, transactive memory significantly predicts efficiency when all other variables are held constant. Unusually, the TMS composite score was not significantly related to efficiency in the zero-order correlations in Table 9.7. It appears, that, the other variables in this combination are acting as suppressors, thereby, improving the predictive value of TMS. This is considered to be a spurious result, based on this particular combination. Therefore, *hypothesis 25* is not supported for efficiency. But it may be concluded that transactive memory, in the presence of social interaction and team tacit knowledge is a predictor of efficiency when the effects of the other two variables are removed, but verification of this finding is beyond the scope of the present study.

Figure 9.10 Regression Coefficients Predicting Transactive Memory and Team Tacit Knowledge



Note: Coefficients in blue are not significant.

9.8 Predicting Relationships for Minor Models

9.8.1 Predicting Social Interaction

Hypothesis 26 predicted that proximity, team size, diversity, and psychological safety would predict social interaction (quality and quantity). In order to test this hypothesis, two standard regressions were conducted, for quality and quantity of social interaction, the results are represented in Tables 9.11 and 9.12, respectively, these regression coefficients are also illustrated in Figure 9.2.

The categorical variable proximity, which has five levels was dummy coded. Categorical predictor variables cannot be entered directly into a regression model and be meaningfully interpreted. Proximity was converted to four dichotomous variables, since a categorical variable with k levels will be transformed into k-1 variables each with two levels. Dichotomous variables have the advantage that they can be directly entered into the regression model. The modal category was dropped from the regression analysis i.e. proximity between 0 and 5 metres, to be used as a relative measure. The R^2 and F values are not affected by the choice of which category to eliminate (Miles & Shevlin, 2001).

The standard multiple regression is shown in Table 9.11. The regression fit was rather good (R^2 = 60 %) and the overall relationship was significant ($F_{7, 40}$ = 8.44, p<.001). Only the beta weight for team size was significant, therefore with all other independent variables held constant, team size has a significant negative relationship with quality of social interaction. This means that scores on the quality of social interaction increase by 0.64 of a standard deviation for every unit decrease in team size. Psychological safety is no longer significantly related to quality of social interaction when the effects of the other independent variables are partialled out, suggesting that team size is the 'real' influence on quality of social interaction.

Table 9.11 Multiple Regression of Quality of Social Interaction on Team Size, Presence of Formal Knowledge Sharing System, Diversity, Psychological Safety and Proximity

Independent Variables	Beta	t	R^2	R^2_{adj}	F	Df
			.60	.53	8.44***	7, 40
Team size	- .64	-5.36***				
Diversity	.14	1.21				
Psychological safety	.16	1.09				
6-10 metres	.00	.04				
11-30 metres	- .10	- .95				
Different office	.00	.06				
Different building	- .12	-1.17				

***P<.001

Table 9.12 Multiple Regression of Quantity of Social Interaction on Team Size, Presence of Formal Knowledge Sharing System, Diversity, Psychological Safety and Proximity

Independent Variables	Beta	T	R^2	R^2_{adj}	F	Df
			.47	.37	5.00**	7, 40
Team size	- .32	-2.33*				
Diversity	.10	.75				
Psychological safety	.23	1.68				
6-10 metres	- .08	- .61				
11-30 metres	- .47	-4.00**				
Different office	- .03	- .26				
Different building	- .03	- .28				

*p<.05, **p<.01

In Table 9.12, the regression model accounted for 47% of the variance in quantity of social interaction and the overall relationship was significant ($F_{7, 40}$ = 5.00, p<.01). The beta weight for team size was significant, therefore with all other independent variables held constant, team size has a significant negative relationship with quantity of social interaction. This means that scores on the quantity of social interaction increase by .32 of a standard deviation for every unit decrease in team size. Psychological safety, which had a strong, significant positive correlation with quantity of social interaction is no longer significant (Beta = .23, P>.05) when the effects of the other independent variables are partialled out. This suggests that psychological safety makes a strong joint contribution to explaining quantity of social interaction but not a unique contribution in this regression equation. Team size has the most 'unique' influence on quantity of social interaction. The proximity coefficient was significant for a distance of 11-30 metres, this indicates that for a proximity of 11-30 metres the quantity of social interaction is .47 of a standard deviation less than the modal of proximity of 0-5 metres, while controlling for all other independent variables.

9.8.2 Predicting Transactive Memory

Hypothesis 27 stated that team psychological safety, experience and presence of expertise would predict transactive memory. A standard multiple regression was conducted to test this hypothesis for the weighted transactive memory score (Table 9.11). The regression coefficients are also illustrated in Figure 9.5.

In Table 8, the model was significant ($F_{3, 44} = 13.78$, $p<.01$) accounting for 48% of the variance in transactive memory. Therefore psychological safety, experience and presence of expertise together are a good model for the prediction of transactive memory. The beta weight for psychological safety was significant, therefore with all other independent variables held constant, psychological safety has a significant positive relationship with transactive memory. This means that scores on the transactive memory increase by .61 of a standard deviation for every unit increase in psychological safety. Psychological safety is the most influential predictor in the model.

Table 9.11 Multiple Regression of Transactive Memory on Psychological Safety, Years of Experience and Presence of Expertise

Independent Variables	Beta	t	R^2	R^2_{adj}	F	Df
			.48	.45	13.78***	3, 44
Psychological safety	.61	5.08***				
Experience	.13	1.11				
Expertise presence	.07	.55				

***p<.001

9.8.3 Predicting Team performance

Hypothesis 21 predicted that administrative coordination and presence of a formal knowledge sharing system will predict team performance (efficiency and effectiveness).

Two standard multiple regressions were conducted to test the hypothesis for both effectiveness and efficiency, and the results are shown in Tables 9.13 and 9.14, respectively. The regression model was not significant for effectiveness, this is to be expected since the zero-order correlations between the three variables were not significant. Therefore, presence of a formal knowledge sharing system and administrative coordination do not provide a good model to predict effectiveness.

Table 9.13 Multiple Regression of Effectiveness on Administrative Coordination and Presence of a Formal Knowledge Sharing System

Independent Variables	Beta	t	R^2	R^2adj	F	Df
			.06	.01	1.35	2,45
Administrative coordination	.00	.02				
Knowledge sharing system	.24	1.53				

*p<.05, **p<.01

Table 9.14 Multiple Regression of Efficiency on Administrative Coordination and Presence of a Formal Knowledge Sharing System

Independent Variables	Beta	t	R^2	R^2adj	F	Df
			.33	.30	11.01***	2, 45
Administrative coordination	.43	3.34**				
Knowledge sharing system	.25	1.95				

**p<.01, ***p<.001

In Table 9.14, the regression model was significant accounting for 33% of the variance in efficiency ($F_{2, 45} = 11.01$, $p<.001$). The beta weight for administrative coordination was significant, therefore with presence of a formal knowledge sharing system held constant, administrative coordination has a significant positive relationship with efficiency. This means that scores on the efficiency increase by .43 of a standard deviation for every unit increase in administrative coordination. Administrative coordination appears to exert more influence in the model than does the presence of a formal knowledge sharing system.

9.8.4 Predicting New Product Development Capability

Hypothesis 23 predicted that team performance (efficiency and effectiveness) will predict new product development capability. The results of the standard regression used to test this hypothesis is outlined in table 9.15. The regression model accounts for 25 % of the variance in new product development capability and is significant ($F_{2, 45} = 7.52$, $p<.01$). Effectiveness is significantly related to new product development capability, when the effects of efficiency are removed. Effectiveness appears to be more important predictor of new product development capability than efficiency.

Table 9.15 Multiple Regression of New Product Development Capability on Effectiveness and Efficiency

Independent Variables	Beta	t	R^2	R^2adj	F	Df
			.25	.22	7.52**	2, 45
Effectiveness	.39	2.54*				
Efficiency	.16	1.02				

*p<.05, **p<.01

9.9 Tests of Mediation

Two hypotheses predicted mediated relationships: *hypothesis 11* predicted that social interaction (quality and quantity) and team tacit knowledge will be mediated by the development of a transactive memory system and *hypothesis 14* predicted that the relationship between social interaction (quality and quantity) and transactive memory will be mediated by psychological safety.

To test these hypotheses a four stage analysis was conducted to test whether the three conditions for mediation were satisfied: (1) the independent variable significantly predicts the dependent variable, (2) the independent variable predicts the proposed mediator, and (3) the mediator is a significant predictor of the dependent variable, when we control for the independent variable (4) If the mediator is a complete mediator of the relationship between the independent variable and the dependent variable, the effect of the independent variable when controlling for the mediator, should be zero (Baron & Kenny, 1986), or at least not significant (Miles & Shevlin, 2001). The results of the mediation analyses for *hypotheses 11* and *14* are shown in tables 9.16 and 9.17 respectively.

Table 9.16 Mediation Analysis for Transactive Memory

Conditions to Demonstrate Mediation in Three Stages	Independent variable	B	t	p	R^2
Stage 1					
Does quality of social interaction significantly predict *team tacit knowledge*?	Quality of social interaction	.59	3.41	<.01	.20
Does quantity of social interaction significantly predict *team tacit knowledge*?	Quantity of social interaction	.02	1.15	>.05	.03
Stage 2					
Does quality of social interaction significantly predict *transactive memory* (composite score)?	Quality of social interaction	1.40	5.22	<.001	.37
Stages 3 & 4					
Does transactive memory predict *team tacit knowledge* when quality of social interaction is controlled?	Transactive memory	.02	.21	>.05	.20
	Quality of social interaction	.56	2.55	<.01	

In stage 1, team tacit knowledge was regressed on quality of social interaction and quantity of social interaction, respectively. Quality of social interaction satisfied the first condition for mediation (B = .59, p<.01), quantity of social interaction did not, and so was not included in further mediation analyses. Furthermore, it is noted that quality social interaction accounts for 37% of the variance in transactive memory. In stage 2 the second order factor of composite transactive memory were regressed on quality of social interaction. In the final stage, team tacit knowledge was regressed on transactive memory, while controlling for quality of social interaction. The mediators ceased to exert a significant influence on team tacit knowledge when quality of social interaction was controlled. Therefore, the third condition for mediation was not met. Therefore social interaction (quality and quantity) and team tacit knowledge are not mediated by transactive memory.

Table 9.17 Mediation Analysis for Team Psychological Safety

Conditions to Demonstrate Mediation in Four Stages	Independent variable	B	t	p	R^2
Stage 1					
Does quality of social interaction significantly predict *transactive memory* (composite score)?	Quality of social interaction	1.40	5.22	<.001	.37
Does quantity of social interaction significantly predict *transactive memory*?	Quantity of social interaction	.16	5.71	<.001	.40
Stage 2					
Does the quality of social interaction significantly predict *psychological safety*?	Quality of social interaction	1.08	3.52	<.001	.21
Does the quantity of social interaction significantly predict *psychological safety*?	Quantity of social interaction	.10	2.8	<.01	.15
Stages 3 and 4					
Does psychological safety predict *transactive memory* when quality of social interaction is controlled?	Psychological safety	.50	4.21	<.001	.58
	Quality of social interaction	.86	3.42	<.01	
Does psychological safety predict *transactive memory* when quantity of social interaction is controlled?	Psychological safety	.51	5.32	<.001	.64
	Quantity of social interaction	.11	4.64	<.001	

In stage 1 the second order factor of transactive memory was regressed on quality of social interaction and the quantity of social interaction respectively. Quality of social interaction and quantity of social interaction were found to be significant predictors of transactive memory, satisfying condition one for mediation.

In the second stage, psychological safety was regressed on the quality of social interaction and the quantity of social interaction respectively. Both quality and quantity of social interaction were significant predictors of psychological safety. The second condition for mediation was met.

The third condition was assessed first for quality of social interaction. Psychological safety was a significant predictor of transactive memory (composite score), while controlling for quantity of social interaction, satisfying the third condition for mediation. The amount of mediation for transactive memory (composite score), was calculated by finding the difference in the slopes from stage 1 to stage 4, which was 1.40 – 0.86 = 0.54. The third condition is now assessed for quantity of social interaction. Psychological safety was a significant predictor of the independent variables, transactive memory, while controlling for quality of social interaction, satisfying the third condition, for mediation. The amount of mediation for transactive memory was calculated by finding the difference in the slopes from stage 1 to stage 4, which was 0. 16 – 0.11 = 0.05.

However, psychological safety can only be viewed as a partial mediator since quality and quantity of social interaction are still significant predictors of transactive memory (composite score), but there was a reduction in effect due to psychological safety.

9.10 Post hoc Predictions with Transactive Memory First Order Factors

The central hypotheses for the main model, were re-run, *post hoc*, with the first order factors of credibility, specialisation and coordination.

9.10.1 Predicting Team Tacit Knowledge

To test the hypothesis that social interaction (quality and quantity) would predict tacit knowledge above and beyond transactive memory (*hypothesis 24*), the first order factors (specialisation, coordination and credibility) were entered together as control variables, in the hierarchical regression (step 1). Scores on the quality and quantity of social interaction were entered in step 2. The results are presented in Table 9.18 and depicted in Figure 9.11.

The results in table 9.18 show that the first model entered in step 1 of the first order factors specialisation, credibility and coordination an explain 24 % of the variance and is statistically significant ($F_{3,\ 44}$ = 4.62, p<.01). Around 30 % of the variance in team tacit knowledge is accounted for by all of the variables combined in the full model, which is statistically significant ($F_{5,\ 42}$ = 3.68, p<.01; see Figure 9.11). Quality and quantity of social interaction describe 6 % of variance in team tacit knowledge above and beyond the first order factors and are not significant (ΔF = 3.71, p>.05).

None of the beta weights were significant for the full model, credibility, coordination, quality of social interaction and team tacit knowledge were all significantly to related to one another (Table 9.7) but each is no longer significantly related to team tacit knowledge when the effects of the others are removed. Indicating that the variables make a strong joint contribution in the model, but may underestimate the unique importance of each variables.

Quantity of social interaction was positively, though not significantly correlated with the criterion variable and has a negative beta weight. To include quantity of social interaction in the model serves to suppress or discount scores on the other predictors of teams scored higher on team tacit knowledge because of quantity of social interaction rather than because of their scores on coordination, credibility and quality of social interaction. Specialisation does not significantly predict team tacit knowledge and is negative in direction, consistent with the zero-order correlation.

Table 9.18 Hierarchical Regression of Team Tacit Knowledge on Specialisation, Credibility and Coordination and on Quality and Quantity of Social Interaction

Independent variables	Standardised beta weights Step1		Step 2		Df
	B	t	B	t	
Step 1: Control variables					3, 44
Specialisation	- .27	-1.86	- .27	- 1.94	
Credibility	.22	1.07	.26	1.13	
Coordination	.31	1.53	.12	.54	
Step 2: Social interaction					
Quality			.33	1.90	5, 42
Quantity			- .10	- .61	
R^2	.24		.30		
R^2_{adj}	.19		.22		
F	4.62**		3.68**		
ΔR^2			.06		
ΔF			1.97		

*p<.05, **p<.01

9.10.2 Predicting Team Performance

Hypothesis 25 predicted that team tacit knowledge will predict team performance (efficiency and effectiveness) above and beyond quality of social interaction, quantity of social interaction and transactive memory. Two hierarchical regressions were conducted to test this hypothesis for effectiveness and efficiency. The results of the two hierarchical regressions are presented in tables 9.19 and 9.20, respectively.

9.10.2.1 Predicting Effectiveness

Table 9.19 presents the results of the hierarchical regression where quality and quantity of social interaction and the first order factors of transactive memory (specialisation, credibility and coordination) were entered as control variables in step 1. Scores on the team tacit knowledge were entered in step 2.

Table 9.19 Hierarchical Regression of Effectiveness on Specialisation, Credibility, Coordination, Social Interaction and on Team Tacit Knowledge

Independent variables	Standardised beta weights Step1		Step 2		Df
	B	t	B	t	
Step 1: Control variables					5, 42
Specialisation	- .01	- .10	.06	.41	
Credibility	.08	.33	.00	.02	
Coordination	.64	2.80*	.61	2.71**	
Quality SI	- .28	-1.56	- .37	-2.04	
Quantity SI	- .13	- .70	- .10	- .55	
Step 2: Team Tacit Knowledge					6, 41
Team tacit knowledge			.28	1.79	
R^2	.25		.31		
R^2_{adj}	.16		.20		
F	2.84*		3.03*		
ΔR^2			.05		
ΔF			3.22		

*p<.05, **p<.01

The results in table 9.19 show that the first model entered in step 1 indicates that specialisation, credibility coordination, quality and quantity of social interaction explain 25% of the variance in effectiveness and is statistically significant ($F_{5, 42} = 2.84$, $p<.05$). Around 31% of the variance in effectiveness is accounted for by all of the variables combined in the full model, which is statistically significant ($F_{6, 41} = 3.03$ $p<.05$; see Figure 9.11). Team tacit knowledge describes 5% of variance in effectiveness above and beyond the first order factors and quality and quantity of social interaction and is statistically non-significant ($\Delta F = 3.22$, $p>.05$). The ratio of beta weights is the estimated unique predictive importance of the independent variable. The only statistically significant beta weight was coordination. Quality and quantity of social interaction act as suppressor variables in this model, since these two variables were positively though not significantly related to effectiveness and are now negatively related to effectiveness in the model.

9.10.2.2 Predicting Efficiency

Table 9.20 presents the results of the hierarchical regression analysis for the 48 teams where the first order factors of transactive memory (specialisation, credibility and coordination) were entered as control variables in step 1. Scores on the team tacit knowledge were entered in step 2 for both regressions.

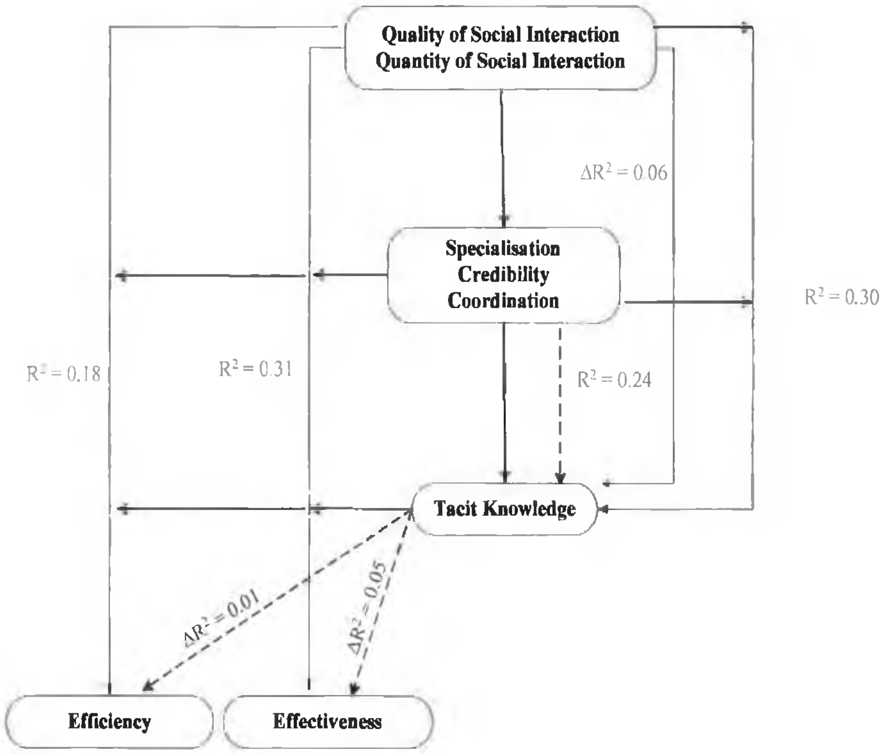
Table 9.20 Hierarchical Regression of Efficiency on Specialisation, Credibility, Coordination, Social Interaction and on Team Tacit Knowledge

Independent variables	Standardised beta weights				Df
	Step1		Step 2		
	B	t	B	t	
Step 1: Control variables					5, 42
Specialisation	.15	.97	.18	1.09	
Credibility	- .02	- .07	- .04	- .17	
Coordination	.57	2.37*	.56	2.92*	
Quality SI	- .31	-1.67	- .35	-1.76	
Quantity SI	- .30	-1.58	- .29	-1.51	
Step 2: Team Tacit Knowledge					
Team tacit knowledge			.10	.59	6, 41
R^2	.17		.18		
R^2_{adj}	.07		.06		
F	1.78		1.52		
ΔR^2			.01		
ΔF			.35		

*p<.05, **p<.01

The hierarchical regression in Table 9.20 is statistically non-significant for the full model ($F_{6, 41}$ = 1.52, p>.05) and accounts for 17% of the variance in efficiency. The hierarchical change (ΔF = 0.35, p>.05) was non-significant and only accounted for 1% of the variance above and beyond the other factors (see Figure 9.11). This means that transactive memory first order factors, quality and quantity of social interaction and team tacit knowledge do not predict efficiency. Moreover, team tacit knowledge does not predict efficiency above and beyond, transactive memory and quality and quantity of social interaction. However, as with Table 9.5, the coordination aspect significantly predicts efficiency when all other variables are held constant, again, this appears to be a spurious result.

Figure 9.11 Regression Coefficients Predicting Transactive Memory First Order Factors and Team Tacit Knowledge



Note: Coefficients in blue are not significant.

9.11 Summary of Results

The results indicate that team tacit knowledge predicts effectiveness but not efficiency above and beyond transactive memory and quality and quantity of social interaction. In addition, quality of social interaction predicts team tacit knowledge above and beyond transactive memory and quantity of social interaction. Transactive memory was not a mediator between social interaction and team tacit knowledge while psychological safety was a partial mediator between social interaction and transactive memory. Formal procedures predicted efficiency but not effectiveness and team performance predicted new product development capability. Coordination was found to predict effectiveness above and beyond social interaction, specialisation, credibility and team tacit knowledge. The implications for these findings are discussed in chapter 10.

Chapter 10
Discussion

10.1 Introduction

The literature review highlighted a number of issues regarding the current status of research investigating tacit knowledge, social interaction, transactive memory and performance in software development teams. In particular, it critiqued the fact that there was confusion in the conceptualisation of tacit knowledge and few measures to investigate tacit knowledge. Indeed, there were no quantitative studies to link social interaction and transactive memory to tacit knowledge at the team level. This chapter moves beyond the description of data and provides a detailed analysis of the research findings, particularly in light of other research studies. It draws together the key findings to present models for tacit knowledge acquisition and sharing in software development teams and SMEs.

The results will be discussed in two parts. In Part I, the results from the study in Chapter 8 of the TTKM development will be analysed and compared to theoretical underpinnings. In Part II the findings of the main study will be discussed, where the TTKM was used along with other measures to examine the predicted hypotheses and test the model hypothesised in Chapter 5.

PART I: THE TTKM STUDY

10.2 Discussion of Results from the TTKM Study

The study outlined in Chapter 8, and the results in Chapter 9, provide initial evidence that the theoretically driven, 14-item, TTKM scale is a conceptually and statistically valid measure, of team based tacit knowledge for software development teams. The characteristics of the scale makes it appropriate for field settings, and is only intended for software development teams. Convergent, discriminant, and criterion-related validity tests suggest the scale behaves as expected, since it was related to (for the most part) similar constructs, distinct from constructs it is not intended to measure, and significantly related to team effectiveness.

The empirical research of this study has successfully applied the repertory grid technique used for expert knowledge to tacit knowledge at the articulated level of abstraction. The TTKM was developed based on the definition forwarded by the Yale group and in part on their methodology. Instead of using SJTs, the repertory grid was employed to measure expert tacit knowledge, at the articulated level of abstraction (Sternberg et al. 2000; Busch et al. 2003). The choice of method was based on the theory that experts and novices differ in the amount and organisation of knowledge (Dreyfus & Dreyfus, 1986; Sternberg et al. 2000). Since, the elicitation of tacit knowledge can be performed using the kind of structured methods used for expert knowledge.

The experts in this study were experienced software development project managers with a reputation for excellence The expert knowledge referred to situational factors that affect team performance in software development teams. These factors will be discussed in light of existing theory and studies, in particular the framework forwarded by Guinan, et al. (1998) in their study of teams at the requirements stage. This framework, discussed in Chapter 5 consisted of internal and external group processes and their antecedents, which were divided in two: behavioural factors and technical factors.

10.3 Discussion of the 14 Factors that Differentiated Novices and Experts

The main findings of the development of the TTKM study, outlined in Chapter 8, were that project managers deemed internal and external group processes important and also antecedent behavioural factors, but not one manager even mentioned technical factors as affecting team performance. In addition, experts displayed a more subtle understanding of factors affecting team performance, since they tended to rate certain, apparently common sense factors in a less polarised manner than novices. The fourteen factors that differentiated between novices and experts are discussed in relation to the framework outlined by Guinan et al. (1998) and where appropriate other studies consistent with the findings are mentioned. The 14 factors of the TTKM can be seen in Figure 8.3.

10.3.1 Factors Related to Internal Group Production Processes

Factors 1, 5, 7, 9, 10 and 11 may be classified as internal group production processes. Both novices and experts saw clear well defined goals (Factor 1) as being a priority, but there was absolutely no variance in the expert group, suggesting that this is of prime importance. This finding is echoed in the Standish report (2001), where clear business objectives, was fourth in importance as an influence on project success. Innovative projects (Factor 5) and adequate resources (Factor 7) were more important to the novices who do not have the experience to know that even without ideal resources quality projects can still be completed, since many software development projects may be deliberately under budgeted to win contracts (Sommerville, 2004; O'Connell, 2001). It must be noted however that experts still rated resources highly probably because when there is a perception that a project will not be getting additional resources, software developers may become demotivated and not fully commit to the goals of the project (DeMarco & Lister, 1987). Small projects (Factor 9), were favoured by experts, with novices tending to rate towards the extensive project pole, again indicating the novices' lack of experience, since large projects may go on for years, are usually one-offs, making it difficult to anticipate problems and transfer previous experience (Sommerville, 2004; Standish Report, 2001). Novices tended towards strict deadlines (Factor 10) indicating a common sense response, but actual software projects are a much messier business and tight deadlines can sometimes be demotivating (DeMarco & Lister, 1987). It appears that experts have a more subtle understanding of deadlines than novices. Experts preferred a small team (Factor 11) probably because there are less communication problems and network points (Brooks, 1995).

10.3.2 Factors Related to Internal Group Relationship Processes

Factors 2, 3, 12, and 13 may be classified as internal group relationship processes (Guinan et al. 1998). Although the experts rated the following factors as important: high motivation (Factor 2), high cooperation (Factor 3) and high-morale (Factor 12) they did not see them in the polarised manner that the novices did. This is most likely to do with experience of knowing that, although very important, experience has shown that they are not necessary in an extreme way, since other factors are also influential. Interestingly novices rated internal competition (Factor 13) as a factor influencing success, unlike the experts, who viewed some competition as influential but generally competition within a team was viewed as not contributing to performance. A reason for this finding may be that internal competition will probably affect coordination and increase conflict, therefore decreasing the chance of having a 'jelled' team (DeMarco & Lister, 1987).

10.3.3 Factors Related to External Group Processes

External group process is evident in Factor 4, with experts acknowledging the necessity to communicate with people who are not team members (Katz & Tushman, 1981). In relation to behavioural factors, diverse team membership (Factor 8) is concerned with experience spread with experts being more conservative than novices in terms of diversity, perhaps due to conflict that may result from diversity (Kiesler, 1978). Team skill is expressed by Factor 6 where team experience is not seen as important to experts, as it is to novices, probably because in practice there is a range of experience within a team, where an effective project manager (Factor 14) can influence the team performance (Guinan et al. 1998; O'Connell, 2001).

In line with previous findings by Guinan et al. (1998) factors that differentiate novices from experts are concerned with internal group process and behavioural antecedents, and not technology. So, although Guinan et al. (1998) conducted their study on teams at requirements stage it seems to hold for software development teams in general. Social, non-technical factors are more important in determining team performance than are technical factors. This finding is corroborated by others such as Curtis et al. (1988), Waterson et al. (1997) and McChesney and Gallagher (2004) have found that structured methods have had a negative effect on established situated practices.

10.3.4 Factors that did not Differentiate Novices and Experts.

Eleven factors did not differentiate the novices and experts, and require a brief mention. These factors were: unclear procedures, lack of measures of success, inaccurate client requirements, management back up and support, on schedule and on budget, short-term project, management decisions challenged, clear team communication, manager in control, third party is involved in the project and clear non-competing roles. Both novices and experts construed unclear procedures, and inaccurate client requirements as adversely affecting project success. This is consistent with CHAOS the seventh and eighth factors that influence project success. i.e. firm basic requirements and formal methodology (Standish Report International, 2001). Lack of measures of success refers to the difficulty inherent in measuring effective performance on software development projects. In terms of short-term projects, both groups indicated that a medium term project is best, that managers decisions should be challenged. In addition, novices and experts felt that clear communication and clear non-competing roles led to successful projects (Kraut & Streeter, 1995). Manager in control, and on schedule and budget are consistent with the findings of the CHAOS ten for 'reliable estimates' and 'experienced project manager' (Standish Report International, 2001). In terms of a third party involved in the project, this was seen by both experts and novices as neutral, having neither a positive nor a negative effect.

10.4 Validity and Reliability of the TTKM

10.4.1 Validity of the TTKM

In terms of validity of the TTKM, it conformed well to Messick's (1995) framework as discussed in Chapter 8. The discriminant and convergent validity refers to *hypotheses 6* and *7,* in Minor Model 3 from Chapter 5. The lack of significant relationship between explicit job knowledge (*hypothesis 6*) and tacit knowledge provided divergent validity for the TTKM. This finding concurs with theoretical propositions about tacit knowledge being acquired with little environmental support, not through formal means (Sternberg et al. 2000). This implies that tacit knowledge regarding the factors that affect team performance on successful projects is not written down or formalised in work practices, but is altogether more practical and experience based.

However, scores on the TTKM were not significantly related to intuition as operationalised as gut instinct (*hypothesis 7*) but convergent validity was provided by a significant correlation between scores on the TTKM and quality of social interaction (*hypothesis 4*) and predictive validity by the significant relationship between scores on TTKM was significantly effectiveness (*hypothesis 9*).

A possible reason as to why the TTKM was not related to intuition possible because it was intended, in this study to measure intuitive actions based on those processes that have emerged through the implicit acquisition of complex knowledge, upon which individuals make decisions (Reber, 1989). In software development, deliberative reflection rather than experience may be the key as to why people differ in the amount of knowledge gained, since experts tend to engage in deliberate and reflective practice (Chi et al. 1988; Ryan & O'Connor, 2004).

