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KNOWLEDGE TRANSFER AND THE USE OF SOCIAL
NETWORKS IN THE BIOPHARMACEUTICAL INDUSTRY:
AN INVESTIGATION INTO THE MICRO-FOUNDATIONS OF
EXTERNAL ABSORPTIVE CAPACITY

CHRISTOPHER ROBERT JEFFS

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Abstract

In order to grow, the pharmaceutical sector has had to heavily rely on both formal and informal innovation networks. However, many analysts consider that the industry has not achieved its growth potential and suggest that this is in part due to the inherent organisational barriers to knowledge transfer that exist in the pharmaceutical sector.

This thesis provides a critical review of the knowledge transfer literature; with particular reference to absorptive capacity, social capital and external knowledge transfer meta-routines. The study takes a pragmatic critical realist approach, using a two stage critical incident technique to elucidate the micro-foundations of problem solving routines as a proxy for knowledge transfer. Thematic analysis on the resulting narratives identifies routinized patterns of information seeking behaviour, reveals the micro-foundations of template use and provides insights into how scientists recognise value in the knowledge that they find.

The study answers calls to research the role of the individual in organisational routines; to uncover the micro-foundations of external absorptive capacity and to determine how value is recognised in new knowledge. A model is proposed that suggests that recognising the value of new knowledge is a construct that is influenced by factors which affect the perceived information quality, the relative subjectivity of the solution and the source's social-identity. The value of knowledge is also further corroborated with the support of other materials or through a wider stakeholder involvement.

The study has adopted a 'strategy-as-practice' approach and contributes to organisational practice by examining how informal external knowledge transfer through problem solving in a biopharmaceutical organisation is accomplished. These insights enable the author to suggest a number of managerial strategies by which pharmaceutical managers might recognise, optimise and facilitate the use of informal networks; whilst protecting their intellectual property and maintaining the potential for innovation.

Declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others.

Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the Business School Ethics Committee in October 2010.

Name: Chris Jeffs

Signature:

Date: 24 April 2013

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Glossary

CoP	Community of Practice
CIT	Critical Incident Technique
DBA	Doctor of Business Administration
IP	Intellectual Property
KBV	Knowledge Based View
NBS	Newcastle Business School
NICR	Northern Institute for Cancer Research
OECD	Organisation for Overseas Economic Co-operation and Development
R&D	Research and Development
RBV	Resource Based View
SECI	Socialisation, Externalisation, Combination, Internalisation
SOP	Standard Operating Procedure

Definitions

The term biopharmaceutical has been interpreted in a variety of ways. The classic view, and the view taken by this author, is that the traditional pharmaceutical sector relates to medicinal products typically formed by synthesising small chemical compounds or drugs.

Biopharmaceutical products are more likely to be large compounds, such as proteins or monoclonal antibodies, which have been formed through biological processes such as mammalian cell culture or fermentation (Lim, Garnsey, & Gregory, 2006; Rader, 2008).

The classification of the terms biopharmaceutical and pharmaceutical is also characterised by the means in which a drug is patented. A pharmaceutical drug is typically protected by patents covering chemical structures, whereas the intellectual property pertaining to a biopharmaceutical drug is most likely to be related to a gene sequence, its use, or the cell line that it was derived from. A commonly cited definition of biopharmaceutical is that provided by Walsh.

“A biopharmaceutical is a protein or nucleic-acid based pharmaceutical substance used for therapeutic or in-vivo diagnostic purposes, which is produced by means other than direct extraction from a native (non-engineered) biological source” (Walsh, 2002, p. 135)

In the interests of brevity, this study will refer to pharmaceutical companies as those which are the larger traditional multinationals which chemically synthesise drugs and biopharmaceutical companies as the typically smaller organisations that generate drugs and intermediates by a biological means. The author does however recognise the limitations of this oversimplified classification.

1 Introduction

1.1 The rationale for the study

The objective of this study is to investigate knowledge transfer and the use of social networks in the biopharmaceutical industry. There are a number of reasons why this topic is of interest. Initially the industry was considered because of the author's familiarity with the industry as a result of a twenty-six year career as a scientist, senior manager and business development executive in the sector.

The pharmaceutical sector is also considered to be of importance as it has been financially underperforming and producing fewer successful biopharmaceuticals than most industry analysts have predicted (Chesbrough, 2011; Horrobin, 2000). Indeed, the recent spate of pharmaceutical mergers is thought to have been triggered by high drug development and drug discovery costs (Macher & Boerner, 2012) and drug pipelines that lack 'blockbuster' candidates (Maddock & Viton, 2011). Barriers relating to external knowledge transfer are also thought to contribute to these industry problems (Newell *et al*, 2008).