10.4.2 Reliability of the TTKM

The reliability of the TTKM is related to validity, in that when establishing validity using factor analysis, reliabilities are sought for each factor. However, the TTKM was not validated using factor analysis. Tacit knowledge was deemed to be a group level construct since different members of the same team held different aspects of the expert tacit knowledge. This was indicated by the reliability coefficients which reached an acceptable level at the team level (Cronbach's alpha = 0.71) but was very low at the individual level (Cronbach's alpha = 0.49). The levels however were in line with reliabilities for knowledge tests according to Legree (1995) and reached acceptable level for psychological tests in general according to the British Psychological Society (2003). Across the TTKM there are diverse areas of knowledge some acquired by the individual some not, therefore the complexities of the tacit knowledge measures reduces the likelihood of obtaining the same levels of internal consistency as for other traditional knowledge and ability tests (Hedlund et al. 2003). This finding concurs with Grant's (1996) assertion that tacit knowledge may be seen as a team-level phenomenon that reflects the ability of teams to absorb new knowledge.

In conclusion the TTKM was valid and reliable at the team-level. The TTKM is therefore a direct, team-level measure of a narrow aspect of domain specific tacit knowledge for software development teams.

10.5 Summary of PART I

Fourteen factors differentiated novices from experts and these were discussed in relation to existing theory and empirical findings. This study forms the basis of a larger study which explores the quality and quantity of social interaction in software development teams and its effect on the acquisition and sharing of articulable tacit knowledge. A benchmark based on the average of expert scores on the 14 factors that differentiate novices from experts was developed to provide a measure of articulable tacit knowledge.

PART II: THE MAIN STUDY

10.6 The Acquisition and Sharing of Tacit Knowledge in Software Development Teams

In the main study, one central model consisting of four sets of variables was hypothesised along with four minor models. The four minor models correspond to the main variables in the study i.e. social interaction (quality and quantity), transactive memory (weighted composite score), team tacit knowledge and team performance (effectiveness and efficiency). Minor model 3 relates to the validation of the TTKM and includes the following three variables: 'reliance on gut instinct', 'familiarity with written procedures' and 'reliance on written procedures' which have already been discussed in Part I.

In this part, the univariate statistics of the survey are outlined with reference to previous studies. Then, all of the models are discussed in terms of relationships among variables and their hypothesised predictions. Then, mediation hypotheses will be discussed. Finally, non-hypothesised relationships and *post hoc* analyses will be outlined. The main model will be discussed first, followed by the models referring to social interaction, transactive memory and team performance, respectively.

10.7 Discussion of Univariate Analysis of Data

Univariate statistics for each measure and the potential range of values for each scale varied depending on the number of items and number of response categories per item. The average team responses to the measures are shown in Table 9.1. In general, the self-report measures are positively skewed and in line with previous studies which used these measures as outlined in Chapter 7.

The teams in this study had good average quality of social interaction in line with Chiu et al. (1995). In addition, the quantity of social interaction mean score was above that of the original study by Levesque et al. (2001). The weighted TMS composite score was higher than the weighted composite in the Lewis (2003) technical team study indicating that the software development teams in this study, on average had a more developed TMS. Furthermore, means and standard deviations for the three first order factors in the present study did not differ very much from the original study by Lewis (2003).

The mean for the TTKM had quite a large standard deviation indicating quite a bit of variation in team responses, with some teams having much tacit knowledge and others relatively little. In terms of efficiency and effectiveness, the present study compares well to the results found by Faraj & Sproull (2000). The mean for psychological safety was positive with an almost identical mean to the one found in the original study by Edmondson (1999). In addition, average team size was within the range for a small team (Daft, 2004) and the average percentage of diversity within the team was around 50%.

The average team response for administrative coordination was slightly lower than that found by Faraj and Sproull (2000), but was above the mid-range. In addition, the percentage presence of expertise was 78%, almost identical to the percentage in the study of software development teams by Faraj and Sproull (2000). Finally, the average responses to the items measuring explicit job knowledge, reliance on gut instinct item, the presence of a formal knowledge sharing system and new product development capability were positively skewed.

In conclusion, the univariate statistics reported in the present study are in line with the findings (where comparisons can be made) with original studies. Furthermore, the self-report measures are positively skewed, this may be due to social desirability bias. However, the comparison with previous studies provides evidence that this is probably not the case or at least the teams in the present study have the same level of social desirability. A further element that may discount social desirability bias is that the dependent measures of effectiveness and efficiency in the present study were rated by the team members, including the manager, in the Faraj and Sproull (2000) study team performance was rated by stakeholders, outside of the team. It appears that teams rate themselves in a slightly less favourable light than stakeholders.

10.8 Main Model and Concomitant Hypotheses

The main model has two central predictions related to *hypotheses 24* and *25*. Each central prediction and concomitant hypothesised relationships with the variables in the main model, will be discussed in turn. *Hypothesis 24* predicted that social interaction (quality and quantity) would predict team tacit knowledge above and beyond transactive memory and *hypothesis 25* stated that team tacit knowledge would predict team performance as measured by efficiency and effectiveness above and beyond social interaction (quality and quantity) and transactive memory.

10.8.1 Predicting Team Tacit Knowledge.

Before examining the first central prediction (*hypothesis 24*) for the main study in detail, the findings for the hypothesised relationships between social interaction (quality and quantity), transactive memory and team tacit knowledge need to be discussed. As predicted, there was a positive relationship between quality of social interaction and quantity of social interaction (*hypothesis 1*) this gives empirical confirmation to the definition of quality of social interaction forwarded by Hoegl (as cited in Lechler, 2001), which, in part, depends on the frequency of the information exchange, therefore these two concepts are interdependent.

Furthermore, both quality and quantity of social interaction were positively and significantly related to the development of a TMS (predicted by *hypothesis 5*). There are several reasons for this finding. Transactive memory, as discussed in Chapter 2 is a subset of TMMs, and laboratory and field studies, indicate that the development of shared mental models is related to social interaction (Klimoski & Mohammed, 1994). However, these studies do not distinguish between quality and quantity of social interaction. The quality is implied, but it is usually the quantity of social interaction that is addressed (e.g. Athans, 1982; Forgas, 1981). In terms of the quantity of social interaction in software development teams, when interaction is reduced, Levesque et al. (2001), found that this will inhibit the formation of shared mental models. In relation to quality of social interaction, TMSs develop as team members learn about one another's expertise (Wegner, 1987), through interpersonal communication (Hollingshead, 1998). In the key field study of transactive memory by Lewis (2003), it was found that the extent to which communication is task-relevant, was positively related to members' TMSs. In these studies, it may be concluded that the quality of social interaction is implied. In the software development arena, evidence comes from the relationship between social interaction and concepts similar to transactive memory. Hoegl's (1998, as cited in Lechler, 2001) study, defined the quality of teamwork as the collaboration within teams. In addition, Faraj and Sproull's (2000) and McChesney and Gallagher (2004) studies of coordination in software development teams also concur with these findings. The manner in which these authors describe coordination is very similar to transactive memory concept.

Transactive memory was therefore, found to be related to both the quality and quantity of social interaction, which is supported by previous research into related TMMs and expertise coordination.

Team tacit knowledge was related to transactive memory providing support for *Hypothesis 10.* This is probably because tacit knowledge is created through social interaction via the development of shared mental models. Team tacit knowledge was related to transactive memory overall. Support for this position comes from related studies into expertise coordination, where teams were found to coordinate their expertise implicitly and mutual knowledge was tacit (Faraj & Sproull, 2000; McChesney & Gallagher, 2004). Finally, quality of social interaction was related to team tacit knowledge, and quantity of social interaction was not, providing partial support for *hypothesis 9,* possible reasons for this finding are discussed next, with the first central prediction.

The central prediction found that quality and quantity of social interaction predicted team tacit knowledge above and beyond transactive memory, providing support for *hypothesis 24*. Together quality and quantity of social interaction accounted for 12% of the variance in team tacit knowledge above and beyond transactive memory. All three variables together accounted for a significant 20% of the overall variance in team tacit knowledge. Quantity of social interaction acted as a suppressor variable suggesting that the quality of informal communication is key to the team tacit knowledge. In addition, transactive memory predicted team tacit knowledge but when quality and quantity of social interaction were included, the unique variance ceased to be significant.

There are several reasons for this finding, firstly, the quality of social interaction referred to the achievement of goals and the improvement of interpersonal relationships (Chiu et al. 1995). The definition of tacit knowledge used in this study was based on Sternberg et al. (2000), who stated that tacit knowledge was tied to personal goals. The quality of social interaction is also tied to the achievement of goals, therefore these two should be related. Anecdotal support for this finding comes from Nonaka and Takeuchi (1995), who posited that social interaction is the means through which tacit knowledge is acquired and shared, though, these authors do not distinguish between quality and quantity of social interaction. Empirical support for this finding may be obtained from

Granovetter (1973) who stated that strong ties, identified by close relationships (among other things), are ideal for the sharing of tacit, complex knowledge, this is also in line with Tsuchiya (1998). Further empirical evidence for this relationship was demonstrated by Busch et al. (2003) from their SNA study in an IT team, who found that tacit knowledge was shared in social interactions. Also in the software development domain, Melnik and Maurer (2004) demonstrated the effectiveness of face-to-face communication, as advocated by the *Agile* approach to software development, in sharing complex knowledge. This complex knowledge is akin to tacit knowledge.

The theoretical and mainly anecdotal link between social interaction and tacit knowledge was therefore established empirically in this study for quality of social interaction but not for quantity of social interaction. In terms of transactive memory, as stated earlier the related area of expertise coordination among software development teams involves mutual tacit knowledge. The reason quality of social interaction predicts team tacit knowledge above and beyond transactive memory is that the development of TMSs and tacit knowledge both require social interaction to develop.

It can be concluded that transactive memory and quality of social interaction both contribute to team tacit knowledge, with quality of social interaction playing a more important role. It may also be concluded, that tacit knowledge is associated with personal goal directed interactions. Social interaction and transactive memory provide a reasonable model to explain the development of team tacit knowledge, with the quality of social interaction being the key.

10.8.2 Predicting Team Performance

The central hypothesis is concerned with team tacit knowledge predicting team performance above and beyond all other main model variables. Before discussing this central prediction, the remaining hypothesised relationships between the main model variables will be discussed. Team performance was measured by efficiency and effectiveness. A significant positive correlation was found between transactive memory weighted composite and effectiveness but not efficiency providing only partial support for *hypothesis 4*. A possible reason for this; is that when measuring team performance, previous self-report measures have investigated effectiveness and not efficiency.

Support for this position maybe obtained from the Faraj and Sproull (2000) study of software development teams, who also found that the similar concept of 'expertise coordination' was related to effectiveness and not efficiency. It appears that transactive memory is not related to the project being on time or on budget. This is probably because efficiency is associated more with planning and formal communication.

Team tacit knowledge was found to be related to effectiveness but not efficiency, providing partial support for *hypothesis 8,* this finding is discussed next in relation to the second central prediction.

The second central prediction found that team tacit knowledge was a significant predictor of effectiveness above and beyond, transactive memory (composite) and quality and quantity of social interaction, but the same did not hold for efficiency, providing partial support for *hypothesis 25.* Dealing with effectiveness first, the model behaved as expected, with team tacit knowledge accounting for 10% of the variance in effectiveness above and beyond transactive memory (composite) score and quality and quantity of social interaction. However, transactive memory is also an important predictor, accounting for around the same amount of variance in effectiveness as team tacit knowledge (see explanation for *hypothesis 4,* above). The whole model accounts for 24% of the variance. Tacit knowledge is a measure of the outcome of TMMs and is therefore related to effectiveness. Theoretical support is proffered by authors hypothesising that tacit knowledge is considered to be a core competitive advantage (Fernie et al. 2003; Hult, 2003). However, it appears that tacit knowledge only contributes partly to competitiveness since effectiveness refers to the achievement of project goals and not budget and schedule. Much of the evidence linking tacit knowledge to team performance is anecdotal (e.g. Nonaka & Takeuchi, 1995). Empirical evidence at the individual level was demonstrated by the Yale group studies, (e.g. Hedlund et al. 2003; Sternberg & Wagner, 1988; Wagner, et al. 1999). At the team-level, this finding is consistent with the Berman et al. (2002) study of basketball teams where tacit knowledge was found to be related to successful performance. These studies measured team performance as 'effectiveness'.

Team tacit knowledge was not related to efficiency. Efficiency refers to time and cost and team tacit knowledge only accounted for 1% of the variance in efficiency, suggesting that efficiency is probably associated with explicit knowledge rather than tacit knowledge. The other variables in the model accounted for 13% of the variance, which was not significant. Efficiency, is very formal and explicit, and would not require tacit knowledge to achieve, rather explicit planning would enhance efficiency (O'Connell, 2001). This finding is not consistent however, with Edmondson (2003), who found that surgical teams were faster when there was more tacit knowledge. The task was measured directly whereas efficiency in the present study is an indirect self-report perception. The two types of measures may not be comparable.

Furthermore, this result may be related to the nature of the task. Drucker (1993) distinguishes between different types of knowledge workers. Members of surgical teams belong to the largest category of knowledge workers, which he calls 'technologists', consisting of workers who deal with both manual and intellectual work. Software developers deal only with 'intellectual' work, the tasks performed by the different groups may also not be comparable.

It is pertinent to note that the previously unrelated transactive memory variable, in the presence of the other variables in the model, now significantly predicts efficiency. This result is considered spurious and cannot be verified within this study, and so is discounted.

Overall, team tacit knowledge, is a key predictor of effectiveness and as such empirical evidence is provided for the mainly theoretical link between tacit knowledge and performance. Furthermore, for the first time, this link has been empirically demonstrated at the team level. Transactive memory is also an important predictor of effectiveness, where software development teams that have heedful interactions and awareness of the location of expertise have a better developed collective mind. This enables the team to reduce cognitive load, thereby, allowing the team to be more effective. Team tacit knowledge, quality and quantity of social interaction and transactive memory were not related to efficiency in this study, furthermore, this model did not predict efficiency.

10.8.3 Predicting Team Tacit Knowledge: First Order Factors

Before discussing the expanded hypothesised model, to include transactive memory first order factors, for predicting team tacit knowledge; the relationships relevant to the first order variables will be outlined first. Therefore, *hypothesis 5* and *hypothesis 10* are also expanded to include the first order variables and are re-examined in light of this.

In an expansion of *hypothesis 5*, to include the first order factors of specialisation, credibility and coordination, it was found that quality of social interaction leads to better coordination and higher levels of credibility within teams. However, the greater specialisation of knowledge within the team, was not related quality of social interaction. It appears that quality of social interaction aids coordination and credibility but not specialisation. The quantity of social interaction, however, was significantly and positively related to all three first order factors.

There are several reasons for these findings. Firstly, specialisation in this case was the degree of differentiated specialised knowledge and the location of that knowledge (Lewis, 2003). Quantity of social interaction leads to knowing the location of specialisation, but quality does not. This may be explained by social exchange theory, in that, to know where specialisation is located may be seen on the economic end of the continuum rather than on the relational end (Rousseau & Parks, 1993) and therefore related to functional communication about the task (Lewis, 2003). Informal social interaction perhaps contributes little to the integration of specialisation, as it is task relevant only. Secondly, coordination resolves task dependencies that result from division of labour (Crowston, 1997). Support for this finding in the present study is acquired from the studies by Faraj and Sproull (2000) and McChesney and Gallagher (2004) who found that in software development teams, members coordinate their actions implicitly. It appears that coordination is also important in SMEs, where it is easier to coordinate because of smaller size. Credibility is concerned with reliance on the knowledge of other members in the team, and is linked. Therefore, having trust in other team members' ability is related to social interaction, the larger the amount and the better the quality of the social interaction the more likely individuals will rely on each others' knowledge. As with all correlational studies, the antecedent cannot be known for definite, therefore, it may also be concluded that the more they rely on each others' knowledge the more likely they are to interact with one another.

In relation to *hypothesis 10,* the first order factors of coordination and credibility were significantly correlated with team tacit. This suggests that working together and trusting others' expertise leads to more tacit knowledge. These findings are consistent with Marks et al. (2002) who found that coordination mediated the relationship between shared mental models and team performance. Knowing the location and degree of expertise i.e. specialisation was not significantly related to team tacit knowledge and was negative in direction, suggesting that differentiation of knowledge actually mitigates against tacit knowledge.

In an expansion of *hypothesis 24,* to include the first order factors of specialisation, credibility and coordination it was found that quality of social interaction no longer predicted team tacit knowledge over and above transactive memory. Furthermore, none of the five variables made a significant unique contribution; instead jointly these variables together predict team tacit knowledge, accounting for 30% of the variance in team tacit knowledge, with quantity of social interaction, acting as a suppressor. A possible reason for these findings is that the second order factor of transactive memory is made up of the weighted composite of three first order factors, to give an overall measure of transactive memory. Each of the first order factors, specialisation, credibility and coordination, measures a separate but related construct, and when entered into the model in this manner behaves as a separate entity.

It can be concluded that transactive memory and quality of social interaction both contribute to team tacit knowledge, with quality of social interaction playing a more important role. However, when transactive memory is broken down into its component parts, no individual variable predicts team tacit knowledge when entered together in the model, but the model accounts for more variance in team tacit knowledge than the TMS composite score.

10.8.4 Predicting Team Performance: First Order Factors

The second central hypothesis is concerned with team tacit knowledge predicting team performance above and beyond all other main model variables. Team performance was measured by efficiency and effectiveness.

When transactive memory is broken down into its component parts, coordination as a construct on its own predicts effectiveness above and beyond quality and quantity of social interaction. This is consistent with the study of software development teams conducted by Faraj and Sproull (2000), where it was found that expertise coordination predicted effectiveness but not efficiency. In addition most of the literature on coordination was conducted in large software development projects, in large companies (e.g. Crowston, 1997; Faraj & Sproull, 2000), but it appears that the importance of coordination for software development teams, holds true for SMEs, in the present study.

Therefore, social interaction, transactive memory and tacit knowledge are important in predicting effectiveness, but of overriding significance, is the role of coordination within the team.

The specialisation factor was not associated with team performance. This is consistent with the Lewis (2003) finding for technical teams. The teams in the present study were from small to medium enterprises and although team size was not a factor in specialisation, it must be assumed that this is related to project scope. The members of teams in SMEs will have task overlap since. Lewis (2003) concluded that TMSs probably operate differently for different types of teams. This appears to be the case for software development teams in SMEs. The specialised division of labour aspect of transactive memory does not appear to hold for such teams. SMEs are less formalised with less centralised decision making (Daft, 2004).

It is likely that software teams in SMEs have integrated specialisation but there is considerable overlap which is probably a function of the task. These teams work together, and there is specialisation, but much knowledge is overlapped. In large organisations this is probably not the case as people will tend to concentrate more on their specialist areas, deepening a developing them. This suggests that the more credibility and coordination in a team the more effective it is. However, effectiveness is not related to the specialisation in the team.

Lewis (2003) found similar in terms of team performance in the 24 technical teams she investigated but not in the student teams. A possible explanation is that expertise in functional teams may be important for team performance but the integration is not so. Tasks do require interaction among the members of the team but some tasks span the knowledge of several members. Further support may be obtained from laboratory studies, where group members were individually trained on the same task developed more overlapping task knowledge and recalled less information overall (Liang et al. 1995; Moreland et al. 1996; Moreland & Myaskovsky, 2000).

It appears that the software development teams in the present study probably had considerable overlapping knowledge. So the division of specialisation is not as clear-cut in these teams. As Lewis (2003) concluded that it is unclear how much knowledge must be overlapping, and how much specialisation is too much and members may also possess complementary specialisations that are not efficient but persist anyway.

10.8.5 Summary of Main Model

The results of the main model predictions, suggest a complex relationship between social interaction and tacit knowledge. The results suggest that tacit knowledge plays a significant role in explaining team effectiveness but not efficiency and scores on the TTKM are a significant predictor of team effectiveness above and beyond all other factors in the main model. Social interaction and the development of a transactive memory system are thought to influence this.

Therefore the quantity of social interaction, is an indicator of how often two people engage in face-to-face communication, this may not be tied to a goal, task or otherwise. So while quality and quantity of social interaction are related, the better the quality the more tacit knowledge there is.

10.9 Minor Model 1: Social Interaction

This model refers to *hypotheses 12, 15, 16* and *17*. The relationship of proximity with social interaction (*hypothesis 17*) is addressed in the predictive model. A positive relationship was found between psychological safety and social interaction, quality and quantity, providing support for *hypothesis 12*. Psychological safety is an important factor in communication, since it measures the safety of the team for interpersonal risk taking (Edmondson, 1999). In addition, the study by Mu and Gnyawali (2003) found that social interaction was related to psychological safety.

Hypothesis 16, which predicted a negative relationship between social interaction and diversity was not supported. Studies investigating diversity have found that diversity adversely impacts on communication (Harrison, et al. 1998; Jackson, et al. 1991). However, this is mainly related to lack of cohesion. It has already been established that the teams in the present study are highly coordinated, therefore, if there is diversity in a team, it is probably counteracted by coordination. Other reasons for this are related to the sample itself and the aggregation. The reason for the lack of relationship is because the interaction is more important. It does not necessarily follow that people who sit near one another will interact informally. Proximity was aggregated to team level using the mode, there was not a great spread of scores, with most people working in close proximity with one another. Diversity was related to previous experience, where rather than teams being made up of people from different functional areas, they were made up from people who had different backgrounds. This was not affected by informal social interaction.

Team size was found to be negatively related to social interaction, quality and quantity, providing support for *hypothesis 15.* This is supported by many studies, and is a standard in communication theory (e.g. Brooks, 1995; Rentsch & Klimoski, 2001).

Hypothesis 26 posited that proximity, team size, team diversity, and psychological safety would predict social interaction (quality and quantity). Together these variables accounted for 47% of the variance in quantity of social interaction and 60% in quality of social interaction. In both cases team size had the greatest unique influence, where the larger the team the greater the reduction social interaction.

In terms of proximity, quantity of social interaction, when proximity was entered as a 'dummy' variable, it was found that for a proximity of 11-30 metres, in relation to the modal category of 0-5 metres, the quantity of social interaction decreased significantly. Kraut et al. (1990) have shown that distance affects communication between team members with 30 metres considered truly remote (Allen, 1977). The more distance there is, the lack of opportunity for interaction.

Proximity, team size, team diversity and psychological safety predict to the quality of social interaction, with smaller teams encouraging more and better interactions. The same hold for quantity of social interaction, with the addition that the frequency of interaction decreasing with distance.

10.10 Minor Model 2: Transactive Memory

Hypotheses 2, 3 and *13* predicted that transactive memory would be positively related to presence of expertise, experience and psychological safety respectively. These hypotheses were supported for the composite transactive memory score. This is consistent with theory, in order for expertise to be coordinated it must be present (Faraj & Sproull, 2000). In a study of the closely related TMM of team work, Smith-Jentsch et al (2001) found team members who had been in the navy service for a long time had greater similarity of mental models. This is not to be confused with development of models from working together. Transactive memory systems develop in an atmosphere that encourages risk taking. Mu and Gnyawali (2003) found that team psychological safety had a significant influence on synergistic knowledge development, a construct related to transactive memory.

Hypothesis 27 predicted that team psychological safety, experience and presence of expertise will predict transactive memory. The regression analysis revealed that this model was significant, accounting for 48% of the variance in transactive memory. and so *hypothesis 27* was supported by the data. Psychological safety made the greatest unique contribution to the model. It appears that an atmosphere safe for risk taking, leads to the development of a transactive memory system.

10.11 Minor Model 4: Team Performance

Hypotheses 19 and *20* predicted the significant positive relationships between team performance as measured by efficiency and effectiveness and control variables thought to affect team performance i.e. presence of a formal knowledge sharing system and administrative coordination. It was found that both administrative coordination and presence of a formal knowledge sharing system are significantly and positively related to efficiency but not effectiveness, providing partial support for the hypotheses. Suggesting that formal coordination and communication influences scheduling and budget but not the quality of the work.

A possible reason for this finding may be that, the efficiency aspect of team performance was related to both administrative coordination and knowledge sharing, where the model with administrative coordination and presence of a formal knowledge sharing system predicted efficiency (*hypothesis 21*). *Hypotheses 19, 20* and *21* were only partially supported, since the predictions did not hold for effectiveness. This is in line with the findings of Faraj and Sproull (2000), who also found that administrative coordination was related to efficiency and not effectiveness. This is related to formal knowledge sharing system. Efficiency relates to budgeting and scheduling and has been found to be associated with formal administrative coordination and reporting procedures which themselves have not been found to be related significantly to effectiveness (Faraj & Sproull, 2000). Effectiveness on the other hand is characterised by how well the team meets project goals, the quality aspect rather than speed and budget.

10.11.1 Predicting New Product Development Capability

It was hypothesised that efficiency and effectiveness would be related to and predict new product development capability (*hypotheses, 22* and *23*). These hypotheses were supported by the data, with the model accounting for 25% of the variance in NPD capability. Empirical support is obtained from Galegher and Kraut (1990) who observed that teams are more effective in bringing a new product to the market in a short time-frame. Ramesh and Tiwana (1999) also argued that NPD is moving towards team-based structures, since team are thought to improve performance.

In summary, it is relevant to note that, effectiveness was the more important variable in the predictive model. It appears that quality of social interaction, leads to the development of transactive memory, and to higher levels of team tacit knowledge. Both team tacit knowledge and transactive memory lead to effective team performance, which in turn influences NPD capability.

10.12 Mediation Analysis

Transactive memory was not a mediator between social interaction (quality and quantity) and team tacit knowledge. Although significantly related to both, it does not form the mediating path between social interaction and team tacit knowledge. It appears that both quality of social interaction and transactive memory are both contributors to the development of team tacit knowledge. Therefore, transactive memory is not the route through which social interaction exerts its influence on team tacit knowledge.

Psychological safety was found to be a partial mediator between transactive memory and social interaction (quality and quantity), therefore, *hypothesis 14*, is partially supported. This finding implies that social interaction does exert some of its influence on transactive memory through psychological safety. This would make sense, in that, an atmosphere conducive to risk taking, will enhance communication and thereby, the development of a transactive memory system. Support for this finding is evident in the study of SKD, a concept similar to transactive memory by Mu and Gnyawali (2003) (section 4.7.2). These authors found that team psychological safety had the most influence on SKD, followed by task conflict and that social interaction had the least influence on SKD.

10.13 Non-Hypothesised Correlations

This research was not intended as an inductive study, however, some non-hypothesised relationships were found. This is to be expected in a study of this magnitude. Most of the correlations were associated with gut instinct and the two aspects of team performance. Some tentative explanations are forwarded for the results.

10.13.1 Correlations with Intuition

Reliance on intuition (gut instinct) was significantly related to experience, psychological safety, transactive memory and team size. Intuition may be acquired by years of experience and through psychological safety in smaller teams which contributes to the development of TMSs. The relationship between intuition and experience has already been discussed in section 10.4.1. Intuition was also related to effective performance. A possible reason for this may be that intuition is not a cognitive construct but a personality characteristic (Gorla & Lam, 2004). If this is the case, then, intuition is probably best treated at an individual level, rather than as a team level construct. The relationship between tacit knowledge and gut instinct or intuition requires further investigation.

Few generalisable conclusions can be made on this, since it was a single item measure. In addition, a single item measure, such as this, would lack the scope to encompass all the aspects of intuition.

10.13.2 Correlations with Explicit Job Knowledge and Team Performance

Reliance on written procedures is related to administrative coordination, as is familiarity with written procedures, providing convergent validity for these measures. Administrative coordination was also positively related to size of team. This makes sense in that the more people present in a team the greater need for a formal communication system, unlike coordination of task which is negatively related to team size. In addition, familiarity with written procedures is associated with the presence of a formal knowledge sharing system, suggests that familiarity with official work procedures is disseminated through a formal knowledge sharing system but tacit knowledge is not. Presence of expertise credibility and coordination were associated with formal knowledge sharing. This is not surprising since trust in others' expertise (credibility) and coordinating that expertise is probably necessary for the sharing of formal, task related knowledge. Transactive memory was negatively related to team size, similar to finding by Rentsch and Klimoski (2001) who found in laboratory teams that team size was significantly related to team member schema agreement.

Having a good knowledge of explicit job procedures is also directly related to effectiveness, efficiency and NPD. This is not surprising since, explicit knowledge of your own job, when applied to the task becomes evident in effective and efficient performance. It is important to highlight, it is the knowledge of the job that is important not relying on the written procedures, indicating that members of the teams rely on expert knowledge, which probably serves as a background to tacit knowledge. Perhaps they rely on their own version of the written rules and procedures that are personally and socially constructed thorough deliberative practice. However, as with intuition caution should be exercised in making any conclusions, in that it is a single item measure.

Effectiveness and efficiency, may therefore, have different predictors (except for familiarity with written procedures which is a common predictor), with effectiveness predicted by mainly non-formal procedures and efficiency predicted by explicit knowledge. processes. It appears that both are necessary for team performance but behave in different ways. A tentative conclusion may be that explicit knowledge is important for both effective and efficient performance, but tacit knowledge is more important for effective performance than is explicit knowledge. Furthermore, tacit knowledge had a stronger correlation with effectiveness than did explicit job knowledge. It is very difficult to separate the two and highlights the problems inherent in overcoming the tacit-explicit dichotomy.

10.14 Summary of Part II

The means and standard deviations for measures in the present study are consistent with previous measures. The central prediction of this study was upheld for quality of social interaction, which predicted team tacit knowledge above and beyond transactive memory and theory and research into related fields concur with this finding. Team tacit knowledge was found to be a key predictor for effectiveness, providing further empirical evidence for the link between team performance and tacit knowledge. However, team tacit knowledge did not predict efficiency, which was in contrast to previous studies. Reasons were offered for these results in light of previous theory and in relation to the literature review. In general, comparisons between the main study and previous theory and research were favourable. Furthermore, a chain of events can be tracked from social interaction to NPD. Quality of social interaction, leads to the development of a TMS and to the development of team tacit knowledge. Both team tacit knowledge and transactive memory predict effective team performance, which in turn predicts NPD capability.

Chapter 11
Conclusions

11.1 Introduction

This study set out to provide a better understanding of the acquisition and sharing of tacit knowledge in software development teams. The research findings and model presented provide empirical support for the previously, mainly anecdotal or theoretical background to this process. This chapter provides a summarised account of the main conclusions of the research. It considers how software SMEs concerned with improving tacit knowledge sharing can intensify social interaction in development teams. Finally, it presents a number of potentially interesting research avenues for future research.

11.2 Key Conclusions

The central goal of the research was to investigate the manner in which tacit knowledge is acquired and shared in knowledge-worker teams, specifically software development teams. This goal and the four key research questions and associated aims set out in Chapter 1, were addressed, leading to a number of important contributions to the understanding of the concept of tacit knowledge and how it is acquired and shared. This research has made considerable progress in addressing key issues and several conclusions may be drawn, related to the development of the TTKM and the investigation of the acquisition and sharing of tacit knowledge.

A central issue was the conceptualisation of tacit knowledge. To date little attempt has been made to address the definition of tacit knowledge. In addition, while tacit knowledge is often heralded as a competitive advantage very few researchers have attempted to measure it. Moreover, there existed no team-level direct measure of tacit knowledge. This study has attempted to overcome this problem by conceptualising, operationally defining and measuring tacit knowledge at the group level. By exploring issues related to tacit knowledge, the research has identified and empirically tested the primary factors identified in the literature that influence the acquisition and sharing of tacit knowledge. Furthermore, this research investigated knowledge-worker teams, specifically software development teams, since these team members own the means of production, and as such, tacit knowledge is very important to them.

In terms of the acquisition and sharing of tacit knowledge in software development teams, as noted in the literature review, links have been identified between, tacit knowledge and social interaction, but these links were mainly anecdotal or theoretical (e.g. Nonaka & Takeuchi, 1995), with very little empirical evidence (e.g. Busch et al. 2003). Transactive memory has been found to be associated with task relevant communication (Lewis, 2003), however, no empirical studies have previously linked transactive memory with both quality and quantity of social interaction. Theoretically, links have been posited between tacit knowledge and the development of TMMs (e.g Nonaka & Takeuchi, 1995), with some empirical studies beginning to emerge (Faraj & Sproull, 2000; McChesney & Gallagher, 2004) however, this link has not been empirically tested with respect to transactive memory. Tacit knowledge is considered to be a core competitive advantage (Fernie et al. 2003; Hult, 2003) and is related to team performance (Busch et al. 2003; Emondson et al. 2003) and TMMs. This study, for the first time, has empirically demonstrated this connection at the team level. Overall, the acquisition and sharing of tacit knowledge, at the team level, through social interaction and the development of a transactive memory system has never been tested, in part due to the absence of a suitable team-level measure of tacit knowledge. This research represents an important step forward in our understanding of the concept of tacit knowledge and how knowledge-worker teams, in particular software development teams, learn and share such knowledge, to enhance team performance.

A number of conclusions can be drawn from the research, which are summarised under the headings of the four questions posed in Chapter 1.

i. How do we define and measure tacit knowledge?
ii. How is tacit knowledge acquired and shared in knowledge-worker teams?
iii. What impact does tacit knowledge have on team performance?
iv. Why is tacit knowledge important for knowledge-worker teams?

11.2.1 Conclusions About How Tacit Knowledge is Defined and Measured

Theoretical claims about the tacit knowledge construct are abundant, however, there is a paucity of empirical studies, due in part to the lack of empirical measures, and in part, the problems of conceptualising and defining tacit knowledge. Three conclusions are forwarded in relation to the tacit knowledge construct.

i. It may be concluded that, tacit knowledge can be measured directly at the articulated level of abstraction. Using methods and procedures similar to the

Yale group studies, and the repertory grid technique to develop the scale items, it was found that the questionnaire was effective at tapping the tacit knowledge construct. The development of the TTKM for software development teams, is an extension of individual-level, tacit-knowledge research to consider team-level behaviour.

ii. It may also be concluded that the TTKM, is a valid and reliable measure of tacit knowledge at the team level, but not at the individual level. More studies would be needed to further test the reliability and expand the validity.

iii. It may be concluded that, tacit knowledge is not job knowledge, since tacit knowledge at the team level is not related to explicit job knowledge, nor to gut instinct. Gut instinct or intuition, is most likely a personality characteristic and as such should be treated as an individual level variable. Further study into the link between intuition and tacit knowledge is warranted.

11.2.2 Conclusions Related to the Acquisition and Sharing of Tacit Knowledge

The main goal of this research was to investigate how tacit knowledge is acquired and shared in knowledge worker teams, more specifically in software development teams. In this respect an advance has been made in our understanding of this process and six conclusions are made on the basis of the research.

i. It is concluded that tacit knowledge is acquired and shared directly, through good quality social interactions and through the development of a TMS, since, TMSs are important for the acquisition and sharing of team tacit knowledge, because they enact 'collective minds' of teams. However, quality of social interaction is a more important route through which teams can learn and share tacit knowledge, than is transactive memory.

ii. The frequency of interaction indirectly aids the acquisition and sharing of tacit knowledge since it leads to better quality interactions and a more developed TMS.

iii. Transactive memory is not a mediator between social interaction and team tacit knowledge, indicating that both have separate contributions to make to the acquisition and sharing of tacit knowledge and that social interaction does not exert its influence by this route.

iv. This study treated quality and quantity as separate entities, which provided a more in-depth analysis of the influence of social interaction. Both quantity and quality of social interaction enable the development of transactive memory systems.

v. Furthermore, it can be concluded that social interactions are encouraged by smaller teams, working in an environment that promotes psychological safety and with team members located at relatively small distances from one another.

vi. In addition, an experienced team, with a high level of expertise, in an environment of psychological safety may encourage the development of a TMS.

11.2.3 Conclusions for the Impact of Tacit Knowledge on Team Performance

A central prediction in the present study is the predictive capacity of team tacit knowledge, social interaction and transactive memory for team performance as measured by effectiveness and efficiency. The following conclusions are forwarded:

i. It is concluded that team tacit knowledge and transactive memory are both important factors in the prediction of effectiveness but not efficiency. Team tacit knowledge does predict effectiveness above and beyond quality and quantity of social interaction and transactive memory but indeed, transactive memory could also predict effectiveness above and beyond team tacit knowledge. Transactive memory is a factor in successful team performance and is enacted in tacit knowing of the location and awareness of team member expertise. Therefore software development teams with a well developed transactive memory system will have higher levels of team tacit knowledge than teams with less developed transactive memory systems. Therefore, team tacit knowledge and the coordination of specialised knowledge within teams are significant factors in effective performance for software development teams.

ii. It is also concluded that efficiency in software development teams, is related to explicit, formal procedures i.e. presence of a formal knowledge sharing and administrative coordination. Efficiency was also found to be related to explicit job knowledge (familiarity with written procedures) and presence of expertise. It is concluded that efficiency is generally associated with explicit knowledge and formal procedures while effectiveness is predicted from tacit knowledge and non-formal procedures.

iii. It may also be concluded that coordination of knowledge within teams may be the most influential factor predicting effective performance over all other factors, however, this conclusion is tentative since it was acquired *post-hoc.* Although there are several studies that link coordination with team performance (e.g. Faraj & Sproull, 2000; Kraut & Streeter, 1995).

iv. A further conclusion is that quality and quantity of social interaction are not directly related to team performance.

v. In relation to developing new products, effective and efficient teams are faster at bringing new products to market. Also, a line may be traced from quality of social interaction to NPD capability, since quality of social interactions, helps develop a TMS and team tacit knowledge, both team tacit knowledge and TMSs are important for effective teams, where effectiveness is an important predictor of NPD capability.

11.2.4 Conclusions for the Importance of Tacit Knowledge for Knowledge-Worker Teams

The practical implications for knowledge-worker teams, more specifically, software development teams are now outlined.

i. Team tacit knowledge can explain along with transactive memory, how members of effective software development teams apply what they know.

ii. The team tacit knowledge construct along with the TMS construct can help us differentiate between low- and high-performing teams by suggesting that members of high-performing teams have developed different aspects of tacit knowledge about successful performance on projects and this knowledge is then applied to team tasks which can be seen in performance.

iii. It may also be concluded that software development teams work with intangible cognitive processes and are knowledge-workers, where expertise in software development teams requires coordination. However, software development teams in SMEs, have an overlap in roles and expertise when producing software. Therefore, teams in SMEs coordinate their expertise tacitly, and there is less specialisation of expertise than would be expected in larger organisations. Specialising to a great degree, or at least distributed expertise is probably not required for software development teams in SMEs to perform well.

11.3 Methodological Issues and Limitations of the Research

There are several methodological issues and limitations associated with the development of the TTKM study and the main study. These are outlined in the following two sections.

11.3.1 Methodological Issues and Limitations of the TTKM Study

The TTKM was developed in five phases using a mixed method, sequential exploratory approach, utilising triangulation of investigator. The mixed method approach allowed for the 'conversion' of qualitative information into a quantitative instrument.

The online repertory grid technique did not allow for laddering up or laddering down to get a more in-depth view of tacit knowledge. However, the online repertory grid, did allow for speed and cut across geographical boundaries. Face-to-face administration of the repertory grid may lead to investigator bias, but on the other hand may provide deeper and richer knowledge. The trade-off between the two was deemed necessary and practical since that time demands were kept to a minimum for each participant. However, the sample used was not randomly chosen, instead snowball sampling was used which introduces bias in the selection of respondents. However, this bias was a necessary part of the expert sample since the study sought expert project managers who had a reputation for excellence. In addition, the number of experts used for the repertory grids may seem low, thirteen took part phase two. However, this number is in line with findings by Moynihan (2002) who found that the number of themes elicited converged after ten sessions. This finding was echoed in the present study where the number converged after nine sessions. Therefore, thirteen project managers were deemed more than adequate.

There may be bias in the choice of bi-polar constructs used to be representative of each theme. Precautions were taken when categorising the results to ensure as little investigator bias as possible by using two people to categorise and obtain inter-rater agreement (Jankowicz, 2003). Bias may have been introduced by the inequity in the number of experts as compared with the number of novices. This was unavoidable, since novices were easier to access than experts. However, checking for normality and using the non parametric Mann Whitney U test, took this into account.

Finally, the context in which tacit knowledge was investigated is narrow, in that only tacit knowledge related to team performance was elicited. In terms of external validity, generalisability is low, in that the measure can only be used on software development teams. However, the technique used to develop the measure has high external validity in that it can be used on experts in any domain.

11.3.2 Methodological Issues and Limitations of the Main Study

The objective of this study required measuring individuals' perceptions of their informal interactions, development of a transactive memory system, team tacit knowledge and perception of team performance.

This study has the limitations associated with most field research. First, the research design was non-experimental. Regardless of the sophistication of the statistical techniques, causal inferences must be treated with extreme caution when using non-experimental designs. Therefore, even though the results are consistent with prior research and the hypothesised model, causal inferences are withheld.

The survey measure was deemed to be a valid and reliable instrument for use in teams and for the purposes of the present study. However, since the data were collected through a self-report questionnaire, common-method variance could have affected the results of the investigation. Although the general condemnations of self-report methods have been found exaggerated (Crampton & Wagner, 1994). In his review of the role of self-reports in behavioural research, Spector (1994) concluded that, 'properly developed instruments are resistant to the method variance problem' (p. 438). The survey was constructed to reduce as far as possible common-method variance by following the recommendation of Podsakoff and Organ (1986) and Podsakoff et al. (2003) to eliminate the causes of common-method variance.

For example common method variance can artificially inflate bivariate correlations, in complex data relationships. Respondents would not only need to hypothesis-guess correctly, they would also then need to respond accordingly on later survey questions based on their response to earlier ones. This is technically possible, but not terribly likely. Some precautionary steps were taken to avoid bias, by putting the dependent variables after the independent variables. In addition to taking these precautionary steps, the data was assessed for the presence of single method variance bias and several distinct factors were found.

Another source of bias may stem from the performance measure in the present study which was a self-report. Although perceptual data undoubtedly introduces limitations through the possibility of increased measurement error, research has found that there are no significant relationship differences between subjective and objective measures of perceived performance (Bommer et al. 1995; Wall et al. 2004).

A further limitation of this study is that there is no way of knowing if the teams collaborated or interacted with one another while completing the questionnaire. However, the existence of standard deviations across responses, on all measures in all teams provides some support that the teams did not collaborate.

Precautions were taken to ensure a representative sample of SMEs from Ireland and the UK. The response rate was in line with other surveys of the software industry, but still not a representative as one would like. In addition, care was taken when selecting a sample frame to include only those organisations that engaged in software development in teams. This led to a conservative sampling frame, where some companies whose web-sites did not indicate explicitly the nature or content of their activities were eliminated.

11.4 Recommendations and Future Research

Several recommendations are made on the basis of the present study. These are divided into two parts, recommendations for software development teams and recommendations for future research. These are outlined in the next two sections.

11.4.1 Recommendations for Software Development Teams

The type of tacit knowledge related to social interaction is team based, and involves interactions between team members who share and acquire this knowledge, develop transactive memory systems, with different team members possessing different aspects of the team tacit knowledge. The implications for members and managers of software teams is that since tacit knowledge leads to more effective teams, and team tacit knowledge is acquired through social interaction, then it is important to encourage informal social interaction to increase team level tacit knowledge.

Firm conclusions cannot be drawn as to how managers go about increasing social interaction as it was not addressed in this study. However, suggestions forwarded by DeMarco and Lister (1987) regarding the arrangement of office furniture in order to balance privacy and informal interactions in the workplace would be useful. DeMarco and Lister (1987) recommend spatial arrangements that encourage interaction and posit that (a) people work better in natural light, (b) people do not want to work in a perfectly uniform space and (c) for most organizations with productivity problems, there is no more fruitful area for improvement than the workplace. Furthermore, DeMarco and Lister (1987) argue that open-plan offices lack privacy are noisy and therefore counter-productive. Employee requests for private offices are not status driven but due to these factors and co-workers should put their areas together in small suites which will allow interactions to be more easy and natural.

Research in the realm of ecological psychology illustrates how the design of our workplace affects our social interaction. An ecological approach to social behaviour is also useful for guiding the design of things meant to support interaction (e.g. office layout, or collaborative computer systems). This is an area in which the connections between the material and social worlds are most immediately obvious. The more we can understand social behaviour in terms of its material context, the better can design efforts be focused on relevant attributes (Gaver, 1996).

Furthermore Dyba et al. (2004), in their discussion of software development, posit that organisational and cultural arrangements support the acquisition of tacit knowledge by creating a conducive learning environment. They argue that physical arrangements support socialisation and the acquisition of tacit knowledge and two such physical arrangements are advocated: *Project room* with people located together to simplify communication, and *meeting points* which are informal where people can get involved in conversations. These authors advocate that interchanging between structured and unstructured meetings and gatherings may stimulate collective feeling and understanding and provide progress in the project, which is akin to developing a transactive memory system. They outline several factors that promote tacit knowledge acquisition, like pair programming and job rotation. This type of environment is similar to that where Agile methods are used. The implications for software development teams are that processes and methods that may encourage interaction, may also lead directly and indirectly to the development of TMSs and increase tacit coordination. Agile methods and eXtreme Programming appear to focus on this area. In addition, this increases the tacit knowledge base.

Finally, when team members indicated their perception of the number of people in their team, the numbers varied among team members and affected the calculations of within team response rates. Perhaps team boundaries could be clarified by managers with each new project. This would probably enhance communication.

11.4.2 Recommendations for Future Research

Though a significant proportion of the variance in team performance, and in team tacit knowledge was explained, the proportion of unexplained variance in team tacit knowledge presents further research opportunities. Other potential variables, which might have an important influence include, personality, motivation, organisation climate, and practical intelligence. In this vein, it would be useful to tease out the elements that distinguish intuition from tacit knowledge.

Further research with larger samples and varied team types is needed to validate the TTKM scale and examine how the TTKM differs among teams. The TTKM is not intended to be a comprehensive measure of tacit knowledge. Future measures employing the technique used could be developed to measure different aspects of tacit knowledge in software development teams. Perhaps more detailed approach to processes used while developing software, or the languages used. This study has implications for the use of and understanding of tacit knowledge in software development teams. A qualitative study of this would also help advance our understanding of how software development teams use tacit knowledge. In addition, team performance was measured using self-report, it may be useful in future to triangulate, this measure with other forms of effectiveness and efficiency assessment, e.g. stakeholder measures or LOC.

In order to obtain within team agreement when aggregating the individual variables to team level, two different formulae were used. These formulae cannot be directly compared to one another. It is recommended that future studies use the formula forwarded by Lindell et al. (1999) because it truly is a measure of agreement rather than a reliability measure. In addition, their formula allows for variation due to team size. Furthermore, although it is recommended that Lindell et al.'s (1999) formula be used in future, it should be noted that when there are differing numbers of response categories, the scale values change. This means that negative scores cannot be compared with one another. It would be useful to further develop the formula forwarded by Lindell et al. (1999) to allow for this and in order to make direct comparisons.

As team members leave and organisation, it is likely that their individual tacit knowledge leaves with them, unless it is retained in some way within the organisation. It would be useful to investigate the notion that teams act as knowledge repositories for both tacit and explicit knowledge whereby, increasing social interaction in software development teams will enable tacit knowledge to be shared and retained. It may be useful to investigate different tools that enable team members to articulate individual tacit knowledge which may then be recorded for re-use by other team members, may be of interest to software developers.

Finally, it may be useful and of practical benefit to software developers to compare software processes and methods, to ascertain which may be best for the acquisition and sharing of tacit knowledge.

11.5 Contributions and Implications

This research has made several contributions to the body of academic literature and represents an advance in our understanding of how to conceptualise and measure tacit knowledge and in how it is acquired and shared in software development teams.

11.5.1 Contributions and Implications of the TTKM Study

The repertory grid based on personal construct psychology provides a useful technique to access the subtleties of expert knowledge, because it does not separate the knowledge from the knower (Kelly, 1955/1991). As discussed in Chapter 8, the repertory grid provided access to private worlds. This method was deemed best for use in this context since it was brief and allowed for comparison among experts. It also possesses the properties of qualitative methods enabling the respondent to complete the grid using his/her own words. In addition, the grid was administered online, which eliminates to a large degree, researcher bias.

The items elicited from the experts concur with existing theory and have implications for the planning (e.g. goal setting and resources) and management of software development teams where emphasis needs to be placed on enhancing or minimising these group factors (e.g. minimise competition and enhance morale). In addition, when selecting team members there should some experience spread but not too much and it is best to keep the team small. Overall technical aspects of software development do not appear to contribute to project success.

The main contribution of this measure is the five phase technique itself, which is loosely based on the Yale Group approach, but is new, in that it uses the repertory grid to elicit expert's tacit knowledge and uses a 'supplied grid' to elicit team based tacit knowledge. Therefore the technique used advances our measurement of tacit knowledge to the team level, it is not as cumbersome or time consuming as SJTs (Ryan & O'connor, 2004).

It is suggested that the repertory grid captures the context and the personal nature of knowledge since it is based on bi-polar construing within a given context. It was appropriate to use this method for the sample of project managers because it was easily tailored to that particular type of expert (Shadbolt & Milton, 1999). In addition, the technique used is very adaptable to different contexts, since it is easily changed.

Overall, the TTKM is conceptually, theoretically and statistically valid according to Messick's (1995) framework to establish validity. The TTKM advances our knowledge of how tacit knowledge may be measured directly at the articulated level of abstraction and at the team level.

The study also makes practical contributions for researchers and practitioners. Because the tacit knowledge items do not depend on the task domain, or on the length or complexity of team tasks, the scale could be used to compare teams over time, and in a variety of task settings and contexts. Since the scale consists of self-report items that can be interpreted using basic statistical techniques, practitioners could also administer the scale in their own organizations to diagnose levels of team tacit knowledge.

11.5.2 Contributions and Implications of the Main Study

The primary contribution of this research is the extension of individual-level, cognition-focused tacit-knowledge research to consider team-level behaviour. This study makes some important contributions to tacit knowledge theory. First, it provides conceptual and empirical evidence that tacit knowledge can be measured at the articulated level of abstraction and is evident in the differences between novices and experts as the Yale group proposed. Findings from this study complement past studies that measured tacit knowledge by individuals and by proxy (e.g. Edmondson 2003; Hedlund et al. 2003; Berman et al. 2002). This is important to field research, since measuring tacit knowledge by direct means is infeasible in many applied settings.

In addition, the main study empirically demonstrates that tacit knowledge is related to quality of social interaction. The positive and significant correlations between the tacit knowledge and quality of social interaction provide evidence for the anecdotal evidence forwarded by researchers such as Nonaka and Takeuchi (1995) and quantitative evidence for qualitative investigations, like those carried out by Busch et al. (2003).

Furthermore, it has been shown that transactive memory contributes to team tacit knowledge and to a software development team's effective performance. Also, coordination above all other factors leads to effective performance. This implies that in software SMEs, the teams are highly coordinated, this coordination leads to effective performance. Teams in software SMEs probably work in a more informal manner than teams in large MNCs, where most team-level research has been conducted. It appears that teams in the present study have more overlapping roles and less specialised methods f working together than would be expected if they worked in a large MNC.

In addition, a sequence linking quality of social interaction and NPD can be traced from quality of social interaction, which leads to the development of a TMS and to the development of team tacit knowledge which both predict effective team performance, which in turn predicts NPD capability. This illustrates by extrapolation, the key role quality of social interaction plays in team performance and NPD capability.

A final contribution for software practitioners and researchers is that, the present study may provide a theoretical background and empirical evidence for Agile methods for software development. It was posited by Chau et al. (2003) and Chau et al. (2004), that there is a need for knowledge sharing to enable software organisations to leverage tacit knowledge. These authors argue that this knowledge sharing would occur through face-to-face interactions through the methods used in eXtreme Programming. The present study has demonstrated that tacit knowledge is acquired through high quality social interaction and through the development of a transactive memory system. These issues are accounted for by Agile methods and it appears that the Agile approach to software development enhances effectiveness.

References

Abrahamson, P., Salo, O., Ronkainen, J., & Warsta, J. (2002). *Agile software development methods: Review and analysis.* VTT Publications. Retrieved September 3, 2004, from http://www.inf.vtt.fi/pdf/.

Allee, V. (1997). 12 Principles of Knowledge Management. *Training and Development, 51*(11), 71-74.

Allen, T. (1977). *Managing the flow of technology*. Cambridge, Mass.: MIT Press.

Ambler, S. (1999). Comprehensive approach cuts project failure. *Computing Canada, 25*(1), 15-16.

Anastasi, A., & Urbina, S. (1997). *Psychological testing* (7th ed.). NJ: Prentice-Hall.

Ancona, D. G., & Caldwell, D. F. (1992). Bridging the boundary: External activity and performance in organizational teams. *Administrative Science Quarterly, 37*, 634-665.

Anderson, J.R. (1976). *Language, memory and thought*. Hillsdale, NJ: Erlbaum.

Anderson, J. (1983). *The architecture of cognition.* Cambridge, MA: Harvard University Press.

Anderson, J. (1993). *Rules of the mind.* Hillsdale, NJ: Erlbaum.

Anderson, R.J., Hughes, J.A., & Sharrock, W.W. (1986). *Philosophy and the human sciences.* London: Croom Helm.

Argyris, C. (1993). *Knowledge for action.* San Francisco: Jossey-Bass.

Argyris, C., & Schön. D. (1978). *Organizational learning: A theory of action perspective*. Reading, MA: Addison-Wesley.

Athans, M. (1982). The expert team of experts approach to command-and-control (C^2) organizations. *IEEE Control Systems Magazine, 2/3*, 30-38.

Austin, J. R. (2003). Transactive memory in organizational groups: The effects of content, consensus, specialization, and accuracy on group performance. *Journal of Applied Psychology, 88*(5), 866-878.

Babbie, E. (2001). *The practice of social research* (9th ed.). Belmont CA: Wadsworth.

Babbie, E., & Halley, F. (1994). *Adventures in social research: Data analysis using SPSS.* Thousand Oaks, CA: Pine Forge Press.

Bales R.F. (1950) *Interaction Process Analysis: A Method for the Study of Small Groups.* Reading, MA: Addison-Wesley.

Banister, P., Burman, E., Parker, I., Taylor, M., & Tindall, C. (1994). *Qualitative methods in psychology.* Buckingham: Open University Press.

Bannister, D. (1981) Personal construct theory and research method. In P. Reason & J. Rowan (Eds.), *Human inquiry: A sourcebook of new paradigm research* (pp. 191-199). New York: Wiley.

Bannister, D., & Fransella, F. (1989). *Inquiring man: The psychology of personal constructs* (3rd ed.). London: Routledge.

Bantel, K.A. (1994). Strategic planning openness: The role of top team demography. *Group & Organization Management, 19*(4), 406-424.

Barker, R., & Camarata, M. (1998). The role of communication in creating and maintaining a learning organization: Preconditions, indicators and disciplines. *The Journal of Business Communications, 35,* 443-467.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*, 1173-1182.

Bartlett, F.C. (1932). *Remembering*. Cambridge: Cambridge University Press.

Baumard, P. (1999). *Tacit knowledge in organizations*. London: Sage.

Bean, A. G., & Roszkowski, M. J. (1995). The long and short of it. *Marketing Research, 7*(1), 20-26.

Beck, K. (1999). *Extreme programming explained: Embrace change.* Reading, MA: Addison- Wesley.

Bell, R. C. (2001) Some new measures of the dispersion of dependency in a situation-resource grid. *Journal of Constructivist Psychology, 14*, 227-234.

Berg-Cross, G. & Price, M. E. (1989). Acquiring and Managing Knowledge using a Conceptual Structures Approach. *IEEE Transactions on Systems, Man, and Cybernetics, 19*, 513-527.

Berger, P., & Luckmann, T. (1967). *The social construction of reality*. New York: Anchor.

Berman S.L., Down J., & Hill C.W.L. (2002). Tacit knowledge as a source of competitive advantage in the National Basketball Association. *Academy of Management Journal, 45*(1), 13-31.

Berry, D. C., & Broadbent, D. E. (1995). Implicit learning in the control of complex systems: A reconsideration of some of the earlier claims. In P. A. Frensch & J. Funke (Eds.), *Complex problem solving: The European perspective* (pp. 131-150). Hillsdale, NJ: Erlbaum.

Blackler, F. (1995). Knowledge, knowledge work and organizations: An overview and interpretation. *Organization Studies 16*(6), 1021-1046.

Blau, P. (1964). *Exchange and power in social life*. New York: Wiley.

Boehm, B. W. (1981). *Software engineering economics*. Englewood Cliffs, NJ: Prentice-Hall.

Boehm, B. W. (1987). Improving software productivity. *Computer, September*, 43-57.

Bommer, W .H., Johnson, J. J., Rich, G. A., Podsakoff, P. M., & Mackenzie, S .B. (1995). On the interchangeability of objective and subjective measures of employee performance: A meta-analysis. *Personnel Psychology, 48*, 587-605.

Bowers, C. A., Urban, J. M., & Morgan, B. B. (1992). *The study of crew coordination and performance in hierarchical team decision making* (Report No. TR-92-01). Orlando, FL: University of Central Florida, Team Performance Laboratory.

Bouthillier, F., & Shearer, K. (2002). Understanding knowledge management and information management: the need for an empirical perspective. *Information Research, 8*(1), paper no. 141. Retrieved August 12, 2003, from http://InformationR.net/ir/8-1/paper141.html

Bransford, J.D. (1990). Anchored instruction: Why we need it and how technology can help. In D. Nix & R. Sprio (Eds), *Cognition, education and multimedia*. Hillsdale, NJ: Erlbaum Associates.

British Psychological Society (2003). *Psychological testing centre-FAQs*. Retrieved May 5, 2003, from http://www.psychtesting.org.uk/public/faqs.asp?id=143&image=headers/testtakers.gif&sectionid=4&section=1

Brooks, F. (1987). No silver bullet: Essence and accidents of software engineering. *IEEE Computer, 20*(4), 10-19.

Brooks, F. (1995). *The mythical man-month: Essays on software engineering.* Reading, Massachusetts: Addison-Wesley.

Brown, S. M. (1992) Cognitive mapping and repertory grids for qualitative survey research: Some comparative observations. *Journal of Management Studies, 29*(3), 287-307.

Brown, J. S., & Duguid, P. (1991). Organizational learning and communities of practice: toward a unified view of working, learning, and innovation. *Organization Science, 2*(1), 40-57.

Bruer, J.T. (1993). The mind's journey from novice to expert. *American Educator, 6*(15), 38-46.

Bruner, J. (1966). *Toward a theory of instruction.* Cambridge, MA: Harvard University Press.

Bruner, J. (1990). *Acts of meaning.* Cambridge, MA: Harvard University Press

Brusoni, S., Prencipe, A., & Pavitt, K. (2001). Knowledge specialization, organizational coupling and the boundaries of the firm: Why do firms know more than they make? *Administrative Science Quarterly, 46*(4), 597-621.

Bryman, A. (2001). *Social research methods*. Oxford: Oxford University Press.

Buckley, F., Monks, K., & Sinnott, A. (1998). Communications enhancement: A process dividend for the organization and the HRM department? *Human Resource Management, 37* (3&4), 221-234.

Burrell, G. & Morgan, G. (1979). *Sociological paradigms and organisational analysis.* London: Heinemann.

Busch, P., Richards D., & Dampney, C. N. G. (2003). The graphical interpretation of plausible tacit knowledge flows. *Conferences in Research and Practice in Information Technology, 24,* Australian Computer Society.

Busch, P., & Richards, D. (2004). Acquisition of articulable tacit knowledge. *Proceedings of the Pacific Knowledge Acquisition Workshop (PKAW '04), in conjunction with, The English Pacific Rim International Conference on Artificial Intelligence, August 9-13, Auckland, NZ*, 87-101.

Button, G., & Sharrock, W. (1995). Practices in the work of ordering software development. In: A. Firth (Ed.), *The discourse of negotiation: studies of language in the workplace* (pp.159-180). Oxford: Pergamon.

Campbell, D.T. (1960). Recommendations for the APA test standards regarding construct, trait, and discriminant validity. *American Psychologist, 15*, 546-553.

Campbell, D. T., & Fiske, D. W. (1959). Convergent and discriminant validation by the multi-trait, multi-method matrix. *Psychological Bulletin, 56*, 81-105.

Cannon-Bowers, J. A., & Salas, E. (1990). *Cognitive psychology and team training: Shared mental models in complex systems.* Paper presented at the annual meeting of the Society for Industrial and Organizational Psychology, Miami, Florida.

Cannon-Bowers, J. A., Salas, E., & Converse, S. A. (1993). Shared mental models in expert team decision making. In N. J. Castellan (Ed*.), Individual and group decision making* (pp. 221-246). Hillsdale, NJ: Erlbaum.

Chan, D., & Schmitt, N. (1998). Video-based versus paper-and-pencil method of assessment in situational judgment tests: Subgroup differences in test performance and face validity perceptions. *Journal of Applied Psychology, 82*, 143-159.

Charness, N., Krampe, R. T., & Mayr, U. (1996). The role of practice and coaching in entrepreneurial skill domains: An international comparison of life-span chess skill acquisition. In K. A. Ericsson (Ed*.), The road to excellence: The acquisition of expert performance in the Arts and Sciences, Sports, and Games* (pp. 51-80). Mahwah, NJ: Erlbaum.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology*, *4*, 55-81.