The extensive creation of alliances between research institutes, biopharmaceutical companies and pharmaceutical companies lends weight to the assumption that the industry is a tightly bound fusion between leading edge science and business. However, it has been suggested that this is not a natural partnership as science aims to explore the underlying traits and theories, a process that requires dissemination, challenging and building on each other's work (Gilsing & Nooteboom, 2006; Polyani, 1962). The scientific regime is motivated by opportunities to gain creditability through for example citation and reputation rather than financial gains (Latour & Woolgar, 1986, p. 194, 205). Businesses however tend to focus on results within a paradigm of secrecy and with a preference for a quick return on investment (Merton, 1973). This dynamic tends to result in commercial secrecy in the sector (Murray & Stern, 2007).

Concerns over the loss of intellectual property (IP) have led to a lack of knowledge sharing between organisations (Haas & Park, 2010; Newell *et al*, 2008). This view has been supported by studies which suggest that rather than taking a collaborative trust-based attitude to knowledge transfer and relational development, the pharmaceutical sector tends to take a 'black-box'

approach which focusses on securing returns on their intellectual property instead of maximising future innovation potential (Diestre & Rajagopalan, 2012; Dosi, Marengo, & Pasquali, 2006). In particular the sector requirement for cumulative learning and the integration of critical tacit knowledge does not link *'islands of expertise'* (Pisano, 2006, p. 2). As a result it is proposed that the pharmaceutical sector requires new approaches to strategic management which change the 'appropriability regime' and aid knowledge transfer (Hurmelinna, Kylaheiko, & Jauhiainen, 2007).

The issues relating to the lack of knowledge transfer in the pharmaceutical sector have been identified as receiving little empirical attention (Azoulay, 2004; Macher & Boerner, 2012). In order to address the calls for further research and to provide organisational insights to the micro-foundations of knowledge transfer practice, three research questions have been proposed that fill recognised gaps in the knowledge transfer literature. These will be discussed later in this chapter.

The introductory chapter provides a contextual background to the pharmaceutical sector. It introduces the organisational theories of social networks and knowledge transfer in relation to the biopharmaceutical industry, and provides the basis for a more focussed and critical evaluation of contemporary research in the literature review. The chapter concludes with a discussion of the research questions before providing a synopsis of the remaining chapters in the thesis.

1.2 The pharmaceutical sector

The global pharmaceutical sector is one of the largest sectors in the world, with a market size estimated to be \$900 billion, with the USA, EU and Japan accounting for fifty five percent of the market (IMAP, 2011). In order to understand the biopharmaceutical industry context it may be useful to consider briefly the historical development of this sector.

The biopharmaceutical industry owes its origins to the discovery of drugs such as aspirin, insulin and penicillin in the early 20th century. In the 1930s the pharmaceutical sector started to utilise systematic drug discovery as a means of randomly screening potential drug candidates.

Screening led to a large scale sampling of the natural environment and the isolation and synthesis of drug candidates found in these samples (Casper & Matreves, 2003). It was not until after the Second World War that the new drug target receptors were identified, which lead to important new therapeutic mechanisms for treating diabetes, hypertension and glaucoma (Drews, 2000). Despite being relatively random in its approach, the screening process was for many decades the dominant form of drug discovery and accounts for approximately 95% of drugs in use today (Pisano, 2006).

An average drug requires over \$1.0 billion in investment and may take twelve years from discovery to market (Koka & Lands, 2004). One in five thousand compounds that enter into pre-clinical testing make it to human testing, and only one in five of these is approved with biopharmaceuticals having a lower clinical approval success rate in comparison to pharmaceutical products (Ahn & Meeks, 2008; Rothaermel & Deeds, 2004).

1.2.1 The development of the biopharmaceutical industry

The biopharmaceutical industry was founded on the recombinant DNA discoveries made in the early 1970s and the subsequent development of genomics and proteomics which occurred in the following decades. The early entrants to the biopharmaceutical sector were commonly ‘spun-out’ from university research projects and were funded by venture capital. The new biopharmaceutical companies often used development technologies that were unique to the industry and were considered to be potentially competence-destroying to the prevailing pharmaceutical sector. New scientific techniques increased the number of potential drug targets

from approximately five hundred to the many thousands that are present in tissues and genetic material. Today the biopharmaceutical sector has approximately 300 drugs approved for sale and these target nearly four hundred different disease indications (Ahn *et al*, 2010).