Chau, T., Maurer, F., & Melnik, G. (2003). Knowledge sharing: Agile methods vs. Tayloristic methods. *In Proceedings of the IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises, 9-11 June*. Linz, Austria. IEEE Computer Society. Retrieved December 2, 2004, from http://sern.ucalgary.ca/~milos/papers/2003/ChauMaurerMelnik.pdf

Chau, T., & Maurer F. (2004). Knowledge sharing in agile software teams *.In Proceedings of the Symposium on Logic versus Approximation.* Springer. Retrieved December 2, 2004, from http://www2.umassd.edu/SWPI/xp/papers/ChauMaurer2004.pdf

Chen, W., & Hirschheim, R. (2004) A paradigmatic and methodological examination of information systems research from 1991 to 2001, *Information System Journal, 14*, 197–235.

Chi, M. T. H., Glaser, R., & Farr, M. J. (1988). *The nature of expertise.* Hillsdale, NJ: Erlbaum.

Chi, M. T. H., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In R. S. Sternberg, (Ed.), *Advances in the psychology of human intelligence* (Vol. 1, pp. 1-75). Hillsdale, NJ: Erlbaum.

Chiu, C., Hong, Y, Mischel, W. & Shoda, Y. (1995). Discriminative facility in social competence: Conditional versus dispositional encoding and monitoring-blunting of information. *Social Cognition, 1*(1), 49-70.

Choo, C. W. (1998). *The knowing organization: How organizations use information to construct meaning, create knowledge, and make decisions.* New York: Oxford University Press.

Church, A. H., & Waclawski, J. (2000). *Is there a method to our madness? Survey and feedback method effects across five different settings.* Paper presented at the 15th Annual Meeting of the Society for Industrial and Organizational Psychology (SIOP), April 15, New Orleans, Louisiana.

Clancey, W. J. (1995). A tutorial on situated learning. In J. Self (Ed.), *Proceedings International Conference on Computers and Education* (pp.49-70). Charlottesville, VA: AACE. Retrieved November 12, 2001, from http://cogprints.org/323/00/139.htm

Clancey, W. J. (1997). *Situated Cognition: on human knowledge and computer representations.* Cambridge: Cambridge University Press.

Clark, N. K. & Stephenson, G. M. (1989). Group remembering. In P. Paulus (Ed.), *The psychology of group influence* (pp357-391). Hillsdale, NJ: Erlbaum.

Cleeremans, A. (1977). Sequence learning in a dual-stimulus setting. *Psychological Research-Psychologische Forschung, 60*(1-2), 72-86.

Cleeremans, A. (1997). Principles for implicit learning. In D. Berry (Ed.), *How implicit is implicit learning?* (pp. 195-234). Oxford: Oxford University Press.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). New York: Academic Press.

Cohen, M. D., March, J. G., & Olsen, J. P. (1972). A garbage can model of organizational choice. *Administrative Science Quarterly, 17*(1), 1-25.

Collis, B., & Winnips, K. (2002). Two scenarios for productive learning environments in the workplace. *British Journal of Educational Technology, 33*(2), 133-148.

Commission (2003). *Commission recommendation May 6th 2003 concerning the definition of micro, small and medium-sized enterprises* (Official Journal L 124 of 20/05/2003). Retrieved September3, 2004 from http://europa.eu.int/scadplus/leg/en/lvb/n26026.htm.

Compton, P., & Jansen, R. (1990). A philosophical basis for knowledge acquisition. *Knowledge Acquisition, 2*, 241-257.

Cook, S. D. N. & Brown, J. S. (1999). Bridging epistemologies: The generative dance between organizational knowledge and organizational knowing. *Organization Science, 10* (4), 381-400.

Cook, C., Heath, F., & Thompson, R. (2000). A meta-analysis of response rates in Web- or Internet-based surveys. *Educational & Psychological Measurement, 60*(6), 821-36.

Cooke, F. L. (2003). Maintaining change: The maintenance function and the change process. *New Technology, Work and Employment 18*(1), 35-49.

Couger, J. D. (1988). Motivators vs demotivators in the IS environment. *Journal of Systems Management 39*, 36-41.

Couger, D., & Zawacki, R. (1980). *Motivating and managing computer personnel*. New York: Wiley.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd ed). Thousand Oaks, CA.: Sage.

Crowston, K. (1997). A coordination theory approach to organizational process design. *Organization Science, 8*(2), 157-175.

Curtis, B. Krasner, H. & Iscoe, N. (1988). A field study of the software design process for large systems. *Communications of the ACM, 31*(11), 1268-1287.

Daft, R.L. (2004). *Organization theory & design* (8th ed.). Ohio: South-Western.

Davenport, T. & Prusak, L. (1998). *Working knowledge*. Boston, MA: Harvard Business School Press.

Davis, R., Shrobe, H., & Szolovits, P. (1993). What is a knowledge representation? *AI Magazine*, 14(1), 17-33.

DeMarco, T., & Lister, T. (1987). *Peopleware: Productive projects and teams*. New York: Dorset House.

Denzin, N. K. (1970). *The research act in sociology: A theoretical introduction to sociological methods*. London: Butterworth.

Denzin, N. K. (1989). *The research act* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Denzin N. K., & Lincoln, Y. S. (2000). *Handbook of qualitative research* (2nd ed.). Thousand Oaks, Sage.

Department of Trade and Industry (DTI), United Kingdom, (1998). *Our competitive future: Building the knowledge driven economy. White paper*, DTI, London.

Department of Trade and Industry (DTI) United Kingdom, (2004). *Sector competitiveness analysis of the software and computer services industry*. DTI, London. Retrieved September 3, 2004 from http://www.dti.gov.uk/industries/software/Sector_Competitiveness_Analysis.doc.

Desouza, K. C. (2003).Facilitating Tacit Knowledge Exchange. *Communications of the ACM. 46*(6), 85-88.

Dillman, D. A. (2000). *Mail and Internet surveys: The tailored design method* (2nd ed.). New York: Wiley.

Dreyfus, H., & Dreyfus, S. (1986). *Mind over machine: The power of human intuition*. New York: Free Press.

Drucker, P. (1993). *Post-Capitalist society*. New York: Harper Business.

Dummett, M. (1978). *Truth and other enigmas*. London: Duckworth Press.

Dutton, J., Walton, E., & Abrahamson, E. (1989). Separating the wheat from the chaff: The important dimensions of strategic issues. *Journal of Management Studies, 26*(4), 379-396.

Dybå, T., Dingsøyr, T., & Moe, N.B. (2004). *Process improvement in practice: A handbook for IT companies*. London: Kluwer.

Dyer, William G. (1987). *Team building: issues and alternatives* (2^{nd} ed.). Reading, MA: Addison-Wesley.

Easterby-Smith, (1980). The design, analysis and interpretation of repertory grids. *International Journal of Man-Machine Studies, 13*, 3-24.

Edmonson A. (1999). Psychological safety and learning behaviour in work teams. *Administrative Science Quarterly, 44*, 350-383.

Edmondson, A. C. (2002). The local and variegated nature of learning in organizations: A group-level perspective. *Organization Science, 13*(2), 128-146.

Edmondson, A. C., Winslow, A. B., Bohmer, R. M. J., & Pisano, G. P. (2003). Learning how and learning what: Effects of tacit and codified knowledge on performance improvement following technology adoption. *Decision Sciences, 34*(2), 197-223.

Edwards, J. S. (2003). Managing software engineers and their knowledge. In A. Aurum, R. Jeffery, C. Wohlin & M. Handzic (Eds.), *Managing software engineering knowledge* (pp. 5-27). New York: Springer.

Edwards, D. & Middleton, D. (1986). Joint remembering: Constructing an account of shared experience through conversational discourse. *Discourse Processes, 9*, 423-459.

Eisenberg, E.M. (1984). Ambiguity as strategy in organizational communication. *Communication Monographs, 51*, 227-242.

Ellis, R. D., Jankowski, T. B., Jasper, J. E., & Tharuvai, B. S. (1998). Listener: A tool for clientside investigation of hypermedia navigation behaviour. *Behavior Research Methods, Instruments and Computers, 30,* 573-582.

Eraut, M. (2000). Non-Formal Learning and Tacit Knowledge in Professional Work. *British Journal of Educational Psychology 70*, 113-136.

Ericsson, K. A., Krampe, R., & Tesch-Römer, C. (1993) The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 3*, 363-406.

Ericsson, K. A., & Lehmann, A.C. (1996). Expert and exceptional performance: Evidence on maximal adaptations on task constraints. *Annual Review of Psychology, 47*, 273-305.

Ericsson, K. A., & Smith, J., (Eds.) (1991). *Toward a general theory of expertise: Prospects and limits.* Cambridge: Cambridge University Press.

Eysenck, M.W., & Keane, M.T. (2000). *Cognitive psychology* (4th ed.). East Sussex: Psychology Press Ltd.

Faraj, S. & Sproull, L. (2000). Coordinating expertise in software development teams. *Management Science, 46* (12), 1554-1568.

Farrell, L. (2001). Negotiating knowledge in the knowledge economy: Workplace educators and the politics of codification. *Studies in Continuing Education, 23*(2), 201-214.

Faught, K. S., Whitten, D., & Green Jr., K. W. (2004). Doing survey research on the internet: Yes, timing does matter. *Journal of Computer Information s, 44*(3), 26-34.

Feigenbaum, E. & McCorduck, P. (1983). *The fifth generation: Artificial intelligence and Japan's computer challenge to the world.* New York: New American Library.

Fernie, S., Weller, S., Green, S.D., & Newcombe, R. (2003). Knowledge sharing: context, confusion and controversy. *International Journal of Project Management, 21*(3), 177-187.

Firestone, W. A. (1987). Meaning in method: The rhetoric of quantitative and qualitative research. *Educational Researcher 16*(7), 16-21.

Fiske, D. W. (1982). Convergent-discriminant validation in measurements and research strategies. In D. Brinbirg & L. H. Kidder (Eds.), *Forms of validity in research* (pp. 77-92). San Francisco: Jossey-Bass.

Flaherty, T. B., Honeycutt, E. D., Jr., & Powers, D. (1998). Exploring text-based electronic mail surveys as means of primary data collection. *The 1998 Academy of Marketing Science National Conference Proceedings,* 260-64.

Flanagan, J. C. (1954). The critical incident technique. *Psychological Bulletin, 51*, 327-358.

Forgas, J. P. (1981). Social episodes and group milieu: A study in social cognition. *British Journal of Social Psychology, 20*, 77-87.

Fowler, F. J. (1988). *Survey research methods.* Newbury Park, CA: Sage.

Fransella, F. & Bannister, D. (1977). *A manual for repertory grid technique*. London: Academic Press.

Gagné, R. M. (1985). *The conditions of learning and theory of instruction* (4th ed.). New York: Holt, Rinehart, and Winston.

Gaines, B. R. (1987). Rapid prototyping for expert systems. In M. D. Oliff, (Ed.), *Intelligent manufacturing: Proceedings of the First International Conference on Expert Systems and the Leading Edge in Production Planning and Control* (pp. 45-73).

Gaines, B. R. & Shaw, M. L. (1995). Concept maps as hypermedia components, *International Journal of Human-Computer Studies*, *43* (3), 323-361.

Gaines, B .R., & Shaw, M. (2003). WebGrid III. [Computer software]. Retrieved from http://tiger.cpsc.ucalgary.ca:1500/WebGrid/

Galegher, J., & Kraut, R. E. (1990). Computer-mediated communication for intellectual teamwork: A field experiment in group writing. *Proceedings of the Conference on Computer- Supported Cooperative Work*, 65-78.

Galliers, R D (1991). Choosing appropriate Information Systems research approaches: a revised taxonomy. In H. E. Nissen, H .K. Klein, & R. A. Hirschheim, (Eds.), *Information Systems research: Contemporary approaches and emergent traditions* (pp. 327-345). Amsterdam: New Holland.

Gardner, H. (1985). *The mind's new science*. New York: Basic Books.

Garrety, K., Robertson, P. L., & Badham, R. (2004). Integrating communities of practice in technology development projects. *International Journal of Project Management, 22*, 351-358.

Gaver, W. (1996). Affordances for interaction: The social is material for design. *Ecological Psychology 8*(2), 111-129.

Gellner, E. (1980). *Society and Western Anthropology.* New York: Columbia University Press.

Gibbs, W. (1994). Software's chronic crisis. *Scientific American, September*, 86-95.

Gibson, J. J. (1977). The theory of affordances. In R. E. Shaw & J. Bransford (Eds.), *Perceiving, acting and knowing: Toward an ecological psychology* (pp. 67–82). Hillsdale NJ: Erlbaum.

Giddens, A. (1975). *Positivism and sociology.* London: Heinemann Educational Books.

Gill, J., & Johnson, P. (1991). *Research methods for managers*. London: Chapman.

Glass, R.L (1992). *Building quality software*. Englewood Cliffs, NJ: Prentice-Hall.

Gorla, N., & Lam, Y.W. (2004). Who should work with whom? *Communications of the ACM, 47*(6), 79-82.

Gottfredson, L. S. (2001). Book Review: Practical Intelligence in Everyday Life. *Intelligence, 29*, 363-365.

Gourlay, S. (2002). *Tacit knowledge, tacit knowing or behaving?* Paper presented at the Third European Conference on Organizational Knowledge, Learning, and Capabilities, Athens, Greece, April 2002. Retrieved September 15, 2003, from http://www.alba.edu.gr/OKLC2002/Proceedings/pdf_files/ID269.pdf

Granovetter, M. S. (1973). The strength of weak ties. *American Journal of Sociology, 78*(6), 1360–1380.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal, 17*(Special Issue), 109-122.

Green, K., Medlin, B. & Medlin, R. (2001). Strategic human resource management: Measurement scale construction. *Academy of Strategic and Organizational Leadership Journal*, *5*(2), 99-112.

Green, K., Medlin, B. & Whitten, D. (2001). Internet survey methodology: Comparison with mail surveys. *Quirk's Marketing Research Review*, XV(7), 56-59.

Greeno, J. G. (1998). The situativity of knowing, learning, and research. *American Psychologist, 53*(1), 5-26.

Groen, G. J. & Patel, V. L. (1988). The relationship between comprehension and reasoning in medical expertise. In M. T. H. Chi, R. Glaser & M. J. Farr (Eds.), *The Nature of Expertise* (pp. 287-310). Hillsdale, NJ: Erlbaum.

Guignon, C. (Ed.), (1992). *The Cambridge companion to Heidegger*. Cambridge: Cambridge University Press

Guinan, P., Cooprider, J., & Faraj, S. (1998).Enabling software development team performance during requirements definition: A behavioural versus technical approach. *Information Systems Research, 9*(2), 101-125.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N.K. Denzin & Y.S. Lincoln (Eds.), *Handbook of qualitative research* (pp.105-117). Beverly Hills: Sage.

Hackman, J. R. (1987). The design of work teams. J. Lorsch, (Ed.), *Handbook of organizational behaviour* (pp. 315-342). Englewood Cliffs, NJ: Prentice-Hall

Hackman, J.R. (1992). Group influences on individuals in organizations. In M. D. Dunnette & L. M. Hough, (Eds.), *Handbook of industrial and organizational psychology*(pp.). Palo Alto, CA: Consulting Psychologists Press.

Hager, P. (2000). Know-how and workplace practical judgement. *Journal of Philosophy of Education* 34(2), 281-296.

Haleblian J.,& Finkelstein S. (1993). Top Management Team Size, CEO Dominance, and Firm Performance: The Moderating Roles of Environmental Turbulence and Discretion. *Academy of Management Journal*, *36,* 844-863.

Hammer, M., & Champy, J. (1993). *Reengineering the corporation: A manifesto for business revolution*. New York: HarperCollins.

Hanks, W. F. (1991). Foreword by William F. Hanks. In J. Lave & E. Wenger (Eds.), *Situated learning: Legitimate peripheral participation* (pp. 13–24). New York: Cambridge University Press

Hansen, M., Nohria, N., & Tierney, T. (1999). What's your strategy for managing knowledge? *Harvard Business Review, 77*(2), 106-116.

Hare, A. P. (1981). Group size. *American Behavioral Scientist, 24*, 695-708

Harrison, D. A., & McLaughlin, M. E. (1993). Cognitive processes in self-report responses: Tests of item context effects in work attitude measures. *Journal of Applied Psychology, 78*, 129-140.

Harrison, D. A., McLaughlin, M. E., & Coalter, T. M. (1996). Context, cognition, and common method variance: Psychometric and verbal protocol evidence. *Organizational Behavior and Human Decision Processes, 68,* 246-261.

Harrison, D. A., Price, K. H., & Bell, M. P. (1998). Beyond relational demography: Time and the effects of surface- and deep-level diversity on work group cohesion. *Academy of Management Journal, 41*, 95-107.

Hayashi, A. (2000). When to trust your gut. *Harvard Business Review, 29*(2), 2000, 59-66.

Hayes, F. (1997). Managing user expectations. *Computerworld, 31*, 8-9.

Hedlund J., Forsythe G. B., Horvath, J. A., Williams, W. M., Snook, S., & Sternberg R.J. (2003). Identifying and assessing tacit knowledge: understanding the practical intelligence of military leaders. *Leadership Quarterly, 14*(2), 117-140.

Henderson, J., & Lee, S. (1992). Managing I/S design teams: A control theories perspective. *Management Science, 38*(6), 757-777.

Hoffman, R., Shadbolt, N. R., Burton, A. M., & Klein, G. (1995) Eliciting knowledge from experts: A methodological analysis. *Organizational Behavior and Decision Processes, 62*, 129-158.

Hollingshead, A. B. (1998a). Communication, learning, and retrieval in transactive memory systems. *Journal of Experimental Social Psychology, 34*, 423-442.

Hollingshead, A. B. (1998b). Retrieval processes in transactive memory systems. *Journal of Personality and Social Psychology, 74*(3), 659-671.

Hollingshead, A. B. (2001). Cognitive interdependence and convergent expectations in transactive memory. *Journal of Personality and Social Psychology, 81*(6), 1080-1089.

Holtzman, W. H. (1978). *Introduction to psychology.* London :Harper and Row.

Holyoak, K. J. (1984). Mental models in problem solving. In J.R. Anderson & S.M. Kosslyn (Eds.), *Tutorials in learning and memory* (pp. 283 –307). New York: W.H. Freeman.

Hsu, P. (1938). Contributions to the theory of 'Student's' t test applied to the problem of two samples. *Statistical Research Memoirs, 2,* 1-24.

Hult, G. T. M. (2003). An integration of thoughts on knowledge management. *Decision Sciences, 34*(2), 189-195.

Hunter, L. C., & Beaumont, P.(2002). *Managing knowledge workers: The HRM Dimension (CIPD Research Report)*, London: CIPD.

Hutchins, E. (1991). The social organization of distributed cognition. In L. B. Resnick, J. M. Levine and S. D. Teasley (Eds.), *Perspectives on socially shared cognition.* (pp.283-307). Washington, DC: American Psychological Association.

Iansiti, M., & MacCormack, A. (1997). Developing Products on Internet Time. *Harvard Business Review, 75*(Sept.-Oct.), 108-117.

Industrial Development Authority, Ireland (2003). Annual Report. Retrieved August 6, 2004, from http://www.idaireland.com/uploads/reports/Annual_report_03/index.html

Jackson, P. (1990). *Introduction to expert systems* (2nd ed.). Boston, MA: Addison-Wesley.

Jackson, S. E., Brett, J. F., Sessa, V. I., Cooper, D. M., Julin, J. A., & Peyronnin, K. (1991). Some differences make a difference: Individual dissimilarity and group heterogeneity as correlates of recruitment, promotions, and turnover. *Journal of Applied Psychology, 76*(5), 675-689.

James, W. (1890). *The principles of psychology.* New York: Dover.

James, L. R., Demaree, R .G., & Wolf, G. (1984). Estimating within-group interrater reliability with and without response bias. *Journal of Applied Psychology, 69*(1), 85-98.

Jankowicz, D. (2003). *The easy guide to repertory grids*. London: Wiley.

Jiang, J. J., Klein, G., & Discenza, R. (2002). Perception differences of software success: Provider and user views of system metrics. *The Journal of Systems and Software, 63*, 17-27.

Johannessen, J. A., Olaisen, J., & Olsen, B. (2001). Mismanagement of tacit knowledge: the importance of tacit knowledge, the danger of information technology, and what to do about it. *International Journal of Information Management, 21*, 3-20.

Katz, R. (1982). The effects of group longevity on project communication and performance. *Administrative Science Quarterly, 27*, 81-104.

Katz, R., & Tushman, M. (1981). An investigation into the managerial roles and career paths of gatekeepers and project supervisors in a major R&D facility. *R & D Management, 11*, 103-110.

Kelly, G. A. (1955/1991). *The psychology of personal constructs* (Vols. 1 and 2). London: Routledge.

Kellysearch (n.d.) Directory of Software Companies. Retrieved June-November, 2003, from http://www.kellysearch.com/gb-product-20876.html

Kemerer, C. F. (1989). An agenda for research in the managerial evaluation of computer-aided software engineering tool impacts. *Proceedings of the Twenty-Second Hawaii International Conference.* Kailuo-Kona, HI, 210-228.

Kennedy, P. (1985). *A guide to econometrics* (2^{nd} ed.). Cambridge, MA: MIT Press

Keppel, G. (1991). *Design and analysis: A researcher's handbook* (3^{rd} Ed.). Englewood Cliffs, NJ: Prentice Hall.

Kerlinger, F. N. (1986). *Foundations of behavioural research* (3^{rd} ed.) New York: Holt, Rinehart & Winston.

Kidder, L. (1981). *Research methods in social relations.* New York: Holt, Rinehart & Winston.

Kiesler, S. B. (1978). *Interpersonal processes in groups and organizations.* IL: AHM

Kimble, G. A., Hilgard E.R., & Marquis, D.E. (1961). *Conditioning and learning.* New York: Appleton Century-Crofts.

Klein, K. J., Dansereau, F., & Hall, R. J. (1994). Levels issues in theory development, data collection, and analysis. *Academy of Management Review, 19*, 195-229

Klimoski R., & Mohammed S. (1994). Team mental model - construct or metaphor. *Journal of Management, 20*(2), 403-437

Kobes, B. W. (1991). On a model for psycho-neural coevolution. *Behavior and Philosophy, 19*(2), 1-18. ·

Koskinen, K., Pihlanto, P., & Vanharanta, H. (2003). Tacit knowledge acquisition and sharing in a project work context. *International Journal of Project Management, 21*, 281-290.

KPMG Consulting (2000). *Knowledge management research report.* London: KPMG Consulting.

Kramer, H., & Thiemann, S. (1987). *How many subjects? Statistical power analysis in research.* Newbury Park, CA: Sage.

Kraut R.E., Egido C., & Galegher J. (1990). Patterns of contact and communication in scientific research collaboration. In J. Galegher & R. Kraut (Eds.), *Intellectual teamwork: The Social and technological bases of cooperative work.* Hillsdale, NJ: Erlbaum.

Kraut, R. E., & Streeter, L. A. (1995). Coordination is software development. *Communications of the ACM, 38*, 69-81.

Kuhn, T. (1962). *The structure of scientific revolutions.* Chicago: University of Chicago Press.

Lanzara, G., & Patriotta, G. (2001).Technology and the courtroom: An inquiry into knowledge making in organizations. *Journal of Management Studies, 38*(7), 943-971.

Larson, J. R., & Christensen, C. (1993). Groups as problem-solving units: Toward a new meaning of social cognition. *British Journal of Social Psychology, 32*, 5-30.

Lau, D. C., & Murnighan, J. K. (1998). Demographic diversity and faultlines: The compositional dynamics of organizational groups. *Academy of Management Review, 23*, 325-340.

Lave, J. (1986). The values of quantification. In J. Law (Ed.), *Power, action, and belief* (pp. 88–111). Boston, MA: Routledge & Kegan Paul.

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life.* Cambridge: Cambridge University Press.

Lave, J. (1993). Situating learning in communities of practice. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 17–36). Washington, DC: American Psychological Association.

Lave, J. (1997). The culture of acquisition and the practice of understanding. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives* (pp. 17–36). Mahwah, NJ: Erlbaum.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge: Cambridge University Press.

Lechler, T. (2001). Social interaction: A determinant of entrepreneurial team venture success. *Small Business Economics, 16*, 263-278.

Legree, P. (1995). Evidence for an oblique social intelligence factor established with Likert-based testing procedure. *Intelligence, 21*, 247-266.

Legge K. (1995). *Human resource management: Rhetorics and realities.* London: MacMillan.

Leonard D., & Sensiper, S. (1998). The role of tacit knowledge in group innovation. *California Management Review, 40*(3), 112-132.

Lesser, E., & Prusak, L. (2000). Communities of practice, social capital and organizational knowledge. In E. L. Lesser, M. A. Fontaine & J. A. Slusher (Eds.), *Knowledge and Communities* (pp. 123-131). Boston, MA: Butterworth-Heinemann .

Levesque, L. L., Wilson, J. M., & Wholey, D.R. (2001) Cognitive divergence and shared mental models in software development project teams. *Journal of Organizational Behavior, 22,* 135–144.

Lewis, K. (2003). Measuring transactive memory systems in the field: Scale development and validation. *Journal of Applied Psychology*, *88*(4), 587-604.

Liang, D. W., Moreland, R., & Argote, L. (1995). Group versus individual training and group performance: The mediating role of transactive memory. *Personality and Social Psychology Bulletin, 21*(4), 384-393.

Linberg, K. R. (1999). Software developer perceptions about project failure: A case study. *The Journal of Systems and Software, 49*, 177-192.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic enquiry*. Beverly Hills, CA: Sage.

Lindell, M.K., Brandt, C.J., & Whitney, D.J. (1999). A revised index of interrater agreement for multi-item ratings of a single target. *Applied Psychological Measurement, 23*(2), 127-135.

Lindley, E., & Wheeler, F. P. (2001). Using the learning square. *Learning Organization 8*(3), 114-124.

Locke, K., & Golden-Biddle, K. (2002). An introduction to qualitative research: Its potential for industrial and organizational psychology. In S. G. Rogelberg (Ed.), *Handbook of research methods in industrial and organizational psychology* (pp. 99-118). London: Blackwell.

Lutz, R. A. (1994). Implementing technological change with cross-functional teams. Research. *Technology Management, 37*, 14-18.

McCarthy, J. (1993). Notes on Formalizing Context. In *Proceedings of 13th International Joint Conference on Artificial Intelligence*, 555-560.

McCarthy, J., & Hayes, P. J. (1969). Some philosophical problems from the standpoint of artificial intelligence. In B. Mehler & D. Michie (Eds.), *Machine intelligence* (Vol. 4). Edinburgh: Edinburgh University Press.

McChesney, I. R. & Gallagher, S. (2004). Communication and co-ordination practices in software engineering projects. *Information and Software Technology, 46*,473-489.

McClelland, D. C. (1976). *A guide to job competency assessment.* Boston: McBer.

McClelland, J. L., Rumelhart, D. E., & The PDP Research Group (1986). *Parallel distributed processing: Vol. 2. Psychological and biological models.* Cambridge, MA: MIT Press.

McClure, B. A. (1990). The group mind: Generative and regressive groups. *The Journal for Specialists in Group Work, 15,* 159-170.

McCue, G. (1978). IBM's Santa Teresa Laboratory—Architecture design for program development. *IBM Systems Journal,* 17(1), 320-41.

McGeorge, P., Crawford, J. & Kelly, S. (1997). The relationship between psychometric intelligence and learning in an explicit and an implicit task. *Journal of Experimental Psychology: Learning, Memory and Cognition, 23*, 239-245.

McInerney, C. (2002). Knowledge management and the dynamic nature of knowledge. *Journal of the American Society for Information Science and Technology, 53*(12), 1009-1018.

McKern, B. (1996). Building management performance for the 21st century. *The Practising Manager, 17*(1), 13-19.

Malone, T., & Crowston, K. (1994). The interdisciplinary study of coordination. *ACM Computing Surveys, 26*(1), 87-119.

Marks, M .A., Sabella, M. J., Burke, C. S., & Zaccaro S. J. (2002). The impact of cross-training on team effectiveness. *Journal of Applied Psychology 87*(1), 3-13.

Massaro, D. W., & Cowan, N. (1993). Information processing models: Microscopes of the mind. *Annual Review of Psychology, 44*, 383-425.

Mathieu, J. E., Goodwin, G. F., Heffner, T. S., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. *Journal of Applied Psychology, 85*(2), 273-283.

Mathison, S. (1988). Why triangulate? *Educational Researcher, 17*(2), 13-17.

Maybery, M., Taylor, M., & O'Brien-Malone, A. (1995). Implicit learning: Sensitive to age but not IQ. *Australian Journal of Psychology, 47,* 8–17.

Melnik, G., & Maurer, F. (2004). Direct verbal communication as a catalyst of agile knowledge sharing. *Agile Development Conference, June, 22-26, 2004, Salt Lake City, Utah.* Retrieved December 2, 2004, from http://www.agiledevelopmentconference.com/files/RP2-2.pdf.

Messick, S. (1995). Validity of psychological assessment: Validation of inferences from persons' responses and performances as scientific inquiry into score meaning. *American Psychologist, 50*, 741-750.

Meyer, R. L. (1998). Avoiding the risks in large software systems acquisitions. *Information Strategy, 14*, 18-33.

Miles, J. N. V., & Shevlin, M.E. (2001). *Applied regression and correlation analysis in psychology: A student's guide.* London: Sage.

Milliken, F. J., & Martins, L. L. (1996). Searching for common threads: Understanding the multiple effects of diversity in organizational groups. *Academy of Management Review, 21*, 402-433

Mills, J., & Clark, M. S. (1994). Communal and exchange relationships: Controversies and research. In R. Erber and R. Gilmour (Eds.), *Theoretical frameworks for personal relationships* (pp.29-42). Hillsdale, NJ: Erlbaum.

Milton, N.R. (2002). *Personal knowledge techniques.* Unpublished doctoral dissertation, University of Nottingham, UK. Retrieved, January 4, 2003, from http://www.epistemics.co.uk/staff/nmilton/thesis/standardframe.htm

Minsky, M. (1975). A framework for representing knowledge. In P.H. Winston (Ed.), *The psychology of computer vision* (pp.211-277). New York: McGraw-Hill.

Mintzberg, H. (1979). *The structuring of organizations: A synthesis of the research.* Englewood-Cliffs, NJ: Prentice-Hall.

Mitchell, R. (1986). Team building by disclosure of internal frames of reference. *The Journal of Applied Behavioral Science, 22,* 15-28.

Mohammed, S., & Dumville, B. C. (2001). Team mental models in a team knowledge framework. *Journal of Organizational Behavior, 22*, 89-106

Mohammed, S., Klimsoki, R. J., & Rentsch, J. R. (2000). The measurement of team mental models: We have no shared schema. *Organizational Research Methods, 3,* 123-165.

Molander, B. (1992). Tacit knowledge and silenced knowledge. Fundamental problems and controversies. In B. Göranzon & M. Florin (Eds.), *Skill and education: Reflection and experience* (pp. 9-31). New York: Springer-Verlag.