However only four in ten products that reach the market achieve profitability (Koka & Lands, 2004) and of the three hundred and fifty publically traded American biopharmaceutical companies less than ten have achieved sustainable profitability (PhRMA, 2006). In addition, the expectation that biopharmaceuticals were going to replace chemical drugs has not materialised; only a few of the earliest biopharmaceutical entrants, such as Amgen, Biogen (now Biogen Idec) and Genentec (now a member of the Roche group) are making substantial profits.

1.2.2 Biopharmaceutical alliances

In later stages of development and once drugs have shown their potential, formal alliances are often created between a biopharmaceutical company and a pharmaceutical company. These alliances provide financial assistance, regulatory experience, late stage clinical development and marketing and distribution (Hendry & Brown, 2006). In return the pharmaceutical companies gain access to intellectual property and technological know-how (Durand, Bruyaka, & Mangematin, 2008; Schweizer, 2005).

Alliances and collaborations have created a new pharmaceutical business model that have moved from an almost exclusive 'in-house' product discovery and development, to one with a new emphasis on value creation within alliances (Hagedoorn & Duysters, 2002; Smart, Bessant, & Gupta, 2007). Such are the potential benefits of external innovation that internal R&D efforts have declined and a new impetus for innovation has been achieved through the commercialisation of external ideas and knowledge (Chesbrough, 2003). An example of pharmaceutical/biopharmaceutical co-development is the alliance between the pharmaceutical giant Bayer and the genomic specialist CuraGen, which was funded through a \$1.34 billion, fifteen year agreement to jointly develop, test and launch therapeutics for metabolic disorders (Van Brundt, 2001).

1.2.3 Networked innovation in the pharmaceutical sector

It is widely accepted that R&D costs may be reduced through ‘open’ or ‘distributed innovation’ and the leverage of networked resources (Alguezaui & Filieri, 2010; Newell *et al*, 2009; Salman & Saives, 2005). The term ‘distributed innovation’ is often synonymously used with the term ‘open innovation’ as they describe innovation input from different sources which might include users, suppliers and rivals (Chesbrough, 2006; von Hippel, 1988). Indeed many authors claim that the natural dynamics of the biopharmaceutical sector has helped to pioneer open innovation (Chiaroni, Chiesa, & Frattini, 2008; Hughes & Wareham, 2010). Open networks have been found to be particularly beneficial in providing opportunities for knowledge creation through the enhanced opportunities for “spill-over” effects, or increasing the likelihood of knowledge leaking through open network channels (Murray, 2002; Owen-Smith & Powell, 2004).

Universities, competitors and other scientists in the field are often regarded as the key sources of early innovation in the biotechnology industry (Fetterhoff & Voelkel, 2006; Powell, 1996, p. 118). Research has established that in the early stages of drug development, biotechnology companies tend to link more often to other new biotechnology companies or university research laboratories rather than to large firms; a finding that is not true in other sectors (Hendry & Brown, 2006; Rothaermel, 2001). Indeed it has been found that 77% of UK biotechnology companies now partner with one or more universities (Kleyn, Kitney, & Atun, 2007).

The drive towards networking and collaboration is likely to be due to the complexity of knowledge and technologies that the biopharmaceutical company needs to encompass (Adegbesan & Higgins, 2011; Christensen, 2003). These technologies include the sciences of biology, chemistry, bioinformatics, mathematics, engineering, physics and medical sciences such as oncology (Archilladelis & Antonakis, 2001). This diversity of requirements has resulted in biotechnology companies clustering around major universities and the formation of cross-disciplinary biopharmaceutical research institutes (Casper & Kettler, 2001; Hendry & Brown, 2001). The Northern Institute for Cancer Research (NICR) is for example owned by and sited on the Newcastle University campus and maintains formal links with other national and international cancer research centres, and has been selected as the focus for study in this research.

1.3 Knowledge transfer theory

Research has shown that innovation may be enhanced by entering new technological areas (Rothaermel & Boeker, 2008); by combining old knowledge with new (Ahuja & Lampert, 2001); by exploiting and combining unique combinations of resources and knowledge (Grant R. , 2002; Hargadon, 2003); and having access to a diversified body of knowledge (Nerkar, 2003; Koka, Zheng, & George, 2011; Penner-Hahn & Shaver, 2005). Knowledge transfer is therefore a crucial factor in the solving of organisational problems and in the development new innovations (Smith, Collins, & Clark, 2005).

1.3.1 Knowledge characteristics

Philosophers have debated what knowledge is for millennia and is recognised in the study of epistemology. According to the ‘epistemology of possession’ knowledge is a personal property which confers meaning and is based on past experience and understanding. However proponents of ‘epistemology of practice’ claim that knowledge is constructed and informed by social interaction and will therefore consist in multiple versions or truths (Newell *et al*, 2009, p.5). In an attempt to cut through this complexity Swan (2008) broadly defined knowledge as the ‘*ability to discriminate across contexts*’ thus encompassing both epistemic perspectives.

However this broad of definition lacks practicality in the light of the claim that knowledge only becomes valuable when it is applied to specific tasks (McDermott, 1999). Unlike information or data, knowledge is a skilful action that allows humans to define, prepare, shape and learn in order to solve a task or problem (von Krogh, Ichijo, & Nonaka, 2000). A more specific definition of knowledge which encompasses many perspectives has been defined by Davenport and Prusak will be used for this research.

“Knowledge is a fluid mix of framed experience, values, contextual information, and expert insights providing a framework for evaluating and incorporating new experiences and information” (Davenport & Prusak, 1998, p. 5).

Knowledge can differ by the degree of explicit or tacit characteristics that it possesses. Explicit knowledge, which is also referred to as the ‘know-what’, may easily be codified, copied and stored and is therefore subject to leakage. It has been suggested that codified knowledge may be

sub-classified as *disembodied* as is illustrated by the progress of science and technology; or *embodied* if it is bound within technological tools, such as scientific instrumentation and machinery (Belussi & Belotti, 2000). Other forms of codified knowledge are represented by ‘organisational artefacts’ and include templates (a subject of this research), protocols and standard operating procedures (SOPs). These forms of knowledge relate to organisational routines and exist to ensure that processes are followed in an optimal manner but they also provide an important means of both ‘intra’ and ‘inter’- organisational knowledge transfer (Winter & Szulanski, 2001).

Tacit knowledge consists of implicit and non-codifiable skills or ‘know-how’ and tends to have ‘sticky characteristics’ which make it difficult to copy (Nonaka & Takeuchi, 1995). This characteristic provides valuable barriers to imitation (Simonin, 1999; Starbuck, 1992) and sustainable value to the organisation (Boisot, 1998; Winter, 1987); but it also creates barriers to knowledge transfer and organisational learning (Nonaka, 1991). Tacit knowledge may be found in complex social interactions and habits, but may also be present in the artefacts that support organisational processes and routines (Spender, 1994; Szulanski, 1996).

1.3.2 The use of social networks as a source of knowledge

Research suggests that informal social ties are superior conduits for knowledge transfer between different organisations, especially those in geographically dispersed locations (Adler & Kwon, 2002; Bell & Zaheer, 2007). Studies of the relationship between network characteristics and knowledge transfer has demonstrated that network ties provide access to resources (Nahapiet & Ghoshal, 1998), thus providing the individual with information and assistance in solving problems (Widen-Wulff *et al*, 2008).

Research on knowledge transfer between biotechnology companies has shown high levels of informal social networking activity between scientists and university sources. Flat structures, interdisciplinary communication and the exchange of skills were found to be beneficial in the generation of new ideas, whereas more formal hierarchies with longer reporting lines may result in barriers to knowledge transfer (Bernstein & Singh, 2006). Informal social networks therefore play an important part in external knowledge transfer routines and have been found to encourage

the smooth operation of the firm's activities by filling in gaps and by assisting employees in their work (Allatta & Singh, 2011).

There are two key enablers in the practice of social networking and knowledge transfer, social capital and the use of information seeking routines. Social capital is a concept that defines the characteristics and precursors of an individual and the structure of their social networks (Nahapiet & Ghoshal, 1998). Information seeking routines are the informal organisational mechanisms that are used when an individual seeks information, typically in order to solve a problem (Johnson *et al*, 1995). Social capital and information seeking routines therefore provide useful frameworks to examine social structures and information seeking behaviour in external knowledge transfer (Johnson, 2004, p. 8), and are the subject of this study.