Moreland, R. L. (1999). Transactive memory: Learning who knows what in work groups and organizations. In L. L. Thompson, J. M. Levine, & D. M. Messick (Eds.), *Shared cognition in organizations: The management of knowledge*. Mahwah, NJ: Erlbaum.

Moreland, R. L., Argote, L., & Krishnan, R. (1996). Socially shared cognition at work: Transactive memory and group performance. In J. L. Nye & A. M. Brower (Eds.), *What's social about social cognition* (pp. 57-84). Thousand, CA: Sage.

Moreland, R. L., & Myaskovsky, L. (2000). Exploring the performance benefits of group training: Transactive memory or improved communication? *Organizational Behavior and Human Decision Processes, 82*(1), 117-133.

Morrow, R. H., & McKee, A. J. (1998). CGI scripts: A strategy for between-subjects experimental group assignments on the World-Wide Web. *Behaviour Research Methods, Instruments and Computers, 30*, 306-308.

Moser, P. K., Mulder, D. H. & Trout, J. D. (1998). *The theory of knowledge: A thematic introduction.* Oxford :Oxford University Press.

Motowidlo, S. J., Dunnette, M. D., & Carter, G. W. (1990). An alternative selection procedure: The low-fidelity simulation. *Journal of Applied Psychology, 75*, 640-647.

Moynihan, T. (2002). *Coping with IS/IT risk management: The recipes of experienced project managers*. London: Springer-Verlag.

Mu, S., & Gnyawali, D. R. (2003). Developing synergistic knowledge in student groups. *The Journal of Higher Education, 74*(6), 689-711.

Mulligan, K., Simons, P., & Smith, B. (1984). Truth-makers. *Philosophy and Phenomenological Research, 44*, 287-321.

Myers, C., & Connor, M. (1992). Age differences in skill acquisition and transfer in an implicit learning paradigm. *Applied Cognitive Psychology, 6*, 429-442.

Myers, M. (1999). Investigating information systems with ethnographic research *Communications of the AIS, 2,* Article 23.

Nandhakumar, J., & Avison, D. E. (1999). The fiction of methodological development: A field study of information systems development. *Information Technology and People, 12*(2), 1999, 176-191.

National Software Directorate (2003). Software companies directory. Retrieved June-November 2003, from http://www.nsd.ie/htm/ssii/company.htm

Neale, I. M. (1989). First generation expert systems: a review of knowledge acquisition methodologies. *The Knowledge Engineering Review*, 105-145.

Neisser, U. (1976). *Cognition and reality*. San Francisco: W.H. Freeman

Nelson, R., & Winter, S. (1982*). An evolutionary theory of economic change.* Cambridge, MA: Harvard University Press.

Newell, A. (1973). Artificial Intelligence and the Concept of Mind. In R.C. Schank & K. M. Colby (Eds.), *Computer Models of Thought and Language* (pp. 1-60). San Francisco: W. H. Freeman.

Newell, A., Shaw, J. C., & Simon, H. A. (1958). Chess-playing programs, and the problem of complexity. *IBM Journal of Research and Development, 2*(4), 320-335.

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, CA: Sage

Paulk, M.C., Weber, C.V., & Curtis, B. (1995). *The capability maturity model: Guidelines for improving software process.* Reading, MA: Addison-Wesley.

Pelz, D. C., & Andrews, F. M. (1966). *Scientists in organizations: Productive climates for research and development.* New York: Wiley.

Perruchet, P. & Pacteau, C. (1990). Synthetic grammar learning: Implicit rule abstraction or explicit fragmentary knowledge? *Journal of Experimental Psychology: General, 119*, 264-275

Pinto, M. B., & Pinto, J. K. (1990). Project team communication and cross-functional cooperation in new program development. *Journal of Product Innovation Management, 7*, 200-212.

Polanyi, M. (1958). Personal Knowledge. London: Routledge

Polanyi, M. (1966) The Tacit Dimension. London: Routledge

Polanyi, M. (1969). Knowing and Being. London: Routledge

Podsakoff, P. M., MacKenzie, S. B. Lee, J., & Podsakoff, N. P. (2003). Common method biases in behavioural research: A critical review of the literature and recommended rememdies. *Journal of Applied Psychology, 88*(5). 879-903.

Podsakoff, P. M & Organ, D. W. (1986). Self-reports in organizational research: Problems and prospects. *Journal of Management, 12*, 69-82.

Proctor, R. W., & Dutta, A. (1995). *Skill acquisition and human performance.* Thousand Oaks, CA: Sage

Putnam, H. (1981). Reason, truth and history. Cambridge University Press.

Ramesh, B., & Tiwana, A. (1999). Supporting collaborative process knowledge management in new product development teams. *Decision Support Systems, 27*, 213-235.

Reber, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behavior 6*(6), 855-863.

Reber, A. S. (1969). Transfer of syntactic structure in synthetic languages. *Journal of Experimental Psychology 81*(1), 115-119.

Reber, A. S. (1976). Implicit learning of synthetic languages: The role of instructional set. *Journal of Experimental Psychology: Human Learning and Memory, 2*, 88-94.

Reber, A. S. (1989). Implicit learning and tacit knowledge. *Journal of Experimental Psychology: General, 118,* 219-235.

Reber, A. S. (1995). *Implicit learning and tacit knowledge: An essay on the cognitive unconscious.* New York: Oxford University Press.

Reber, A. S., & Millward, R. B. (1968). Event observation in probability learning. *Journal of Experimental Psychology, 77*, 317-327.

Reber, A., Walkenfeld, F., & Hernstadt, R. (1991). Implicit and explicit learning: Individual differences and IQ. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 888-896.

Reger, R. K. (1990). The repertory grid technique for eliciting the content and structure of cognitive constructive systems. In A. S. Huff (Ed.), *Mapping strategic thought* (pp. 301-309). Chichester: Wiley.

Reed, S., Hock, H., Lockhead, G., (1983) Tacit knowledge and the effect of pattern recognition on mental scanning. *Memory and Cognition 11*(2), 137–143.

Reed, T.F., & Kelly, D (2002). The skills gap in the Irish software industry. *Irish Journal of Management, 23*(2), 95-109.

Reed, H. J., & Lave, J. (1979). Arithmetic as a tool for investigating relations between culture and cognition. *American Ethnologist, 6*(93), 58–82.

Reichardt, C. S., & Cook, T. D. (1979). Beyond qualitative versus quantitative methods. In T. D. Cook & C. S. Reichardt (Eds.), *Qualitative and quantitative methods in evaluation research* (pp. 7-32). Beverly Hills: Sage.

Rentsch, J. R., & Hall, R. J. (1994). Members of great team think alike: a model of team effectivness and schema similarity among team members. *Advances in Interdisciplinary Studies of Work Teams, 1,* 223-261.

Rentsch, J. R., & Klimoski, R. J. (2001). Why do 'great minds' think alike? Antecedents of team member schema agreement. *Journal of Organizational Behavior, 22*, 107-120.

Rescher, N. (1989). *Cognitive economy: The economic dimension of the theory of knowledge.* Pittsburg: University of Pittsburgh Press.

Resnick, L. B. (1991). Shared cognition: Thinking as social practice. In L. B. Resnick, J. M. Levine & S. D. Teasley (Eds.), *Perspectives on socially shared cognition.* (pp.1-20).Washington, DC: American Psychological Association.

Reynolds, N., Adamamtios, D., & Schlegelmilch, B. (1993). Pretesting in questionnaire design: a review of the literature and suggestions for further research. *Journal of the Market Research Society, 35*(2), 171-182.

Richards, D., & Busch, P. (2003). Acquiring and applying contextualised tacit knowledge. *Journal of Information and Knowledge Management, 2*(2), 179-190.

Richman, H. B., Gobet, F., Staszewski, J. J., & Simon, H. A. (1996). Perceptual and memory processes in the acquisition of expert performance: The EPAM model. In K.A. Ericsson (Ed.), *The road to excellence: The acquisition of expert performance in the arts and sciences, sports, and games* (pp. 167-187). Mahwah, NJ: Erlbaum.

Rogan, J. C., & Keselman, H. J. (1977). Is the ANOVA F test robust to variance heterogeneity when sample sizes are equal? An investigation via a coefficient of determination. *American Educational Research Journal, 14*, 494-498.

Rogelberg, S. G., Church, A. H., Waclawski, J., & Stanton, J. M. (2002). In S. G. Rogelberg (Ed.), *Handbook of research methods in industrial and organizational psychology* (pp. 141-160). London: Blackwell.

Rosch, E. (1978). Principles of categorization. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and categorisation* (pp 27 –48). Hillsdale, NJ: Erlbaum

Rouse, W. B., & Morris, N. M. (1986). On looking into the black box: Prospects and limits in the search for mental models. *Psychological Bulletin, 100*, 349-363.

Rousseau, D.M. (1985). Issues of level in organizational research: Multi-level and cross-level perspectives. *Research in Organizational Behavior, 7,* 1-37.

Rousseau, D. M., & McLean Parks, J. (1993). The contracts of individuals and organizations. In B. M. Staw & L. L. Cummings (Eds.), *Research in organizational behavior* (Vol. 15, pp. 1-43). Greenwich, CT: JAI.

Rousseau, D. M., & House, R. J. (1994). Meso-organizational behavior: Avoiding three fundamental biases. *Journal Organizational Behavior 1*(1), 13–30.

Roy, S., & Nagpaul, P. S. (2000). Measurement of intangibles: Problems of reliability and validity. *Journal of Scientific and Industrial Research, 59*, 689-700.

Rugg, G. & McGeorge, P. (1997). The Sorting Techniques: A tutorial paper on card sorts, picture sorts and item sorts. *Expert Systems, 14*(2), 80-93.

Ruggles, R. (1998). The state of the notion: knowledge management in practice. *California Management Review, 40*(3), 80-89.

Rumelt, R. P. (1984). Towards a strategic theory of the firm. In R. B. Lamb (Ed.), *Competitive strategic management* (pp. 556-570). Englewood, Cliffs, NJ: Prentice-Hall.

Rumelt, R. P. (1987). Theory, strategy, and entrepreneurship. In D. Teece (Ed.), *The competitive challenge* (139-158). Cambridge, MA: Ballinger.

Ruzits-Jha, S. (1995). *Michael Polanyi's integrative philosophy.* Unpublished doctoral dissertation, Harvard University: Department of Education.

Ryan, S., & Hurley, J. (2004). Have total quality management, business process re-engineering and the learning organisation been replaced by knowledge management? An investigation of the meaning, popularity, and practical relevance of late 20th century management theories. *Irish Journal of Management, 25*(1), 41-55.

Ryan S., & O'Connor R. (2003). The elicitation of expert knowledge regarding the factors that affect team performance on software development projects". *Proceedings of the 16th International Conference on Software & Systems Engineering and their Applications, Paris.*

Ryan S., & O'Connor R. (2004). Team Tacit Knowledge as a Predictor of Performance in Software Development Teams. *Proceedings of 16th International Conference on Software Engineering and Knowledge Engineering*, (SEKE, 04). Canada,

Ryle, G. (1949). *The concept of mind.* London: Hutchinson.

Salancik, G., & Pfeffer. J. (1978). A social information processing approach to job attitudes and task design. *Administrative Science Quarterly, 23,* 224–253.

Salomon, G. (1996). Unorthodox thoughts on the nature and mission of contemporary educational psychology. *Educational Psychology Review, 8*(4), 397-417.

Sawyer, S., Farber, J., & Spillers, R. (1997). Supporting the social processes of software development teams. *Information Technology and People, 10*(1), 46-62.

Scarbrough, H., Swan, J. & Preston, J. (1999). *Knowledge management: A literature review.* London: Institute of Personnel and Development.

Scarbrough, H., & Swan, J. (2001). Explaining the diffusion of knowledge management: The role of fashion. *British Academy of Management, 12*, 3-12.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory and Cognition, 13*, 501-518.

Schaefer, D. R., & Dillman, D. A. (1998). Development of a standard e-mail methodology: Results of an experiment. *Public Opinion Quarterly, 3* (62), 378-390.

Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals and understanding.* Hillsdale, NJ: Erlbaum

Schein, E. H. (1985). *Organizational culture and leadership.* San Francisco, CA: Jossey-Bass.

Schein, E. H., & Bennis, W. (1965). *Personal and organizational change via group methods.* New York: Wiley.

Schmidt, F. L., & Hunter, J. E. (1993). Tacit knowledge, practical intelligence, general mental ability, and job knowledge. *Current Directions in Psychological Science, 2*(1), 8-9.

Schneider, M. (1996). *Intellectual capital: The last sustainable competitive advantage*. Report, SRI, USA.

Schneider, B., & Reichers, A. E. (1983). On the etiology of climates. *Personnel Psychology, 36,* 19-39.

Schön, D. A. (1988). Designing: rules, types and worlds. *Design Studies*, *9* (3),181-190.

Schultze, U., & Stabell, C. (2004). Knowing what you don't know? Discourses and contradictions in knowledge management research. *Journal of Management Studies, 41*(4), 449-573.

Seger, C. A. (1994) Implicit learning. *Psychological Bulletin, 115*, 163-196

Shadbolt. N. R. & Burton, A. M. (1995). Knowledge elicitation: A systematic approach. In J. R. Wilson & E. Corlett (Eds.), *Evaluation of human work: A practical ergonomics methodology* (2nd ed.). London: Taylor and Francis.

Shadbolt, N. R., & Milton, N. (1999). From knowledge engineering to knowledge management. *British Journal of Management, 10*, 309-322.

Shaw, M. (1981). *Group dynamics: The psychology of small group behavior* (3rd ed.). New York: McGraw Hill.

Sheehan, K. B., & Hoy, M. G. (1999). Using e-mail to survey internet users in the United States: Methodology and assessment. *Journal of Computer Mediated Communication, 4* (3). Retrieved, May 4, 2003, from http://www.ascusc.org/jcmc/vol4/issue3/sheehan.html

Sheehan, K. B., & McMillan, S. J. (1999). Response variation in e-mail surveys: An exploration. *Journal of Advertising Research, 39* (4), 45-54.

Shotter, J. (1993). *Conversational Realities: the Construction of Life through Language* London: Sage.

Skinner, B.F. (1938). *The behavior of organisms*. New York: Appleton-Century-Crofts.

Skyrme, D., & Amidon, D. (1997). Creating the knowledge-based business. London: Business Intelligence

Sloboda, J. A., Davidson, J. W., Howe, M. J. A., &. Moore, D.G. (1996). The role of practice in the development of performing musicians. *British Journal of Psychology*, *87*, 287-309.

Smith-Jentsch, K. A., Campbell, G. E., Milanovich, D. M., & Reynolds, A. M. (2001). Measuring teamwork mental models to support training needs assessment, development, and evaluation: two empirical studies. *Journal of Organizational Behavior, 22*, 179-194.

Smith, P. C., & Kendall, L. M. (1963). Retranslation of expectations: An approach to the construction of unambiguous anchors for rating scales. *Journal of Applied Psychology ,47*, 149-155.

Smolensky, P. (1988). On the proper treatment of connectionism. *Behavioral and Brain Sciences, 11*, 1-74.

Smoliar, S.W. (2003). Interaction management. The next (and necessary) step beyond knowledge management. *Business Process Management Journal,* 9(3), 337-353.

Solomon, H. (1960). *Mathematic thinking in the measurement of behavior*. Glencoc, IL: Free Press.

Somech, A. & Bolger, R. (1999). Tacit knowledge in academia: its effects on student learning and achievement. *The Journal of Psychology, 133*(6), 605-616.

Sommerville, I. (2004). *Software Engineering* (7th ed.). London: Addison- Wesley

Spector, P. E. (1987). Method variance as an artefact in self-reported affect and perceptions at work: Myth or significant problem. *Journal of Applied Psychology, 72*, 438-443.

Spector, P. E. (1994). Using self-report questionnaires in OB research: A comment on the use of a controversial method. *Journal of Organizational Behaviour, 15,* 385-392.

Spender, J.C. (1998). The dynamics of individual and organizational knowledge. In C. Eden, & J. C. Spender (Eds.), *Managerial and organizational cognition* (pp13-39). London: Sage

Spender, J. C., & Grant, R. M. (1996). Knowledge and the firm: Overview. *Strategic Management Journal, 17*(winter, special issue), 5-9.

St. Julien, J. (1997). Explaining learning: The research trajectory of situated cognition and the implications of connectionism. In D. Kirshner & J. A.Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives* (pp. 261-280). Mahwah NJ: Erlbaum.

Standish Group International (2001). Extreme Chaos. Standish Group Report. Retrieved May 6, 2004 from http://www.standishgroup.com/sample_research/PDFpages/extreme_chaos.pdf

Stanton, J. M., & Rogelberg, S. G. (2001). Using internet/intranet web pages to collect organizational research data. *Organizational Research Methods, 4*, 199-216.

Starkes, J.L., & Allard, F. (Eds.) (1993). *Cognitive issues in motor expertise*. Amsterdam: Elsevier.

Starkes, J. L., Deakin, J., Allard, F., Hodges, N. J., & A. Hayes, (1996). Deliberate practice in sports: What is it anyway?' In K. A. Ericsson (Ed*.), The road to excellence: The acquisition of expert performance in the Arts and Sciences, Sports, and Games* (pp. 81-106). Mahwah, NJ: Erlbaum.

Stasser, G., Vaughan, S. I., & Stewart, D. D. (2000). Pooling unshared information: The benefits of knowing how access to information is distributed among members. *Organization Behavior and Human Decision Processes, 82*, 102-116.

Sternberg, R. J., & Wagner, R. K. (1988). *Practical intelligence: nature and origins of competence in the everyday word.* New York: Cambridge University Press.

Sternberg, R. J., & Ben-Zeev, T. (2001). *Complex cognition*. Oxford: Oxford University. Press.

Sternberg, R. J., Forsythe, G. B., Hedlund, J., Horvath, J., Wagner, R. K., Williams, W. M., Snook, S. A., & Grigorenko, E. L. (2000). *Practical intelligence in everyday life*. Cambridge: Cambridge University Press.

Stewart V. & Stewart, A. (1981). *Business Applications of the repertory grid.* London: McGraw Hill.

Still, A., & Costall, A. (Eds.) (1991). *Against cognitivism: Alternative foundations for cognitive psychology*. Hemel Hempstead: Harvester Wheatsheaf.

Stotts, D., Williams, L., Nagappan, N., Baheti, P., Jen, D. S., & Jackson, A. (2003). Virtual teaming: Experiments and experiences with distributed pair programming *Proceedings of the Third XP Agile Universe Conference (Springer LNCS 2753)* 129 – 141. Retrieved September 23, 2004 from http://collaboration.csc.ncsu.edu/laurie/Papers/XPAUDistributedP.pdf

Subramaniam, M., & Venkatraman, N. (2001). Determinants of transnational new product development capability: Testing the influence of transferring and deploying tacit overseas knowledge. *Strategic Management Journal, 22*, 359-378.

Suchman, L.A. (1987*). Plans and situated actions: The problem of human-machine communications.* Cambridge: Cambridge University Press.

Sun, R., Merrill, E. & Peterson, T. (2001). From implicit skills to explicit knowledge: a bottom-up model of skill learning. *Cognitive Science, 25,* 203-244.

Sveiby, K. E. (1999). *Tacit Knowledge*. De Vos Consultancy. Retrieved August 10, 2001, from http://it-consultancy.com/externa/sveiby-tacit.html

Swan, J.; Clark, P. A. (1992) Organizational decision-making in the appropriation of technological innovation: Cognitive and political dimensions. *The European Work and Organizational Psychologist, 2*, 103-127.

Taatgen, N. (1999) *Learning without limits From Problem Solving towards a Unified Theory of Learning.* Unpublished doctoral dissertation, University of Groningen, Netherlands.

Tabachnik, B. G., & Fidell, L. S. (2001). *Using multivariate statistics* (4th ed.). Needham Heights, MA: Allyn & Bacon

Taub, G. E., Hayes, B. G., Cunningham, W. R., & Sivo, S. A. (2001). Relative roles of cognitive ability and practical intelligence in the prediction of success. *Psychological Reports, 88*, 931-942.

Teece, D. J. (1987). Profiting from technological innovation. In P. J. Teece (Ed.), *The competitive challenge* (pp. 185-219). Cambridge, MA: Ballinger.

Thompson, M. P. A., & Walsham, G. (2004). Placing knowledge management in context. *Journal of Management Studies, 41*(5), 725-747.

Thompson P, Warhurst C., & Callaghan G. (2001). Ignorant theory and knowledgeable workers: Interrogating the connections between knowledge, skills and services. *Journal of Management Studies, 38*(7), 923-942.

Tourangeau, R., Rips, L. J., & Rasinski, K. (2000).*The psychology of survey response.* Cambridge: Cambridge University Press.

Truex, D.P., Baskerville, T., & Travis, J. (2000). Amethodical systems development: The deferred meaning of systems development methods. *Accounting Management and Information Technology, 10,* 53-79.

Tsoukas, H. (1997). The tyranny of light: The temptations and the paradoxes of the information society. *Futures, 29,* 827-843.

Tsoukas, H. (2003). Do we Really Understand Tacit Knowledge? In M. Easterby-Smith and M. Lyles (Eds.) *The Blackwell handbook of organizational learning and knowledge management* (pp.410-427). Malden, Mass: Blackwell.

Tsoukas, H., & Mylonopoulos, N. (2004). Introduction: Knowledge construction and creation in organizations. *British Journal of Management, 15*, Special Issue, S1-S8.

Tsoukas H., & Vladimirou E. (2001). What is organizational knowledge? *Journal of Management Studies, 38*(7), 973-993.

Tsuchiya, S. (1993). Improving knowledge creation ability through organizational learning. *IIIA, Proceedings of International Symposium on the Management of Industrial and Corporate Knowledge 93*, 87-95.

Tsui, A. S., Xin, K. R., & Egan, T. D. (1995). Relational demography: The missing link in vertical dyad linkage. In S. E. Jackson & M. N. Ruderman (Eds.), *Diversity in work teams: Research paradigms for a changing workplace* (pp. 97-129). Washington, DC: American Psychological Association.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory.* New York: Academic Press.

Tulving, E. (1987). Multiple memory systems and consciousness. *Human Neurobiology, 6*, 67-80.

Turner J. R. (1999). *The handbook of project-based management.* Berkshire, England: McGraw-Hill.

Tushman, M.L. (1977). Special boundary roles in innovation process. *Administrative Science Quarterly, 22,* 587-605.

Ungson, G., Braunstein, D. &. Hall, P. (1981). Managerial information processing: A research review. Administrative *Science Quarterly, 26*(1), 116-134.

Van De Ven, A. H., Delbecq, L. A., & Koenig, R. J. (1976). Determinants of coordination modes within organizations. *American Sociological Review, 41*, 322-338.

VanLehn, K. (1996). Cognitive skill acquisition. *Annual Review of Psychology, 47*, 513-539.

Verner, J., & Evanco, W. (2003). The effect of cost and effort estimation on project success. *In Proceedings of ICSSEA, vol.4, 2-4 December 2003, Paris, France,*

Vinter, A., & Detable, C. (2003). Implicit learning in children and adolescents with mental retardation. *American Journal on Mental Retardation, 108*, 94-107.

Von Glasersfeld, E. (1989). Cognition, construction of knowledge, and teaching. *Synthese, 80.* (1), 121-140.

Von Glaserfeld, E (1995). *Radical constructivism: A way of knowing and learning.* Washington, DC: Falmer Press.

Von Krogh, G., Ichijo, K., & Nonaka, I. (2000). *Enabling knowledge creation.* New York: Oxford University Press.

Von Krogh, G., & Roos, J. (1995) A perspective on knowledge, competence and strategy. *Personnel Review*, 24(3), pp. 56-76.

Von Wangenheim, C.G., Punter, T., & Anacleto, A. (2003). Software measurement for small and medium enterprises. A Brazilian - German view on extending the GQM method. In: *Proceedings of the 7th International Conference on Empirical Assessment in Software Engineering (EASE 2003)*, Keele, UK Retrieved November 3, 2004, from http://www.sj.univali.br/prof/Christiane%20Gresse%20Von%20Wangenheim/papers/ease2003.pdf.

Vygotsky, L. (1978). *Mind in society.* Cambridge, Mass: The MIT Press.

Wall, T., Michie, J., Patterson, M., Wood, S. J., Sheehan, M., Clegg, C .W., & West, M. (2004). On the validity of subjective measures of company performance. *Personnel Psychology, 57*, 95-118.

Walz, D.B., Elam, J.J., & Curtis, B. (1993). Inside a software design team: Knowledge acquisition, sharing and integration. *Communications of the ACM, 36*, 63-77.

Watt, J. H. (1999). Internet systems for evaluation research. In G. Gay & T. Bennington (Eds.), *Information technologies in evaluation: Social, moral, epistemological and practical implications* (pp. 23-44). San Francisco: Josey-Bass.

Weible, R., & Wallace, J. (1998). The impact of the Internet on data collection. *Marketing Research, 10* (3), 19-23.

Wagner, R. K., Sujan, H., Sujan, M., Rashotte, C. A., & Sternberg, R. J. (1999). Tacit knowledge in sales. In R. J. Sternberg & J. A. Horvath (Eds.), *Tacit knowledge in professional practice* (pp. 155-182). Mahwah, NJ: Erlbaum.

Wagner R.K., & Sternberg R. J. (1985). Practical intelligence in real-world pursuits: The role of tacit knowledge. *Journal of Personality and Social Psychology, 49*(2), 436-458.

Wagner R.K., & Sternberg R. J. (1991). *TKIM: The common sense manager: Tacit knowledge inventory for managers: Test booklet.* San Antonio: Harcourt Brace Jovanovich.

Walsh, J.P., & Fahey, L. (1986). The role of negotiated beliefs in strategy making. *Journal of Management, 12*, 325-338.

Waterson, P. E., Clegg, C. W., & Axtell, C. M. (1997). The dynamics of work organization, knowledge and technology during software development. *International Journal of Human-Computer Studies 46*, 79-101..

Wegner, D. M. (1987). Transactive memory: A contemporary analysis of the group mind. In B. Mullen & G. R. Goethals (Eds.), *Theories of Group Behavior* (pp. 185-208). New York, NY: Springer-Verlag.

Wegner, D. M., Erber, R., & Raymond, P. (1991). Transactive memory in close relationships. *Journal of Personality and Social Psychology, 61*(6), 923-929.

Weick, K. E. (1979). *The social psychology of organizing* (2nd ed.). Reading, MA: Addison-Wesley.

Weick, K. E. (1996) *Sensemaking in organizations*. Thousand Oaks: CA: Sage

Weick, K.E. (1990). Technology as an equivoque: Sensemaking in new technologies. In P. Goodman & L. Sproull, *Technology and organizations* (pp. 1-44). San Fransisco: Josey Bass

Weick, K.E., &. Roberts K.H. (1993). Collective mind in organizations: Heedful interrelating on flight decks. *Administrative Science Quarterly, 38*, 357-381.

Whitley, E.A. (2000). *Tacit and explicit knowledge; conceptual confusion around the commodification of knowledge.* Paper presented at the BPRC conference on knowledge management: Concepts and controversies10-11, February, 2000: University of Warwick, Coventry, United Kingdom. Available: http://bprc.warwick.ac.uk/papers.html

Wiersema, M. F. & Bantel, K. A. (1992). Top management team demography and corporate strategic change. *Academy of Management Journal, 35*(1), 91-121.

Wilson, T.D. (2002). The nonsense of knowledge management. *Information. Research, 8*(1), Paper no. 144. Retrieved December 10, 2002, from http://InformationR.net/ir/8-1/paper144.html.

Winkler, J.D., Kanouse, D. E., & Ware, J. E., Jr. (1982). Controlling for acquiescence response set in scale development. *Journal of Applied Psychology, 67*, 555-561.

Winograd, T. (1975). Frame representations and the declarative-procedural controversy. In D. G. Bobrow & A. Collins (Eds .), *Representation and understanding* (pp. 185-210). Studies in cognitive science. New York: Academic Press.

Winter, S. G. (1987). Knowledge and competence as strategic assets. In D. J. Teece (Ed.), *The competitive challenge* (pp. 159-184). New York: HarperCollins

Wittgenstein L. (1958). *Philosophical investigations.* Oxford: Blackwell.

Woehr, D.J., & Rentsch, J.R. (2003*). Elaborating team member schema similarity: A social relations modelling approach.* Paper presented at the 18th annual conference of the society for Industrial and Organizational Psychology, Orlando, FL, April 11-13.

Yates, J. & Orlikowski, W. J. (1992). Genres of organisational communication: a structural approach to studying communication and media. *Academy of Management Review*, *17* (2), 299- 326.

Zenger, T. R. , & Lawrence, B. S. (1989). Organization demography: The differential effects of age and tenure distributions on technical communication. *Academy of Management Journal, 32,* 353-376.

Appendices

Appendix A
Corollaries to Kelly's (1955) Personal Construct Theory

Corollary	Explanation
Construction Corollary	A person anticipates events by construing their replications.
Individuality Corollary	Persons differ from each other in their constructions of events.
Organization Corollary	Each person characteristically evolves for his convenience in anticipating events, a construction system embracing ordinal relationships between constructs.
Dichotomy Corollary	A person's construct system is composed of a finite number of dichotomous constructs.
Choice Corollary	A person chooses for himself that alternative in a dichotomized construct through which he anticipates the great possibility for the elaboration of his system.
Range Corollary	A construct is convenient for the anticipation of a finite range of events only.
Experience Corollary	A person's construction system varies and he successively construes the replications of events.
Modulation Corollary:	The variation in a person's construction system is limited by the permeability of the constructs within whose ranges of convenience that variants lie.
Fragmentation Corollary	A person may successively employ a variety of construction subsystems which are inferentially incompatible with each other.
Commonality Corollary	To the extent that one person employs a construction of experience which is similar to that employed by another, his processes are psychologically similar to those of the other person.
Sociality Corollary	to the extent that one person construes the construction processes of another he may play a role in the social process involving the other person.

Appendix B
Covering E-mail to CEO

Dear *Name*,

I am a Ph.D. student at the Business School in Dublin City University. I am investigating how expert tacit knowledge is shared and dispersed through social interaction in software development teams. I have developed an online, 15 minute, interactive questionnaire to investigate this topic and am seeking software development teams to take part in my study. Currently, 16 teams have participated but I am seeking at least 46. The questionnaire is anonymous and teams are only identified by initials. It would be a great help to my study if the development team in *Organisation X* would be willing to participate. If you would like to participate just e-mail this link
http://www.redbrick.dcu.ie/~sharon/OVERVIEW.HTML
or this link
http://ash.eeng.dcu.ie:8080/teamsurvey/OVERVIEW.HTML
to all team members including the team leader.

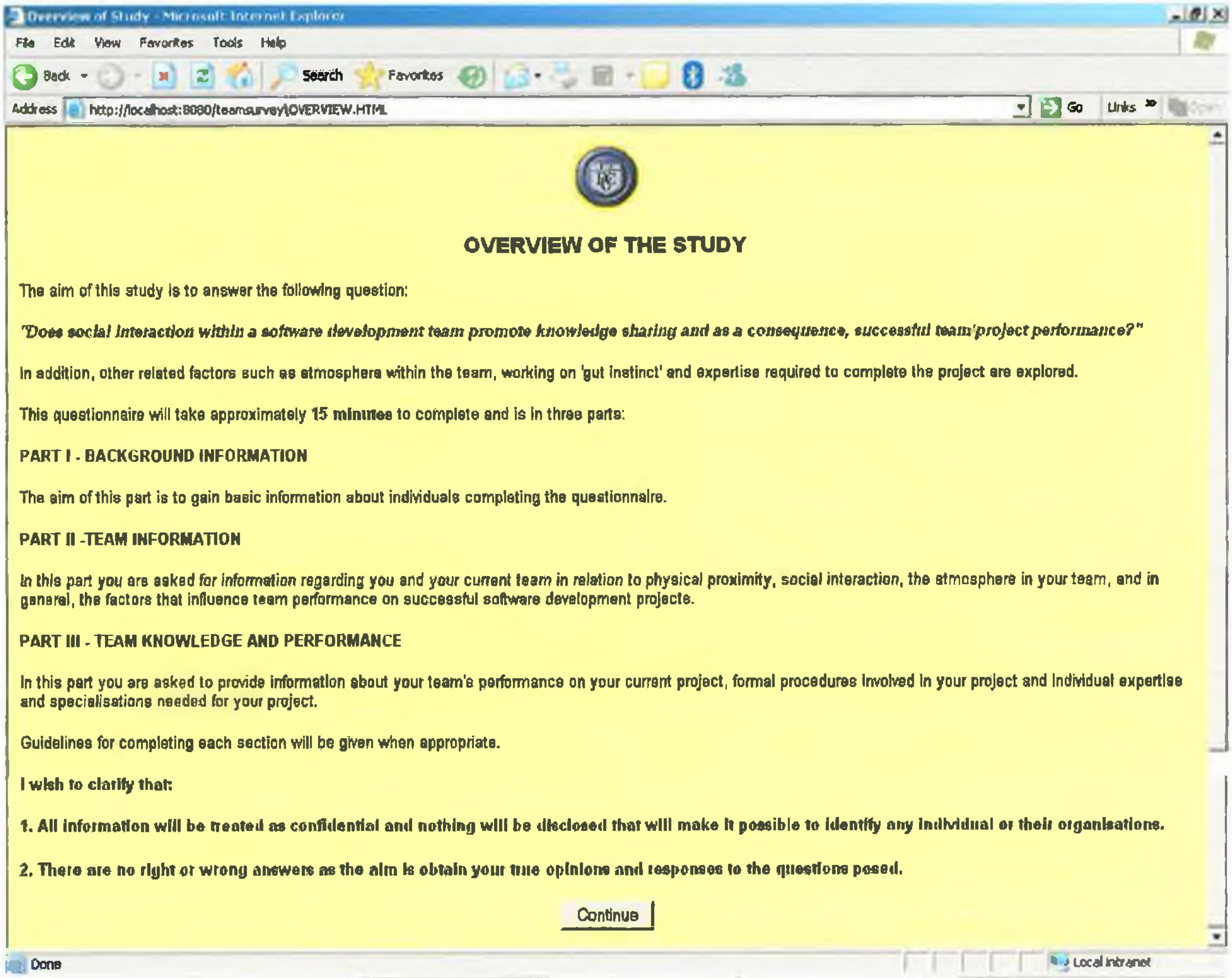
I will send you the results of the study when the results become available.

Please do not hesitate to contact me with any queries or comments.

Thank you and best wishes,
Sharon Ryan
If you want to know more about my study and me please check out my website http://student.dcu.ie/~ryans22/expert/framedoc.html.

Appendix C
Online Survey

Appendix C.1 Overview of the Study



Overview of Study - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address http://localhost:8080/teamsurvey/OVERVIEW.HTML Go Links

OVERVIEW OF THE STUDY

The aim of this study is to answer the following question:

"Does social interaction within a software development team promote knowledge sharing and as a consequence, successful team/project performance?"

In addition, other related factors such as atmosphere within the team, working on 'gut instinct' and expertise required to complete the project are explored.

This questionnaire will take approximately **15 minutes** to complete and is in three parts:

PART I - BACKGROUND INFORMATION

The aim of this part is to gain basic information about individuals completing the questionnaire.

PART II -TEAM INFORMATION

In this part you are asked for information regarding you and your current team in relation to physical proximity, social interaction, the atmosphere in your team, and in general, the factors that influence team performance on successful software development projects.

PART III - TEAM KNOWLEDGE AND PERFORMANCE

In this part you are asked to provide information about your team's performance on your current project, formal procedures involved in your project and individual expertise and specialisations needed for your project.

Guidelines for completing each section will be given when appropriate.

I wish to clarify that:

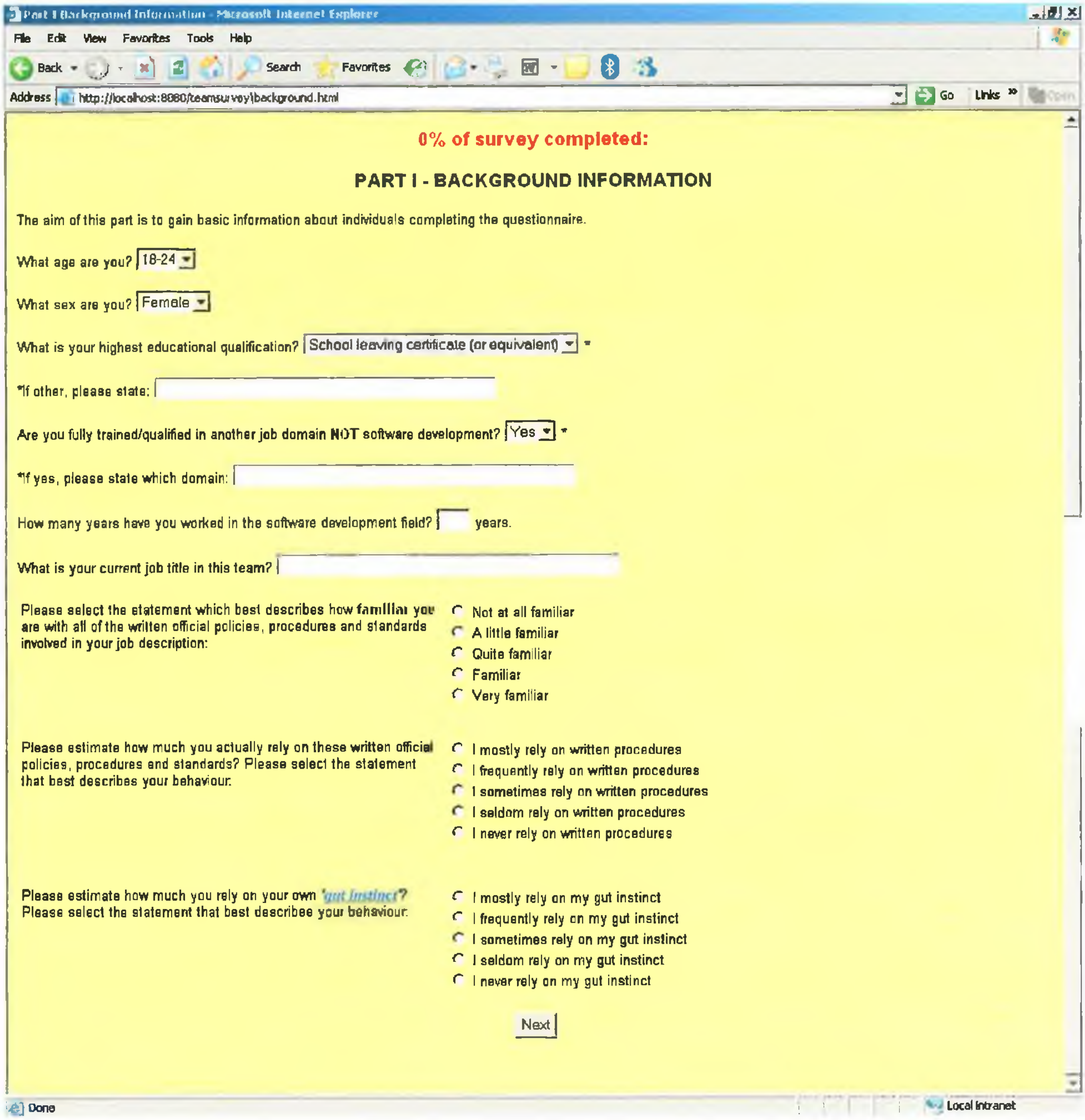
1. All information will be treated as confidential and nothing will be disclosed that will make it possible to identify any individual or their organisations.

2. There are no right or wrong answers as the aim is obtain your true opinions and responses to the questions posed.

Continue

Done Local intranet

Appendix C.2 Demographic Details, Implicit and Explicit Knowledge


Part I Background Information - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://localhost:8080/teamsurvey/background.html

0% of survey completed:

PART I - BACKGROUND INFORMATION

The aim of this part is to gain basic information about individuals completing the questionnaire.

What age are you? 18-24

What sex are you? Female

What is your highest educational qualification? School leaving certificate (or equivalent) *

*If other, please state:

Are you fully trained/qualified in another job domain NOT software development? Yes *

*If yes, please state which domain:

How many years have you worked in the software development field? years.

What is your current job title in this team?

Please select the statement which best describes how familiar you are with all of the written official policies, procedures and standards involved in your job description:

- Not at all familiar
- A little familiar
- Quite familiar
- Familiar
- Very familiar

Please estimate how much you actually rely on these written official policies, procedures and standards? Please select the statement that best describes your behaviour.

- I mostly rely on written procedures
- I frequently rely on written procedures
- I sometimes rely on written procedures
- I seldom rely on written procedures
- I never rely on written procedures

Please estimate how much you rely on your own 'gut instinct'? Please select the statement that best describes your behaviour.

- I mostly rely on my gut instinct
- I frequently rely on my gut instinct
- I sometimes rely on my gut instinct
- I seldom rely on my gut instinct
- I never rely on my gut instinct

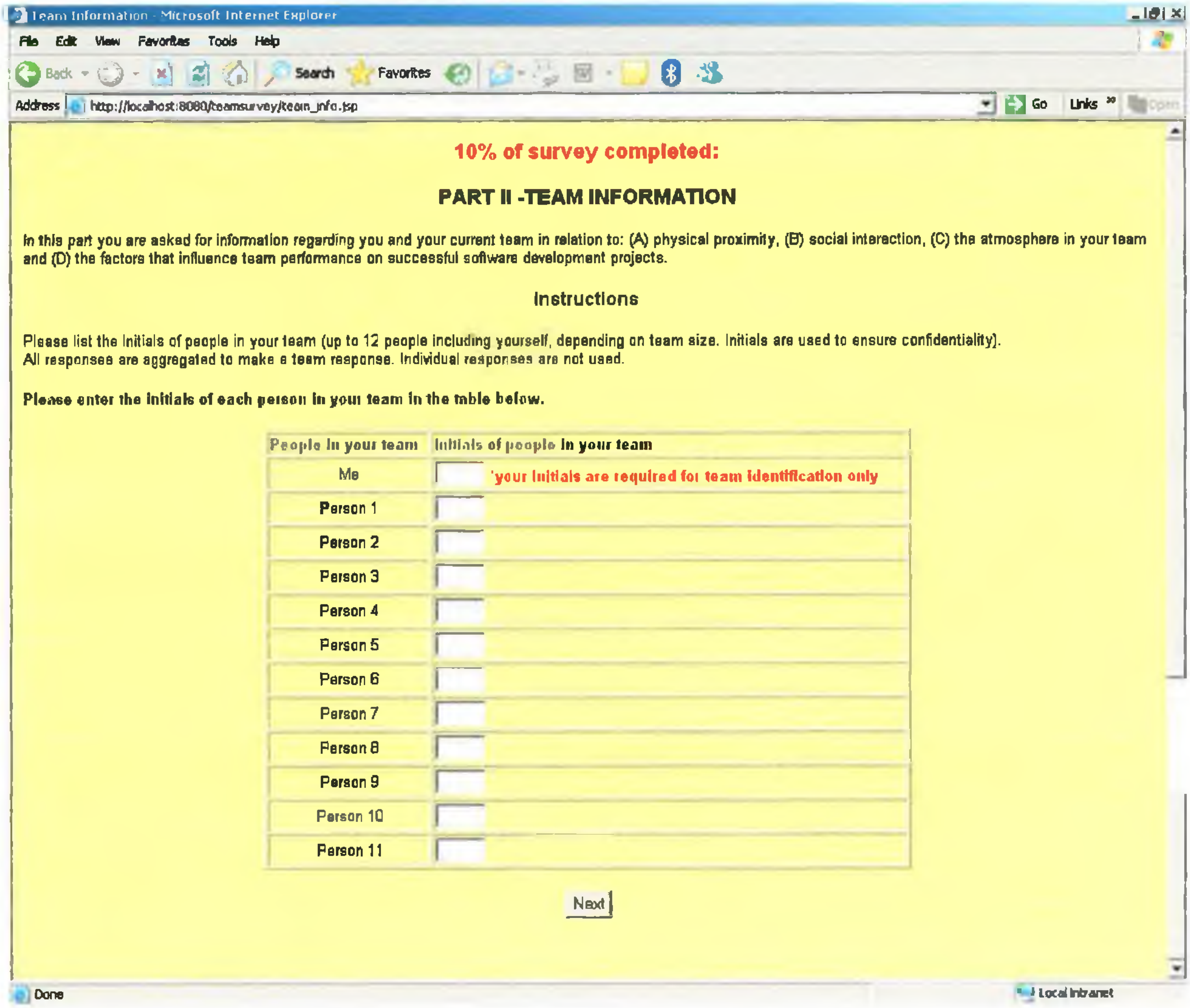
Next

Done Local intranet

NOTE: When respondents clicked on underlined words 'pop-up' definitions appeared. These definitions are presented where appropriate.

__Gut Instinct__ may also be described as implicit, subjective procedures and standards that are difficult to articulate but can be seen in practice.

Appendix C.3 List up to 11 Members



10% of survey completed:

PART II -TEAM INFORMATION

In this part you are asked for information regarding you and your current team in relation to: (A) physical proximity, (B) social interaction, (C) the atmosphere in your team and (D) the factors that influence team performance on successful software development projects.

Instructions

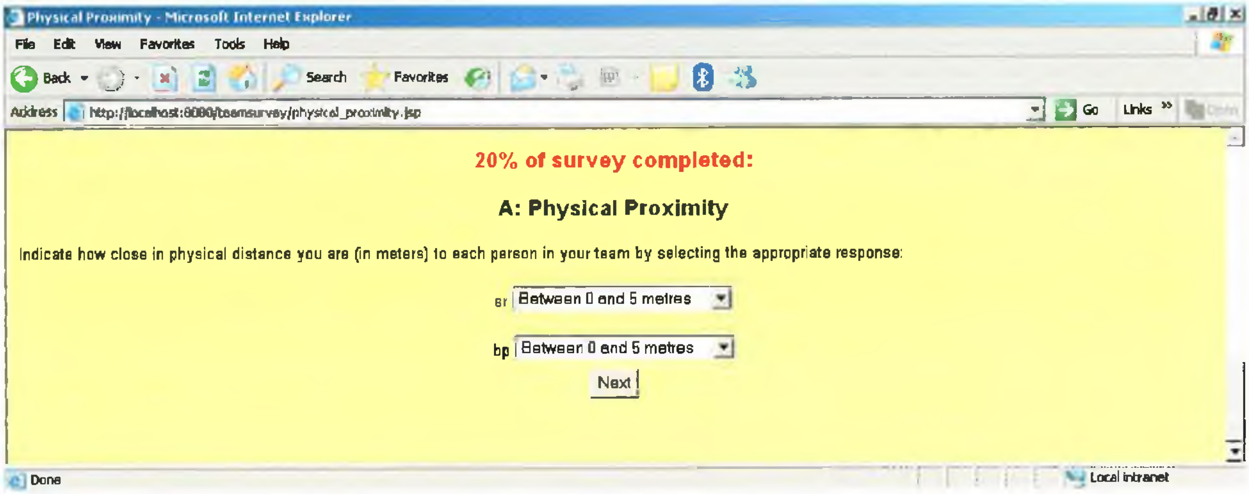
Please list the initials of people in your team (up to 12 people including yourself, depending on team size. Initials are used to ensure confidentiality).
All responses are aggregated to make a team response. Individual responses are not used.

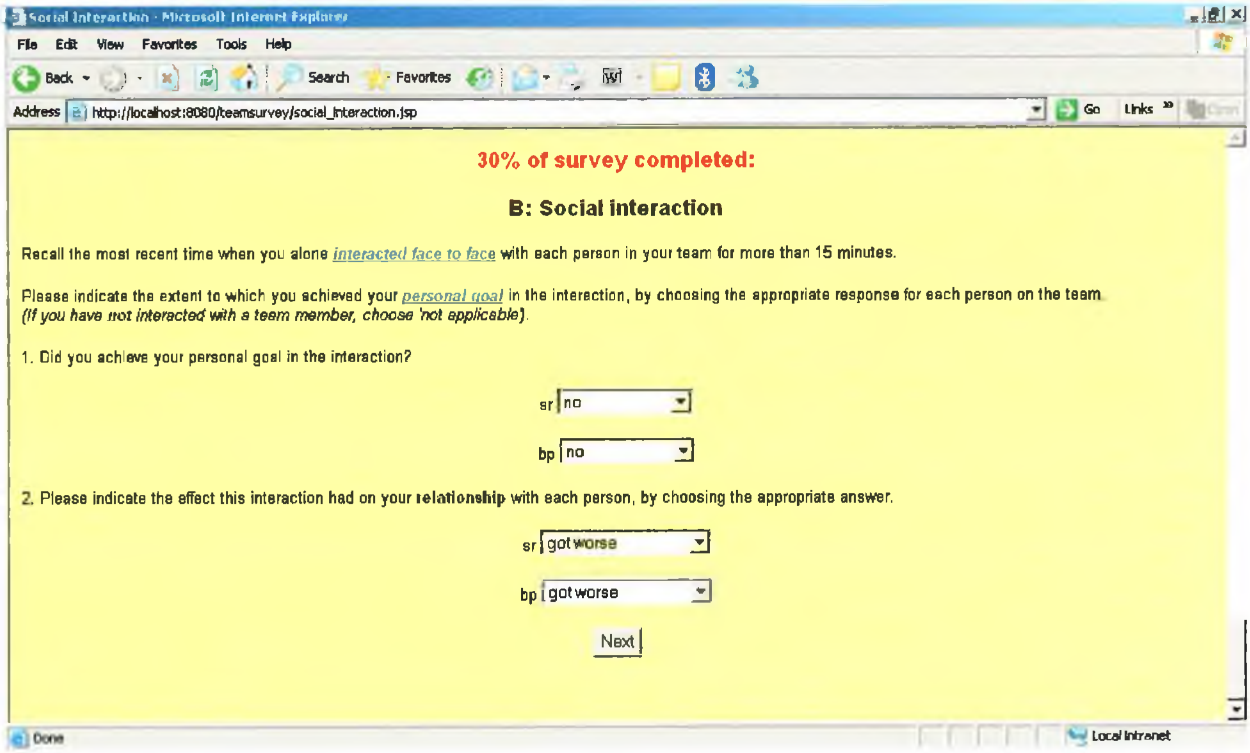
Please enter the initials of each person in your team in the table below.

People in your team	Initials of people in your team
Me	*your initials are required for team identification only
Person 1	
Person 2	
Person 3	
Person 4	
Person 5	
Person 6	
Person 7	
Person 8	
Person 9	
Person 10	
Person 11	

Next

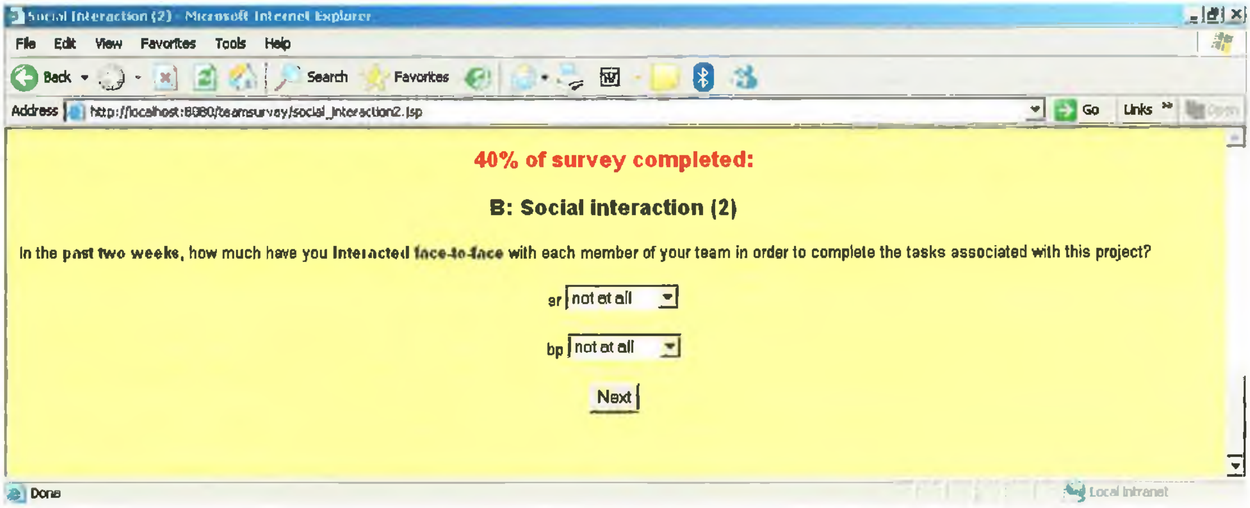
Appendix C.4 Proximity and Social Interaction



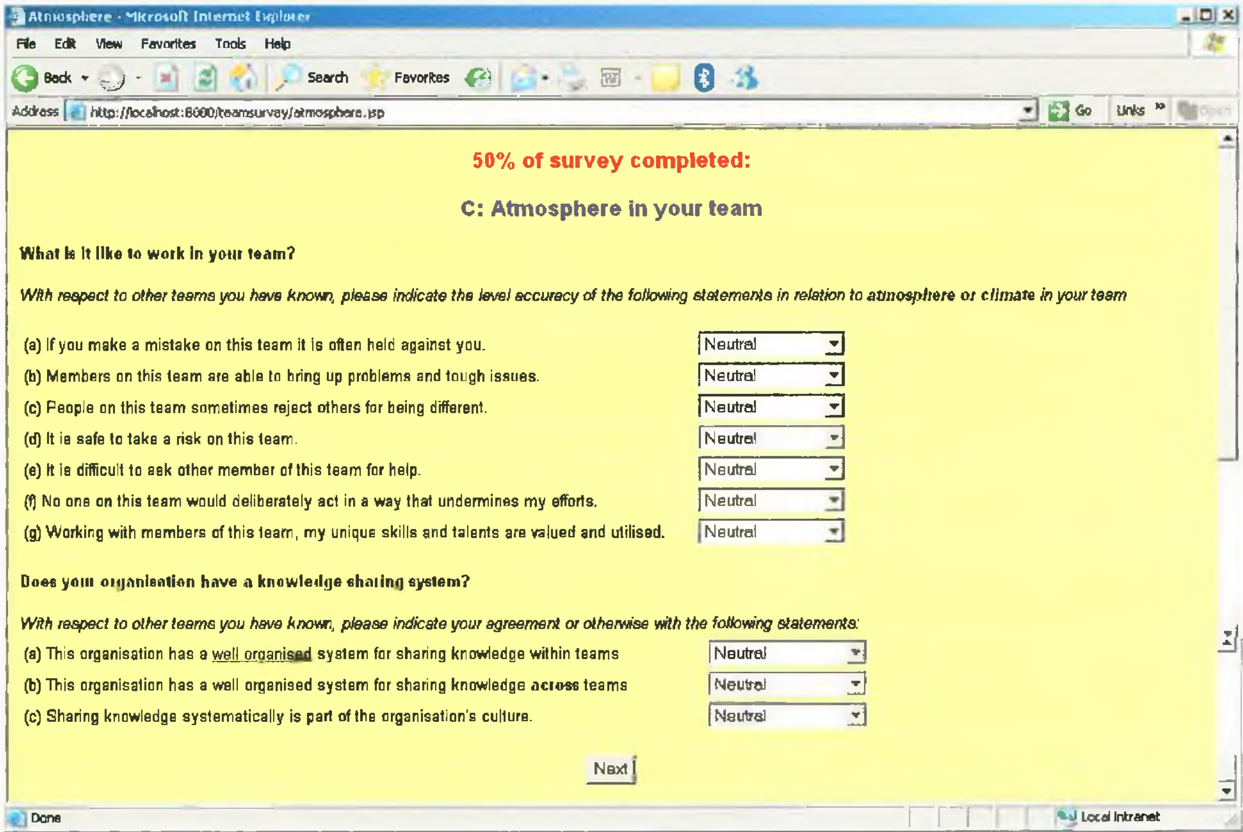


Interacted face to face: *any face to face conversation, work related, personal or social that is informal. This interaction should not refer to formal interactions like scheduled project meeting, performance appraisals etc.*

Personal goal: *your personal goal may be to understand a technical term, get the person to help you achieve a deadline etc.*

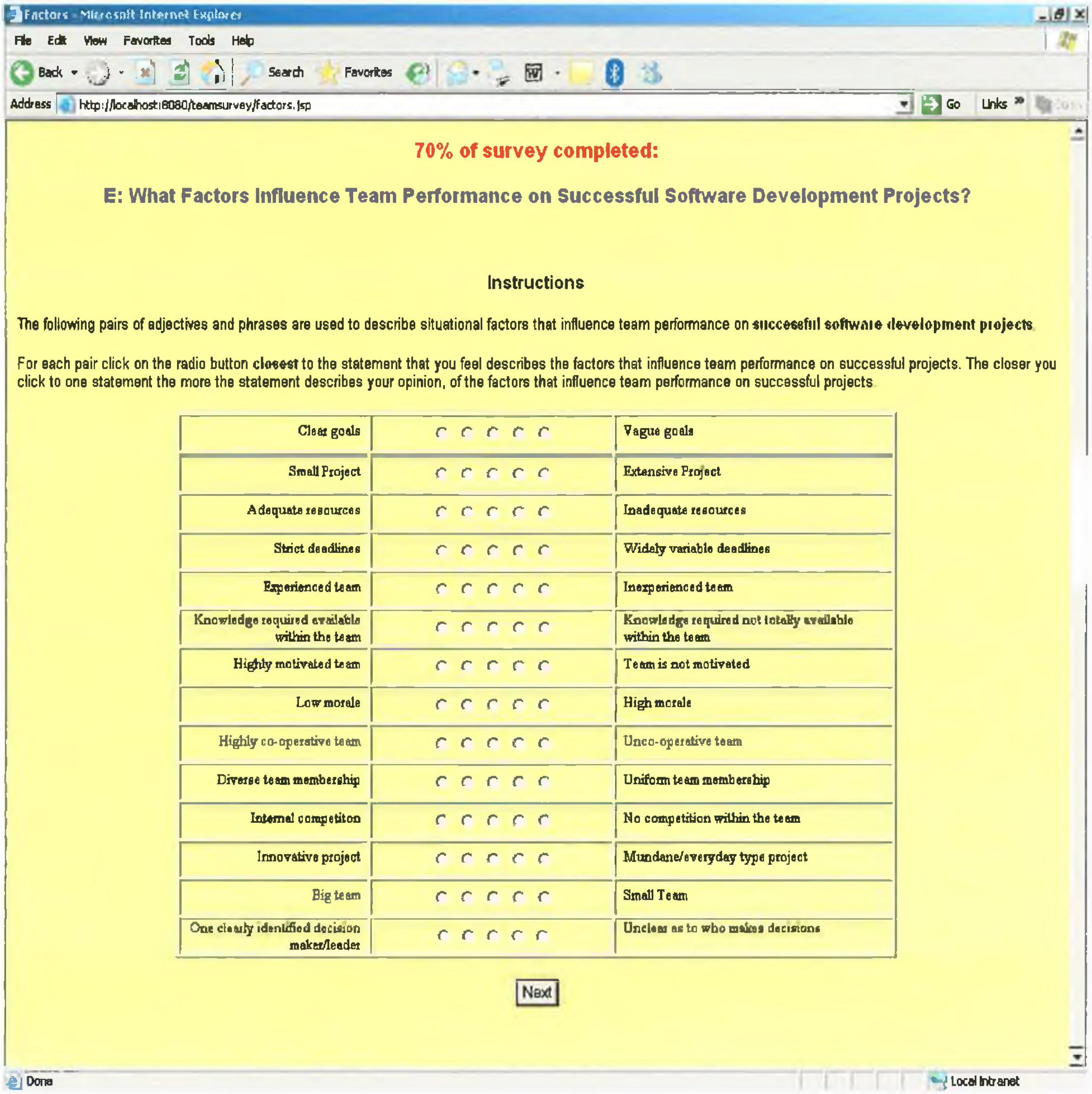


Appendix C.5 Team Psychological Safety and Formal Knowledge Sharing



__Well organised system__ e.g. about clients, managing projects, new approaches, technical issues etc.

Appendix C.6 Team Tacit Knowledge Measure



70% of survey completed:

E: What Factors Influence Team Performance on Successful Software Development Projects?