1.3.3 Absorptive capacity and the knowledge transfer process

The process and stages of organisational knowledge transfer have been extensively studied. A widely cited theory which is considered to be one of the central theories on inter-organisational knowledge transfer and learning is absorptive capacity (Cohen & Levinthal, 1989; Schildt, Keil, Maula, 2012). The ability to absorb knowledge is thought to be dependent on effective knowledge transfer routines and trust which take time to develop (Doz, 1996); suggesting that longer term alliances are better able to transfer knowledge (Simonin, 1999).

The first stage of the absorptive capacity model is generally accepted to be 'acquisition' which requires the recognition of the value of the knowledge that is to be transferred. This critical first step in knowledge transfer is investigated in this research. Knowledge transfer is however only successful if the receiver of the information has prior related knowledge in order to recognise the value of what they are receiving (Kane, 2010; Starbuck & Milliken, 1988). The remaining stages of the absorptive capacity model include the organisational utilisation of the new found knowledge, a factor that provides the potential for innovation.

1.4 Derivation of the research questions and contribution to theory

The lack of knowledge transfer has been established as a potential limiting factor on innovation in the pharmaceutical sector. A basic premise of this research is that in order to overcome barriers to knowledge transfer, biopharmaceutical scientists may resort to using their own informal social networks to solve problems, to exchange knowledge and to progress innovation. An exploratory study will confirm this phenomenon by investigating social networking in different organisations in the sector, the pharmaceutical, the biopharmaceutical and the early research orientated 'spin-out' firm.

The research objective of the main study investigates how scientists use social networks to externally source and transfer knowledge. Three research questions are aligned with this objective in order to provide further definition and to answer calls for further research.

The first research question will determine the micro-foundations of how social networks are used to source and transfer knowledge. The question is deliberately broad in order to capture the temporal processes and behavioural mechanisms in the use of social networks when solving organisational problems. It answers calls for research that investigates the content of routines that drive open innovation (Hughes & Wareham, 2010, p.325). It has also been recognised that the role of individuals in knowledge transfer routines has also only been tangentially studied in the extant literature (Kane, 2010, p. 645; Volberda, Foss & Lyles, 2010, p.948).

The second research question evaluates how templates are used in knowledge transfer, a recognised method for knowledge transfer in organisations. This question answers a call from Jensen & Szulanski (2007, p.1728) to further examine how templates are involved in the knowledge transfer process.

The final research question determines the criteria that characterise the value of new knowledge. This first step in absorptive capacity is recognised in the extant literature as being crucial for the successful transfer of knowledge and is recognised as being under-researched at the micro-foundational level (Torodova & Durisin, 2007, p. 777; Yoo, Vonderembse & Ragu-Nathan, 2011, p.339).

These and other calls for research relating to each research question are summarised in Table 1.1

Table 1.1 Calls for research in the subject area

The relationship between routines and open innovation	Research Question 1	<i>“call to detail the content of routines that drive open innovation” (Hughes & Wareham, 2010, p. 325)</i>
The influence of social capital on organisational routines	Research Question 1	<i>“How does the proximate physiological, physical, and social context in which individuals are embedded affect routines and capabilities performance at the firm level?” (Lewin, Massini, & Peeters, 2011, p. 81)</i>
The role of templates in knowledge transfer	Research Question 2	<i>“The need to further examine the specific mechanisms through which templates affect the [knowledge] transfer process.” (Jensen & Szulanski, 2007, p. 1728)</i>
Investigating the role of the individual in absorptive capacity	Research Question 1&3	<i>“the role of individuals and their interaction has only been tangentially included in research on absorptive capacity” (Volberda, Foss, & Lyles, 2010, p. 948)</i>
The micro-foundations of absorptive capacity	Research Question 1&3	<i>“Future research needs to address the specific operationalization of the capabilities that absorptive capacity comprises” “It is important to focus on the routines and processes that organizations use to acquire, assimilate, transform and exploit knowledge” (Kane, 2010, p. 645)</i>
Valuing new external knowledge	Research Question 3	<i>“Recognizing the value of knowledge is an important and under-researched component of firm absorptive capacity” (Torodova & Durisin, 2007, p. 777)</i>
Evaluating knowledge quality	Research Question 3	<i>“Additional research is required to generalise knowledge quality and its antecedents” (Yoo, Vonderembse & Ragu-Nathan, 2011, p. 339)</i>

1.5 Contribution to practice

In line with the ethos of the Doctorate of Business Administration (DBA) this study also provides an insight into ‘real world organisational issues.’ The management outcomes fall into three categories. Firstly, it provides a practical understanding of knowledge transfer and the use of social networks in the biopharmaceutical industry. Secondly, it provides recommendations for the strategic management of knowledge transfer through social networks and finally it recommends specific training to overcome the existing limitations in inter-organisational knowledge transfer through the use of templates.