Instructions

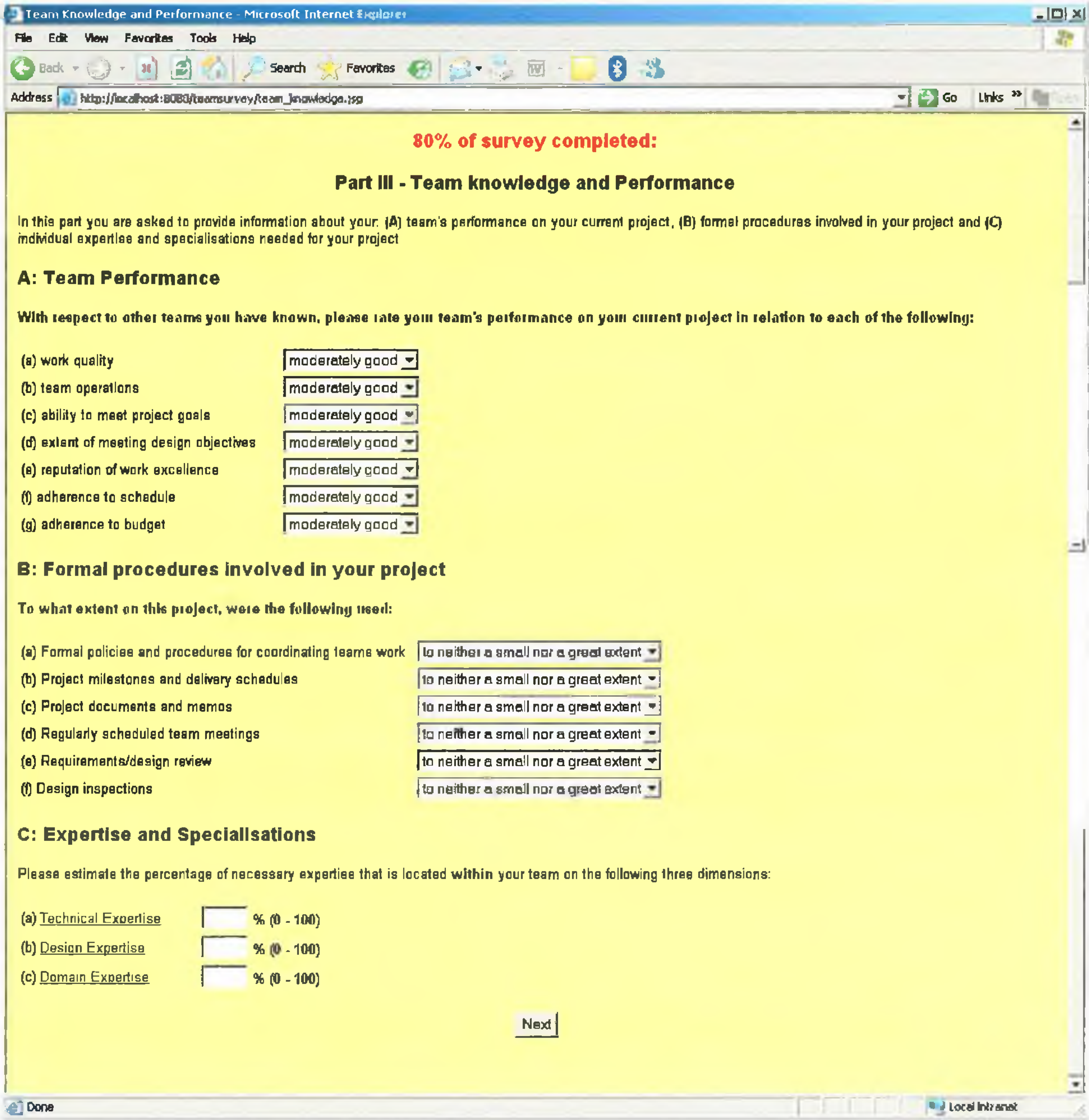
The following pairs of adjectives and phrases are used to describe situational factors that influence team performance on **successful software development projects**

For each pair click on the radio button **closest** to the statement that you feel describes the factors that influence team performance on successful projects. The closer you click to one statement the more the statement describes your opinion, of the factors that influence team performance on successful projects

Clear goals	Vague goals
Small Project	Extensive Project
Adequate resources	Inadequate resources
Strict deadlines	Widely variable deadlines
Experienced team	Inexperienced team
Knowledge required available within the team	Knowledge required not totally available within the team
Highly motivated team	Team is not motivated
Low morale	High morale
Highly co-operative team	Unco-operative team
Diverse team membership	Uniform team membership
Internal competiton	No competition within the team
Innovative project	Mundane/everyday type project
Big team	Small Team
One clearly identified decision maker/leader	Unclear as to who makes decisions

Next

Appendix C.7 Efficiency and Effectiveness (team performance), Administrative Coordination (formal procedures), and Presence of expertise


Team Knowledge and Performance - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites

Address http://localhost:8080/teamsurvey/team_knowledge.jsp Go Links

80% of survey completed:

Part III - Team knowledge and Performance

In this part you are asked to provide information about your: (A) team's performance on your current project, (B) formal procedures involved in your project and (C) individual expertise and specialisations needed for your project

A: Team Performance

With respect to other teams you have known, please rate your team's performance on your current project in relation to each of the following:

(a) work quality	moderately good
(b) team operations	moderately good
(c) ability to meet project goals	moderately good
(d) extent of meeting design objectives	moderately good
(e) reputation of work excellence	moderately good
(f) adherence to schedule	moderately good
(g) adherence to budget	moderately good

B: Formal procedures involved in your project

To what extent on this project, were the following used:

(a) Formal policies and procedures for coordinating teams work	to neither a small nor a great extent
(b) Project milestones and delivery schedules	to neither a small nor a great extent
(c) Project documents and memos	to neither a small nor a great extent
(d) Regularly scheduled team meetings	to neither a small nor a great extent
(e) Requirements/design review	to neither a small nor a great extent
(f) Design inspections	to neither a small nor a great extent

C: Expertise and Specialisations

Please estimate the percentage of necessary expertise that is located within your team on the following three dimensions:

(a) Technical Expertise % (0 - 100)

(b) Design Expertise % (0 - 100)

(c) Domain Expertise % (0 - 100)

Next

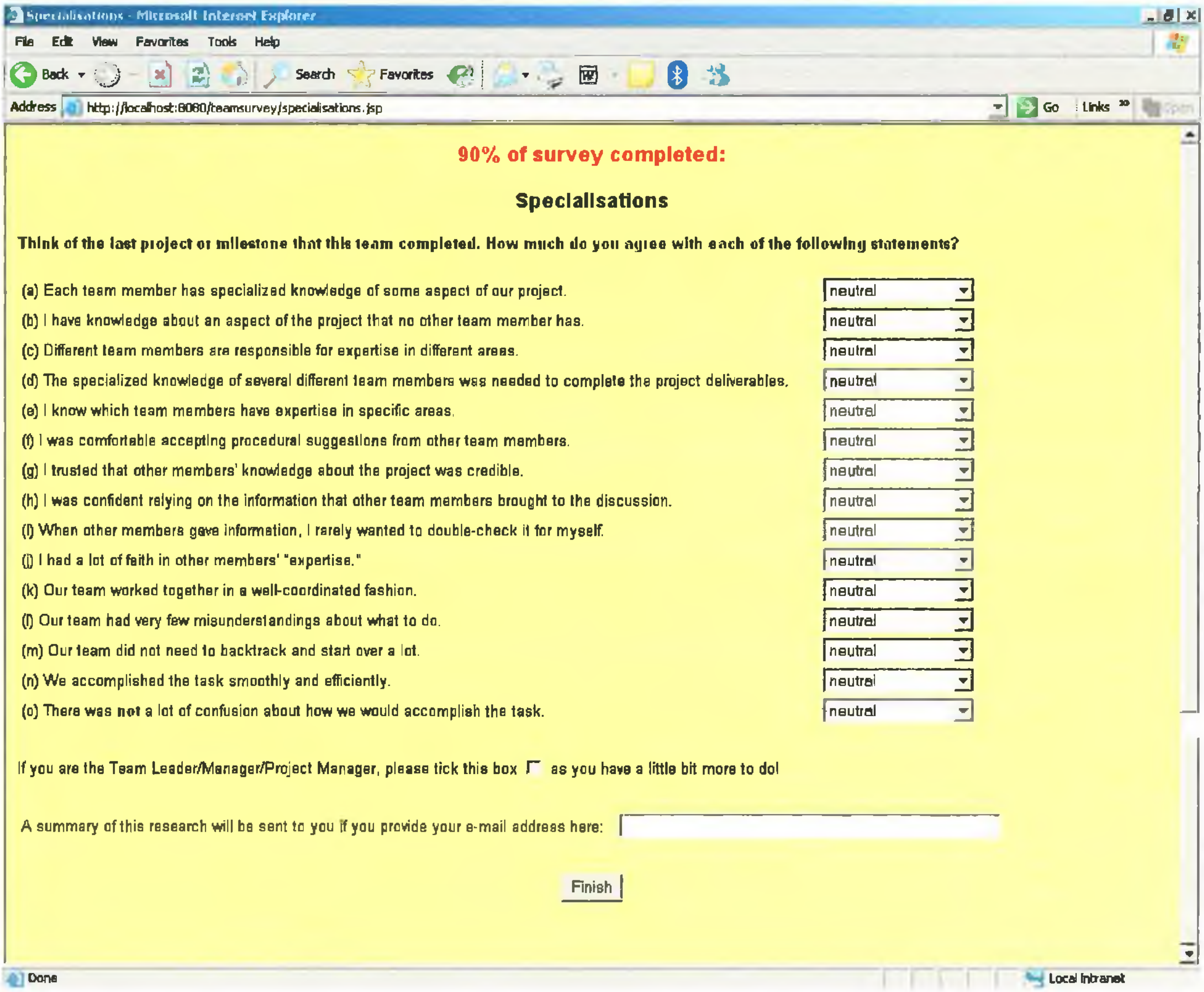
Done Local intranet

***Technical Expertise**: Knowledge about any specialist technical area related to the current project.*

***Design Expertise**: Knowledge about software design principles and architecture.*

***Domain Expertise**: Knowledge about the application of the software and clients job domain.*

Appendix C.8 Transactive Memory



Specialisations - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://localhost:8080/teamsurvey/specialisations.jsp

90% of survey completed:

Specialisations

Think of the last project or milestone that this team completed. How much do you agree with each of the following statements?

(a) Each team member has specialized knowledge of some aspect of our project.	neutral
(b) I have knowledge about an aspect of the project that no other team member has.	neutral
(c) Different team members are responsible for expertise in different areas.	neutral
(d) The specialized knowledge of several different team members was needed to complete the project deliverables.	neutral
(e) I know which team members have expertise in specific areas.	neutral
(f) I was comfortable accepting procedural suggestions from other team members.	neutral
(g) I trusted that other members' knowledge about the project was credible.	neutral
(h) I was confident relying on the information that other team members brought to the discussion.	neutral
(i) When other members gave information, I rarely wanted to double-check it for myself.	neutral
(j) I had a lot of faith in other members' "expertise."	neutral
(k) Our team worked together in a well-coordinated fashion.	neutral
(l) Our team had very few misunderstandings about what to do.	neutral
(m) Our team did not need to backtrack and start over a lot.	neutral
(n) We accomplished the task smoothly and efficiently.	neutral
(o) There was not a lot of confusion about how we would accomplish the task.	neutral

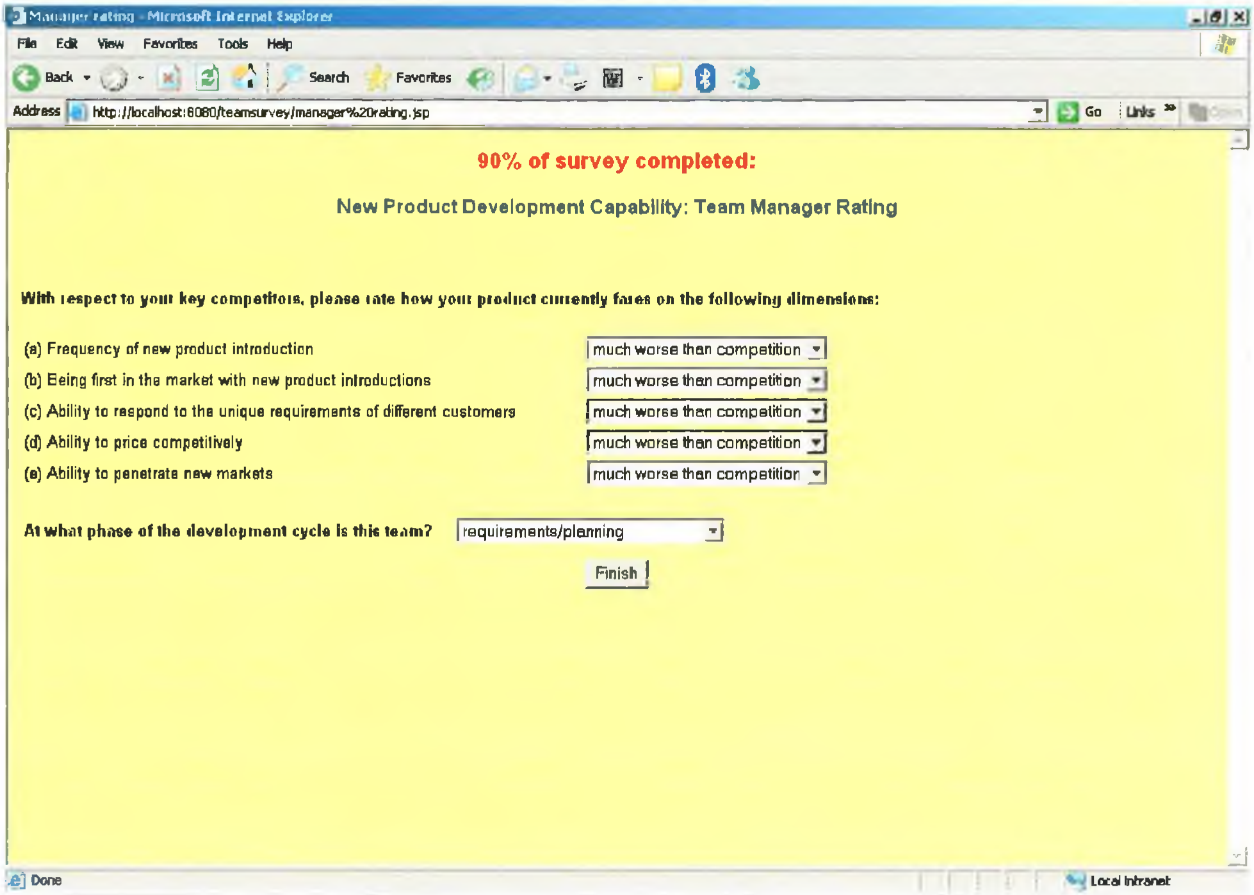
If you are the Team Leader/Manager/Project Manager, please tick this box ☐ as you have a little bit more to do!

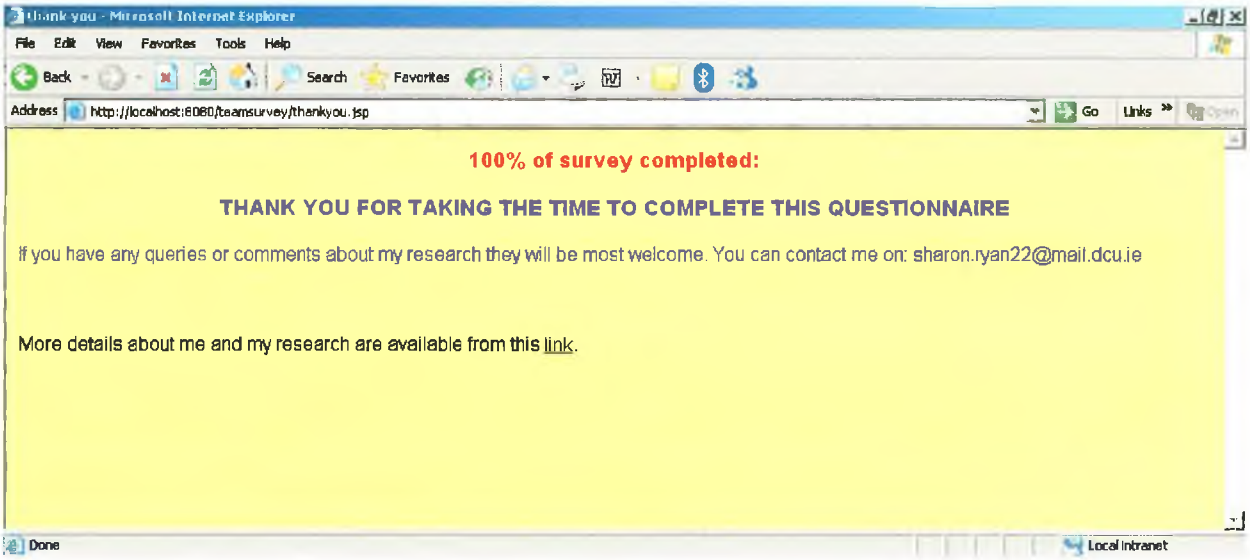
A summary of this research will be sent to you if you provide your e-mail address here:

Finish

Done Local intranet

Appendix C.9 New Product Development Capability and Stage of Development Cycle





Appendix D

Equations for the Calculation of Team Size and Within Team Response Rates

Team Size Calculation

A. *Perceived Team Size Calculation = 4.91*

Calculated according to *EQUATION 1(EQ1):*

$$SIZE_{mean} = \frac{\sum TEAMSIZE_{mean}}{N_{team}}$$

Where:

N_{team} = number of teams

$TEAMSIZE_{mean}$ = mean team size, per team calculated according to the following

EQUATION (EQ2):

$$TEAMSIZE_{mean} = \frac{\left(\sum SI\right) + N_{teamresponses}}{N_{teamresponses}}$$

Where:

$\sum SI$ = The sum of all social interaction item responses per team

$N_{teamresponses}$ = the number of questionnaire responses per team

NOTE: This approach led to some mean team sizes being less than the number of responses for that team. It does however reflect a mean perceived team size (i.e. the size of the team, as perceived by individuals within the team who responded to the survey).

B *Team Size Based on Overall Sample Response = 5.71*

Calculated according to: *EQUATION 3 (EQ3):*

$$SIZE_{mean} = \frac{\left(\sum SI_{overall}\right) + N_{overall}}{N_{overall}}$$

Where:
$\sum SI_{overall}$ = sum over all SI responses (i.e. for the total sample)
$N_{overall}$ = total number of responses for the entire sample

Within Team Response Rate Calculation

C. *Based On Perceived Team Size = 81.15%*

Calculated according to *EQUATION 4 (EQ4):*

$$Rate_{overall} = \frac{\sum Rate_{team}}{N_{team}}$$

Where:

$$Rate_{team} = \frac{N_{teamresponses}}{TEAMSIZE_{mean}} x100 \qquad \textit{EQUATION 5 (EQ5)}$$

i.e. The total number of responses per team, divided by that team's mean size (calculated according to EQ2). This leads to a generous estimation of overall response rate, since some teams on average, underestimated their overall team size (and hence had response rates greater than 100%).

D *Based on Overall Response Rate = 66.06%*

Calculated according to:

$$Rate_{overall} = \frac{N_{overall}}{N_{team} xSIZE_{mean}} x100 \qquad \textit{EQUATION 6 (EQ6)}$$

Where:
$N_{overall}$ = total number of responses for the entire sample
N_{team} = total number of teams
$SIZE_{mean}$ = mean team size, calculated according to *EQ3*

Provides a conservative overall estimate of response rate.

Appendix E

Inter-rater Agreement Calculations

Inter-rater Agreement Calculation: Based On James, Demaree & Wolf (1984)

For each multi-item measure, the within team agreement ($r_{wg(J)}$) is defined by the authors as:

$$r_{wg(J)} = \frac{J\left[1-\left(\overline{s_{xj}^2}\middle/\sigma_{EU}^2\right)\right]}{J\left[1-\left(\overline{s_{xj}^2}\middle/\sigma_{EU}^2\right)\right]+\left(\overline{s_{xj}^2}\middle/\sigma_{EU}^2\right)} \qquad \textit{EQUATION 7 (EQ7)}$$

Where:

J = the number of items in the measure

$\overline{s_{xj}^2}$ = mean of the observed variances

$\sigma_{EU}^2 = \dfrac{A^2-1}{12}$ = the variance of the uniform distribution; where A = response range of the measure.

Equation 7 is an application of the Spearman-Brown prophecy formula to inter-rater agreement. The Spearman-Brown prophecy formula is predictive in nature and is therefore commonly applied to reliability measures (e.g. in measuring the reliability of multiple choice tests). Equation 7 should produce values in the range of 0 to 1 (provided the observed mean variance does not exceed the normal distribution variance), where 1 represents complete agreement, 0.5 represents perfect randomness, and 0 represents complete disagreement. Equation 7 however, breaks down for mean observed variances greater than the variance of uniform distribution (yielding either negative values, or values greater than 1). Furthermore, it is also nonlinear with respect to J (the number of items in the measure), especially for J values of 5 or more.

Lindell et al. (1999) suggest that deriving an agreement measure using the Spearman-Brown prophecy formula is inappropriate, since it implies reliability, rather than agreement. Instead they suggest the measure defined in the following section, as a test of agreement, but not reliability. Their measure is not only linear with respect to the number of measure items, but also holds for observed mean variances greater than the variance of the normal distribution. Furthermore, their measure incorporates weighting based on sample size, allowing for inter-group comparison of inter-rater agreement.

Inter-rater Agreement Calculation: Based on Lindell, Brandt & Whitney (1999)

The inter-rater agreement is defined by the authors as:

$$r^{*}_{wg(J)} = 1 - \frac{\hat{s}^{2}_{xj}}{\sigma^{2}_{EU}} \qquad \textit{EQUATION 8 (EQ8)}$$

Where:

$$\hat{s}^{2}_{xj} = \overline{s^{2}_{xj}}\left(\frac{K}{K-1}\right) = \text{sample size-weighted mean of the observed variances}$$

Equation 8 is linear with respect to J (the number of items in the measure). For a response range of **5**, **EQ8** ranges from -1 (total disagreement) to 1 (total agreement). For a response range of 7, the range is -3.5 to 1 (positive values again indicating agreement and vice versa), but remains linear with respect to the number of items in the measure. For the multi-item measures in the questionnaire, **EQ8** yields good mean levels of team inter-rater agreement, well above the random agreement threshold of 0, for response ranges of both 5 and 7.

Appendix F
Covering E-mail to Project Managers

Dear Manager,

I am a PhD student in DCU business school and am seeking the answer to the following question "What Factors do Managers in Software Development Feel Significantly Influence their Teams' Performance?" I have developed a brief, on-line, interactive questionnaire, which explores your views and opinions of the factors which influence team performance. It is specifically designed for managers of software development teams, and can be accessed from the following web link:

http://redbrick.dcu.ie/~sharon/page1.jsp

I am asking for your time and participation in this research. The questionnaire takes 15 minutes to complete, and is easily accessed on the above link.

Q: "Why should I complete this questionnaire?"

A: Your own responses to the questionnaire are forwarded to you immediately and in a month all participants will receive a findings report, where the most prominent factors which managers believe influence project success will be summarised, analysed and discussed for your benefit.

This study doesn't require you to disclose any information that would make it possible to identify any individual or organisation. If you have any queries, comments or questions, please do not hesitate to contact me.

Thank you in advance for your participation,

Sharon Ryan.

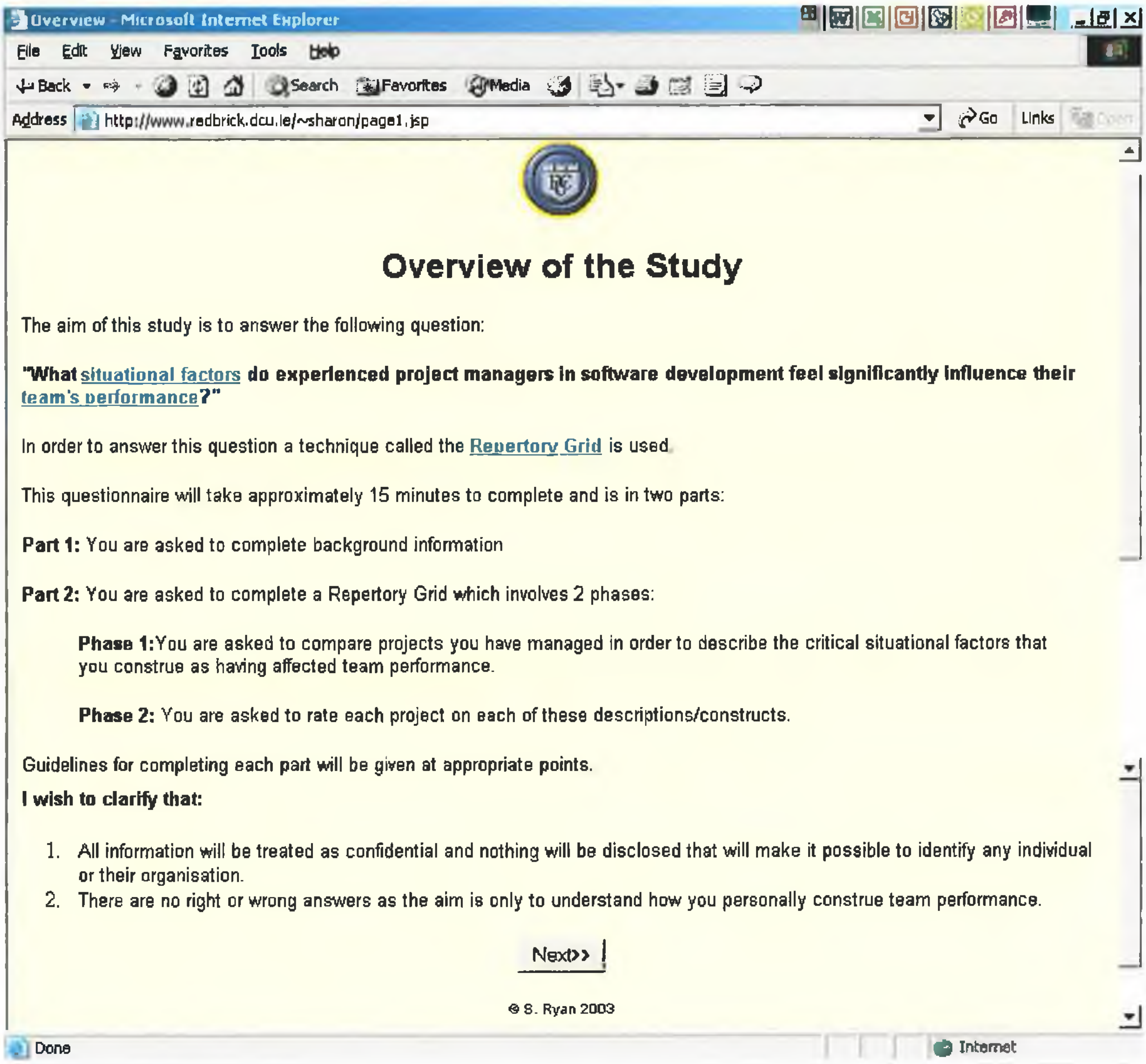
If you want more information about my work or me click on this link:

http://student.dcu.ie/~ryans22/SharonRyan.html

Appendix G

Online Repertory Grid Questionnaire

Appendix G.1 Overview of the Study


Overview - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites Media

Address http://www.redbrick.dcu.ie/~sharon/page1.jsp Go Links

Overview of the Study

The aim of this study is to answer the following question:

"What situational factors do experienced project managers in software development feel significantly influence their team's performance?"

In order to answer this question a technique called the Repertory Grid is used.

This questionnaire will take approximately 15 minutes to complete and is in two parts:

Part 1: You are asked to complete background information

Part 2: You are asked to complete a Repertory Grid which involves 2 phases:

> **Phase 1:** You are asked to compare projects you have managed in order to describe the critical situational factors that you construe as having affected team performance.
>
> **Phase 2:** You are asked to rate each project on each of these descriptions/constructs.

Guidelines for completing each part will be given at appropriate points.

I wish to clarify that:

1. All information will be treated as confidential and nothing will be disclosed that will make it possible to identify any individual or their organisation.
2. There are no right or wrong answers as the aim is only to understand how you personally construe team performance.

Next>>

© S. Ryan 2003

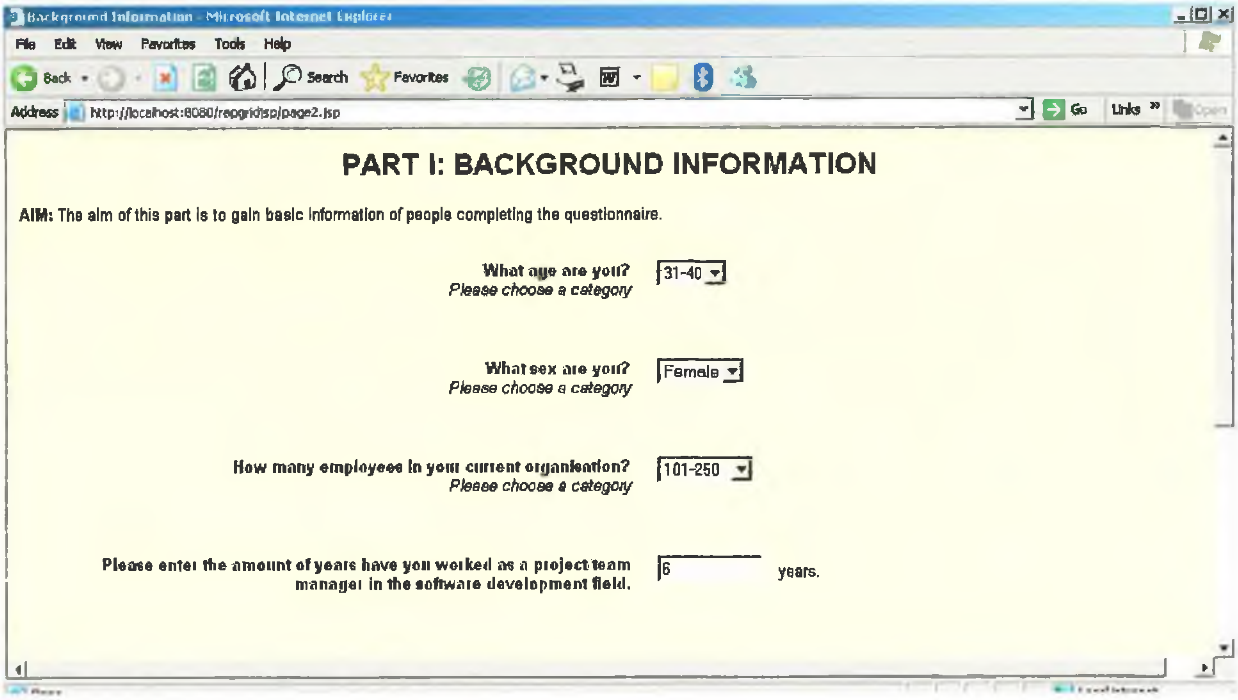
Done Internet

<u>Situational Factors</u>: *By factors I mean things like the make-up of the team, sorts of people involved, clarity of project goals, abilities within the team, resources or whatever. In other words the variety of situations to be dealt with.*

<u>Team Performance</u>: *By team performance I mean things like frequency of critical errors, team's reputation for work excellence, meeting project goals/milestones, keeping to schedule/budget, improvements in the quality of the team's work over the project, meeting client needs or whatever.*

<u>Repertory Grid</u>: *is a technique which accesses a person's subjective, implicit knowledge about a specific subject, in this case 'factors affecting team performance'. It is a two-way classification of information in which relationships are uncovered between a persons' observations of the world (called elements) and how they construct or classify those observations. The elements in this case are projects you have managed The constructs are the descriptions of how the projects are similar or different from each other. Constructs/descriptions have two poles (Bipolar), one pole has a meaning and the other pole contains the opposite of that meaning, e.g. clear goals----unclear goals. Constructs are personal and subjective*

Appendix G.2 Background Information



PART I: BACKGROUND INFORMATION

AIM: The aim of this part is to gain basic information of people completing the questionnaire.

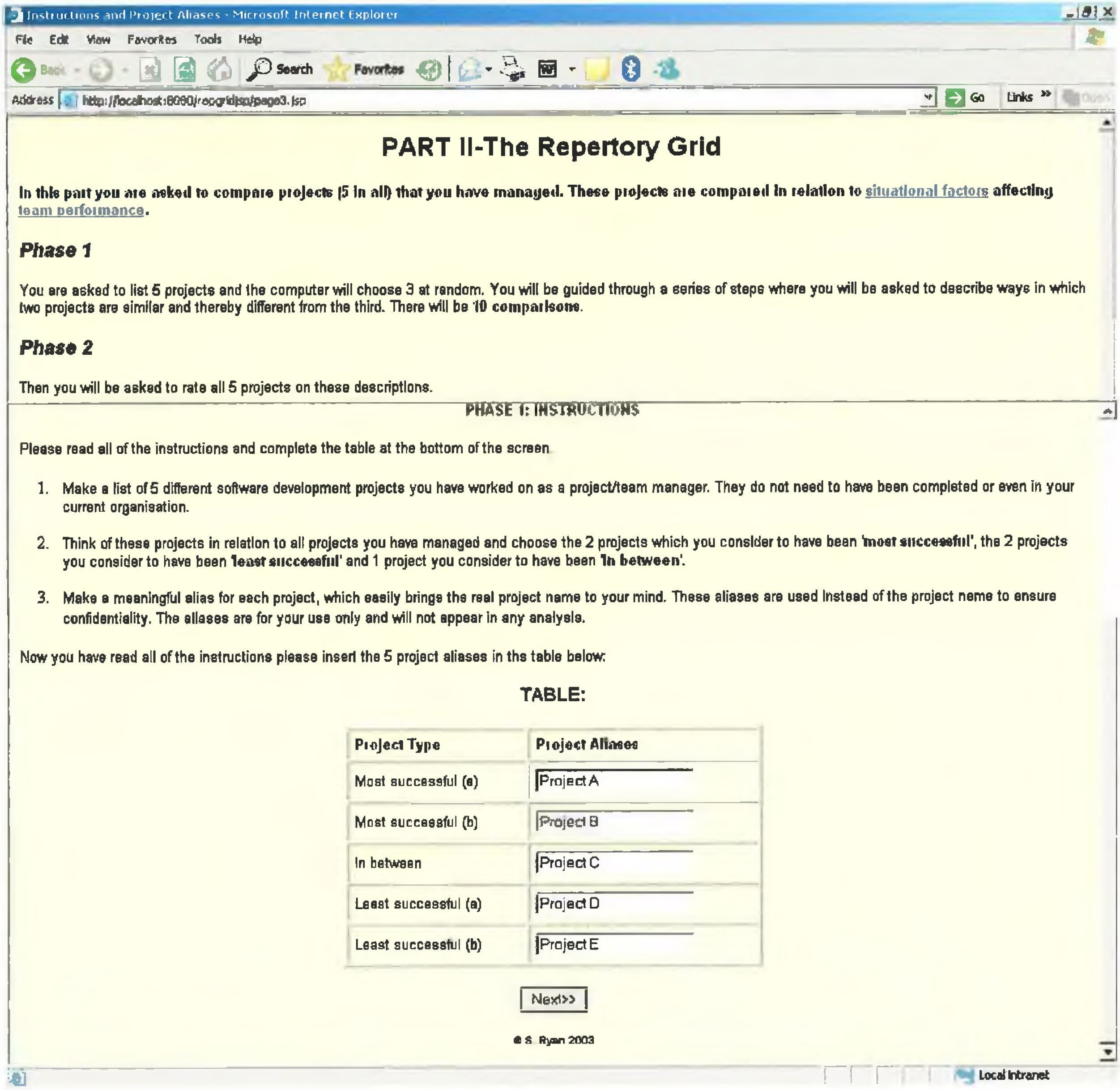
What age are you?
Please choose a category 31-40

What sex are you?
Please choose a category Female

How many employees in your current organisation?
Please choose a category 101-250

Please enter the amount of years have you worked as a project team manager in the software development field. 6 years.

Appendix G.3 Details of the Repertory Grid Process and Listing of Project Aliases.



Instructions and Project Aliases - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://localhost:8080/repgridjsp/page3.jsp

PART II-The Repertory Grid

In this part you are asked to compare projects (5 in all) that you have managed. These projects are compared in relation to situational factors affecting team performance.

Phase 1

You are asked to list 5 projects and the computer will choose 3 at random. You will be guided through a series of steps where you will be asked to describe ways in which two projects are similar and thereby different from the third. There will be **10 comparisons**.

Phase 2

Then you will be asked to rate all 5 projects on these descriptions.

PHASE 1: INSTRUCTIONS

Please read all of the instructions and complete the table at the bottom of the screen

1. Make a list of 5 different software development projects you have worked on as a project/team manager. They do not need to have been completed or even in your current organisation.
2. Think of these projects in relation to all projects you have managed and choose the 2 projects which you consider to have been **'most successful'**, the 2 projects you consider to have been **'least successful'** and 1 project you consider to have been **'in between'**.
3. Make a meaningful alias for each project, which easily brings the real project name to your mind. These aliases are used instead of the project name to ensure confidentiality. The aliases are for your use only and will not appear in any analysis.

Now you have read all of the instructions please insert the 5 project aliases in the table below:

TABLE:

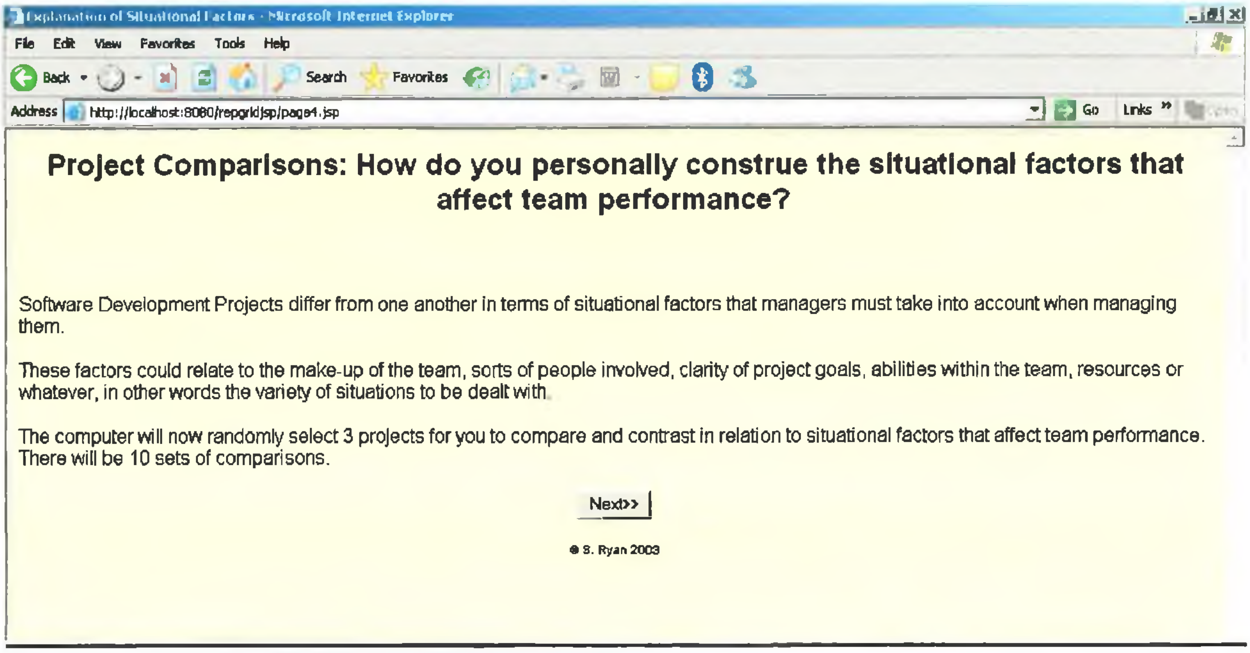
Project Type	Project Aliases
Most successful (a)	Project A
Most successful (b)	Project B
In between	Project C
Least successful (a)	Project D
Least successful (b)	Project E

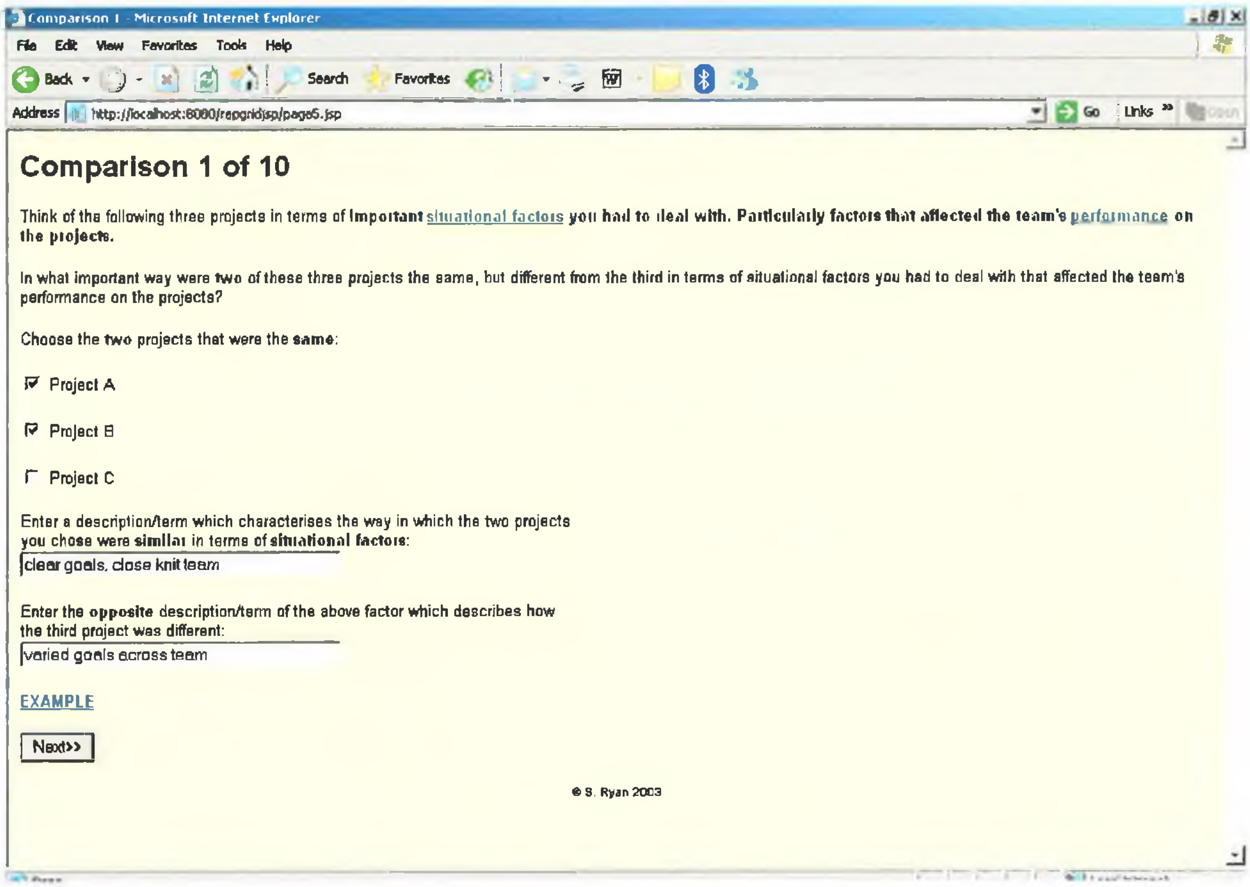
Next>>

© S. Ryan 2003

Local intranet

Appendix G.4 10 Triadic Project Comparisons





Example: *For each 'similar description' there is necessarily an 'opposite description' e.g. project A and C are similar because they had **clear goals** and thereby different from project D which had **unclear goals**. This is known as a bipolar description/construct*

Appendix H

Bipolar Constructs under each Theme

Table H.1 Categorisation of Bipolar Constructs under each Theme

(1)	**Clear well-defined goals**	
1	Unclear management goals	Clear management goals
2	Clear end goal required	Unclear goals
3	Clear goals	Unclear goals
4	Clear goals	Unclear goals
5	Unclear goals	Clear goals
6	Clear goals	Unclear goals
7	Clear goals	Unclear goals
8	Clear goals	Vague goals
9	Unclear goals	Clear goals
10	Moving goals	Project plan
11	Moving goals	Project plan
12	Clear goals, capable team	Exploratory goals, inexperienced
13	Clear goals, close knit teams	Varied goals across teams
14	Clear goals, solid changed management	Unclear goals
15	Goals moved	Clear goals
16	Well defined	Ambiguity
17	Ill-understood goals	Well defined
18	Well defined	Poor defined goals
19	Project scope was poorly defined	Clear project scope
20	Could clearly specify solution	No clear specification available
21	Moving goals	Project Planning
(2)	**Team is motivated and capable**	
22	Willingness to get tasks completed	Lack of willingness to get tasks completed
23	Commitment	No deadline
24	Commitment	Reluctance
25	Constructive developers	Mostly negative developers
26	Clear goals, capable team	Exploratory goals, inexperienced
27	Very high calibre teams	No clarity on project goals
28	Highly motivated team	De-motivated team
(3)	**Co-operative team**	
29	Common goal	Unclear goals
30	Individual performance required	Team cohesion important
31	Team united	Team not united
32	Poor team co-operation	Good team work
33	Highly co-operative teams	Unco-operative team
34	Lack of teamwork	Good team work
35	Strong intra-group cooperation	Lack of intra-group co-operation
(4)	**Knowledge required for project is available within the team**	
36	Resources/knowledge available	Resources/know how not available
37	Outsourced/remote work	Single location team
38	Knowledgeable team	Team lacked knowledge
39	Knowledge required is available within the team	Knowledge required is not totally available within the team
40	Good technical knowledge of system	Technical difficulties not forseen
(5)	**Clear procedures and methodology**	
41	Unclear procedures	Clear procedures

42	Unclear methodology	Definite list of tasks/steps
43	Clear objectives	Unclear objectives
44	Deadlines	less strict deadlines
45	Project planning	Moving goals
46	Lack of clear purpose	Clearly defined purpose
47	Sketchy initial objectives	Clear initial objectives
(6)	**Innovative project**	
48	Exciting Project	Dull project
49	Mundane project	New idea
50	Good enthusiasm and challenges	No budget, no time
51	Good enthusiasm and challenges	No budget, no time
52	Good enthusiasm and challenges	No budget, no time
53	Goals technically hard	Goals technically easy
54	Innovative ideas to marketplace	Not particularly ground breaking
(7)	**Project length**	
55	Closed upon completion	Ongoing
56	Short-term project completed	Ongoing project
57	Short-term project	Long-term project
58	Once off investments short term	Long-term with 5yr reviews
(8)	**Experienced team**	
59	Committed, experienced	Third party
60	Young team mentoring needed	Experienced team self determining
61	Inadequate initial team experience	Adequate initial team experience
62	established systems within the org	No real experience within client
(9)	**Adequate resources**	
63	Resources feasible	Unfeasible
64	Under funded	Adequate resources
65	Adequate resources	Inadequate resources
66	Most required resources to hand	Many resources not at hand
67	Time not dedicated 100% to project	Time totally dedicated to one project
(10)	**Diverse team membership**	
68	Clear goals, close knit teams	Varied goals across team
69	Multi functional experienced	Uni-functional inexperienced
70	Cross functional learning and team	Discrete team members
71	Multi-skilled team	Similar skills
72	Team predominately IT technical etc.	Substantial involvement of users
(11)	**Project scope and importance**	
73	Scope importance	Smaller in scope/importance
74	Small	Large
75	Small project	Large project
76	Large project	Small project
77	Large project	Small project
(12)	**Strict deadlines**	
78	strict deadlines	Widely variable deadlines
79	Definitive deadline for delivery	More strategic/longterm
80	Technical inputs to a deadline	Delivery of management info more longterm
(13)	**Third party is involved in the project**	
81	No third party	Large
82	External interference	No changes made outside
83	External vendors used to deliver	Rollout driven by internal team
84	Involved 3rd party suppliers	Established in-house skills
(14)	**Team size**	
85	Small focused team	Under funded
86	Big team	Small team

87	Smaller closer teams	Large organisation
88	Same size teams	Own project
(15)	**Clearly specified client requirements**	
89	Clear client specifications	Unclear specifications
90	Inaccurate client requirements	Well defined client requirements
91	Lack of commercial/business analysis	Good business requirement specified
(16)	**Managerial experience and control**	
92	Lack of control	Controlled, well managed
93	Inexperienced manager	Experienced manager
94	Manager in control	Manager not in control
(17)	**Management back up & support**	
95	Management back up and resources	Low budget
96	Management back up and resources	Little resources and limited time
97	Management back up and resources	One main programmer
98	Management back up and resources	Small budget and no time
99	Management back up and support	Lack of management support
100	Clear sponsorship within the org	No sponsor/champion at client
(18)	**Low morale**	
101	Low morale	Highly pressured
102	Conflict	Independence
103	No team spirit	Team spirit
(19)	**On schedule and On budget**	
104	Projects were rushed	Time was taken
105	On time on budget	On time, not on budget
106	On schedule, within budget	Project was of poor quality
107	On time and of high quality	No clear scope, not on time
(20)	**Measure of Success Criteria in evidence**	
108	Clear initial success measures	Unclear initial success measures
109	Lack of measures of success	Comprehensive measures of success
110	Clear objectives/success criteria	Regulatory requirement but unclear
(21)	**Clear team communication**	
111	Poor feedback given	Good communication
112	Team was kept informed	No feedback given to team
113	Clear team communication	Misinterpreted communication
(22)	**Team challenges to management are welcome**	
114	Management decisions challenged	Management decisions unchallenged
115	Team challenges welcome	Little time and financial resources
(23)	**Competition within the team**	
116	Highly competitive team	Team worked steadily
117	Internal competition	Team work
(24)	**Clear non-competing roles**	
118	Clear divison of labour	No clear division of labour
119	Clear non-competing roles	Role confusion and overlap
(25)	**Client's needs met**	
120	Fully met client needs	Did not meet client need
121	Did not meet client needs	Scope clear
122	On time and met client needs	Did not meet client needs

123	On time happy clients	Client was not happy
(26)	**Client from same organisation**	
124	Internal organisation focus	Critical for business continuity
125	Organisation wide impact	Specific to one business area
(27)	**Other**	
126	Government	Internal change
127	Workflow (consistent)	Internal changes
128	Software development	Cultural change
129	Required business re-engineering	Mostly upgrade of existing systems
130	Delivery of management information systems	Upgrading the technical tools
131	Change management training specific users	Just in time training for all users
132	Regulatory/Safety related projects	Commercial project

Appendix I

Number of Constructs under Each Theme by Manager

Table I.1 Number of Constructs under each Theme by Manager

Theme #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Total**
1			9		2	3	1			3	1		1	20
2	1	2	1			1					1	1		7
3				1		1	1			3		1		7
4	1					1	1					1	1	5
5	3				2					1		1		7
6							2		3			1	1	7
7	1			1			1	1						4
8		1				1						1	1	4
9	1				2							2		5
10						3	1	1						5
11	1	1			3									5
12	1			1				2						4
13		1		1				1					1	4
14					1				1	1			1	4
15				1							1		1	3
16	1					1	1							3
17									5				1	6
18		2		1										3
19				1							3			4
20												2	1	3
21				2		1								3
22				1					1					2
23							1			1				2
24							1			1				2
25											4			4
26								2						2
27		3						3					1	7
Total no of constructs	10	10	10	10	10	12	10	10	10	10	10	10	10	**132**

*person 6 had 12 constructs as two were split.

Appendix J

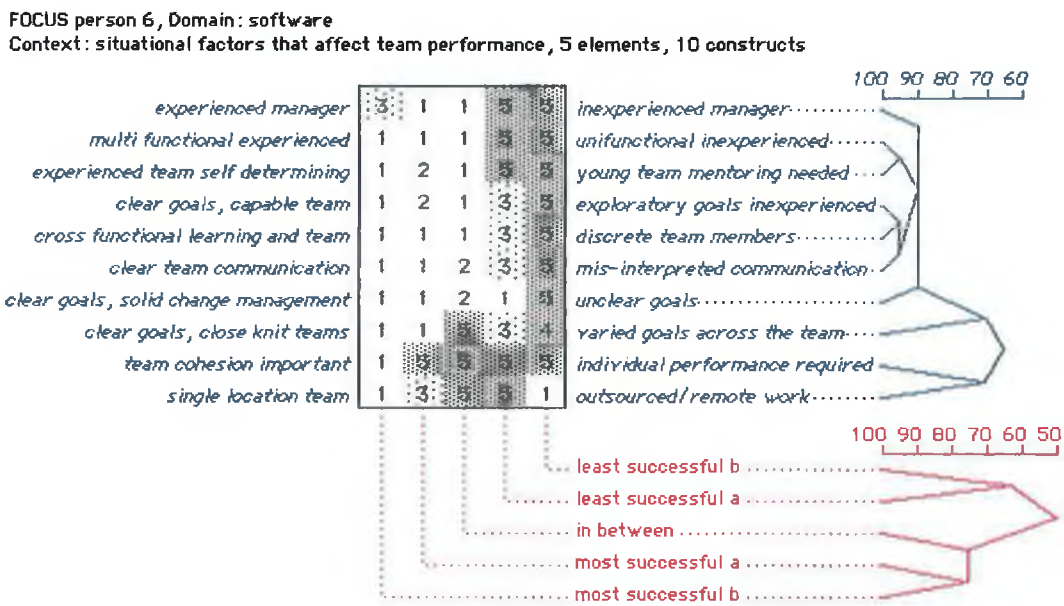
Example of Personal Grid Analysis

Cluster analysis for person 6

In cluster analysis, project types (most successful a, most successful b, in between, least successful a, and least successful b) that are fairly similar, are placed together and connected by a shorter edge than project types that differ in some respect. The same is true of the constructs.

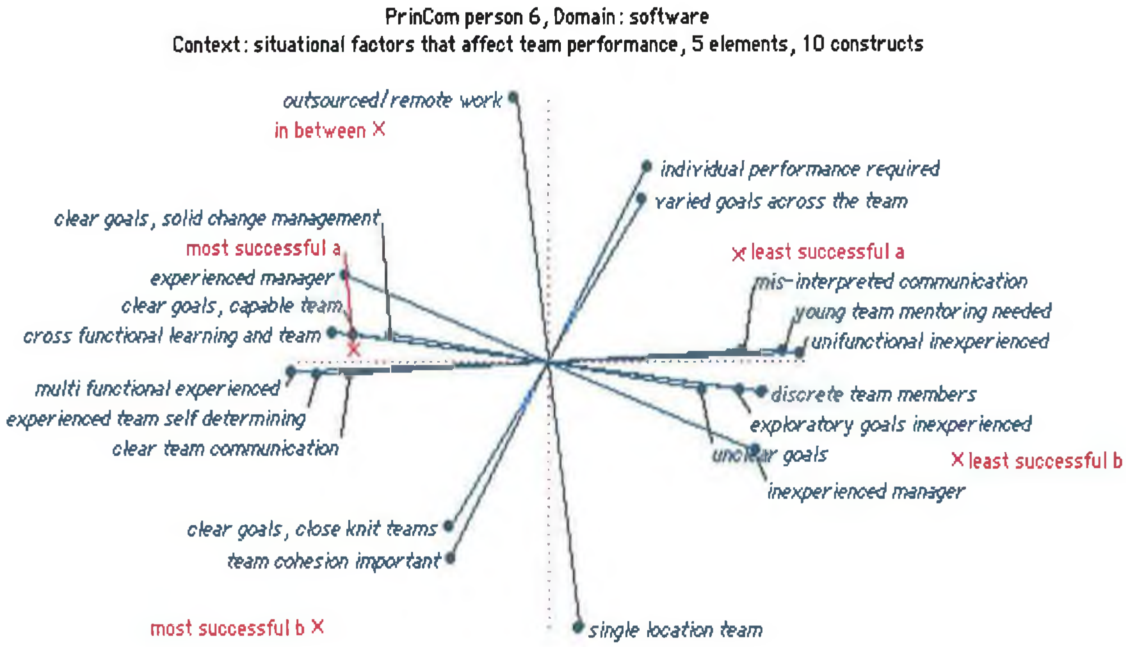
The two most successful projects are similar to one another and the two least successful projects are related to each other. The in between project is more closely related to the successful projects than the least successful. In terms of constructs 'multi functional experienced', 'experienced, self determining' are closely related, as are 'clear goals, capable team', 'crossfunctional learning and team' and 'clear team communication'. These two sets of constructs are also closely related to one another.

Figure J.1 Cluster analysis



Principal Components Analysis

The PrinCom map is a type of diagram that provides a principal components analysis of the grid by rotating it in vector space to give maximum separation of elements in two dimensions. As we can see in the diagram below, the constructs play the role of measures of project type (i.e. successful, in between and least successful) and have polar values connected by a line. The closer the project types the more similar they are in terms of the constructs.



In this particular diagram, the two most successful projects are actually differentiated by different constructs, with ‘most successful a’ being in a different quadrant to ‘most successful b’ project. This may be interpreted as illustrating the diverse and different constructs that constitute different successful projects. Although it is interesting to note that ‘least successful a and b’ seem to be the polar opposite of ‘most successful a’. The manner in which this person construed the most successful projects indicates that they see different situational factors affecting different projects, for this context. Cognitive complexity is a combination of differentiation and integration and involves construing in a multidimensional way.

Although the two most successful projects are highly correlated, they are also differentiated by 2 constructs. The differentiation is not so crude though, as ‘most successful b’ is not exactly atop ‘team cohesion important’. The amount of constructs and themes and the level of integration and differentiation apparent in this grid would indicate that this manager is approaching cognitive complexity.

Appendix K

Factors that influence team performance on successful software development projects

Factor No.			
1	Clear goals	☐☐☐☐☐	Vague goals
2	Highly motivated team	☐☐☐☐☐	Team is not motivated
3	Highly co-operative team	☐☐☐☐☐	Unco-operative team
4	Knowledge required available within the team	☐☐☐☐☐	Knowledge required is not totally available within the team
5	Unclear Procedures	☐☐☐☐☐	Clear procedures
6	Innovative project	☐☐☐☐☐	Mundane/everyday type project
7	Short-term project	☐☐☐☐☐	Long-term project
8	Experienced team	☐☐☐☐☐	Inexperienced team
9	Adequate resources	☐☐☐☐☐	Inadequate resources
10	Diverse team membership	☐☐☐☐☐	Uniform team membership
11	Small project	☐☐☐☐☐	Extensive project
12	Strict deadlines	☐☐☐☐☐	Widely variable deadlines
13	Third party is involved in the project	☐☐☐☐☐	No involvement of a third party from outside the team
14	Big Team	☐☐☐☐☐	Small Team
15	Inaccurate client requirements	☐☐☐☐☐	Well-defined client requirements
16	Manager in control	☐☐☐☐☐	Inexperienced manager
17	Management back up & support	☐☐☐☐☐	Lack of management support
18	Low morale	☐☐☐☐☐	High morale
19	On schedule and On budget	☐☐☐☐☐	Behind schedule and over budget
20	Lack of measures of success	☐☐☐☐☐	Comprehensive measures of success
21	Clear team communication	☐☐☐☐☐	Misinterpreted communication
22	Management decisions challenged	☐☐☐☐☐	Management decisions go unchallenged
23	Internal competition	☐☐☐☐☐	No competition within the team
24	Clear non-competing roles	☐☐☐☐☐	Role confusion and overlap
25	One clearly identified decision maker/leader	☐☐☐☐☐	Unclear as to who makes the decisions

Appendix L
Levene's Test for Homogeneity of Variance

Table L.1 Levene's test of Homogeneity of Variance for Students (N = 124)

	Factors	Levene's Test for Homogeneity of Variance F
1	Clear goals	19.78*
2	Highly motivated team	0.69
3	Highly co-operative team	0.62
4	Knowledge required available within the team	0.02
5	Unclear Procedures	0.37
6	Innovative project	0.12
7	Short-term project	1.61
8	Experienced team	2.71
9	Adequate resources	1.93
10	Diverse team membership	5.96*
11	Small project	1.85
12	Strict deadlines	8.56*
13	Third party is involved in the project	7.93*
14	Big Team	0.53
15	Inaccurate client requirements	2.02
16	Manager in control	2.71
17	Management back up & support	4.22*
18	Low morale	4.80*
19	On schedule and On budget	3.68
20	Lack of measures of success	0.02
21	Clear team communication	3.23
22	Management decisions challenged	10.48*
23	Internal competition	0.19
24	Clear non-competing roles	3.10
25	One clearly identified decision maker/leader	1.48

* $p<.05$

Appendix M

T-test Results comparing Ireland and the UK on all Variables

Table M.1 T-test results for Ireland the UK on all Variables

Variable	Ireland (N= 23)		UK (N = 25)		
	Mean	S.D.	Mean	S.D.	t
1. QSI	13.32	1.79	12.38	1.93	-1.76
2. Quantity of SI	69.35	15.91	60.24	17.56	-1.85
3. Specialisation	21.38	3.08	20.36	3.05	-1.56
4. Credibility	22.22	2.09	21.10	2.52	-1.66
5. Coordination	21.28	2.83	19.97	2.95	-1.57
6. Transactive memory	43.14	4.33	40.84	4.21	-1.87
7. Team Tacit Knowledge	5.23	2.53	5.73	2.47	0.68
8. Effectiveness	18.33	2.48	18.51	3.05	0.22
9. Efficiency	6.23	1.60	6.70	1.35	1.09
10. Psychological Safety	40.61	4.26	38.16	4.38	-1.96
11. Team size	4.57	2.38	5.22	2.32	0.96
12. Diversity	52.25	39.68	48.27	37.24	-0.36
13. Formal knowledge Sharing System	9.43	2.07	8.92	1.83	-0.90
14.Experience	11.86	5.38	11.40	4.68	-0.31
15. Expertise Presence	81.35	15.78	78.75	10.59	-0.68
16. Reliance on Gut Instinct	1.02	0.66	0.98	0.59	-0.17
17. Familiarity with Written Procedures	4.15	0.90	4.00	0.62	-0.69
18. Reliance on Written Procedures	2.05	1.07	1.95	0.84	-0.36
19. Administrative Coordination	17.59	4.66	19.87	3.74	1.88
20. New Product Development	12.91	1.50	13.32	2.43	0.69

All mean differences were non-significant.