1.6 The research questions

The three research questions that are the foundation of this thesis are summarised below.

The research objective is to understand how scientists externally source and transfer knowledge

Research Question 1: How do scientists use their social networks to obtain knowledge?

Research Question 2: How do scientists use templates in knowledge transfer?

Research Question 3: What criteria are used to determine the value of new knowledge?

In order to achieve the main objective and answer the research questions this study will build on extant theory in the following areas.

1. *Social networks* which are an informal source and means of channelling knowledge from a source to the initiator (Hull, Coombs, & Peltu, 2000; Koen *et al* 2001).
 - a. *Social capital* which is used to develop social networks and identify appropriate contacts thus enabling knowledge transfer (Nahapiet & Ghoshal, 1998)
 - b. *Information seeking routines* and the micro-foundational behaviours which are used when seeking new knowledge (Johnson *et al*, 1995)
2. The *absorptive capacity* model will provide the acquisition stage of knowledge transfer and, in particular, the concept of valuing new knowledge (Cohen & Levinthal, 1990).

3. The *characteristics of knowledge* in the transfer process, including the use of templates and the degree of tacitity (Nonaka & Takeuchi, 1995).
4. The importance of *knowledge overlap* as an antecedent to understanding (Puranam, Singh, & Chauduri, 2009)

1.7 Overview of the methodological approach

In order to uncover the individual external knowledge transfer routines in a biopharmaceutical organisation, the main study evaluates the micro-foundations of external absorptive capacity. Organisational routines are considered to play an important role in the building of uniqueness as they channel the behaviours, objectives and actions of the organisation towards specific goals and enable the capture and sharing of organisational knowledge (Levitt & March, 1988; McGrath & Argote, 2001). The micro-foundations are the actions that an *individual* takes in order to fulfil the function of an organisational routine (Felin & Foss, 2005). Micro-foundations are important as the micro-level organisational practices are often lost in the aggregate macro-level research which predominates in this area.

Problem solving has been selected as a ‘proxy’ for knowledge transfer as it has been previously recognised as a major source of knowledge transfer between organisations (Alvarez & Barney, 2005; Widen-Wulff *et al*, 2008; Uzzi, 1997). An investigation of problem solving provides a connection between the theoretical areas of external absorptive capacity and knowledge transfer as well as providing an objective boundary and focus to the research methodology.

This empirical study achieved the objective by undertaking a series of qualitative interviews with biopharmaceutical scientists in a biopharmaceutical research institute. Interviews were conducted in two parts, the first used the critical incident technique; the participants narrated a scientific problem that had been solved and the second part comprised of further probing questions. The resulting narrative was transcribed and analysed by the means of a structured thematic analysis. The resulting encoded narrative provided insights into the micro-foundations of the use of social networks, the use of templates in knowledge transfer and an understanding of how new external knowledge is valued in the biopharmaceutical sector.

1.8 A synopsis of each of the chapters

The thesis is comprised of a number of discrete chapters. The chapters have been structured around the research objective and research questions in order to provide a clearly defined and focussed narrative.

This introductory chapter (Chapter 1) has provided a context to the study by highlighting the issues relating to the lack of innovation in the pharmaceutical sector. It has been proposed that this deficiency may be due to a lack of inter-organisational knowledge transfer. A number of factors including the use of social networks, absorptive capacity and the characteristics of knowledge have been recognised as important for successful knowledge transfer to occur. Research questions have been proposed in order to investigate this phenomenon. The chapter has concluded with the methodological approach and the expected contributions to organisational management and academic theory.

The literature review (chapter 2) undertakes a critical review of the use of social networks for knowledge transfer and introduces the concepts of social capital and the absorptive capacity construct; it also provides a review of the use of templates in the knowledge transfer process. It then critically evaluates the micro-foundations of knowledge transfer routines and concludes with a review of literature on how value is recognised in new knowledge.

The methodology chapter (Chapter 3) justifies the Pragmatic Critical Realist perspective taken for the research and describes how the chosen research methodologies comply with this context. This is followed by a detailed description of each of the research methodologies that were used, how the sampling was performed and how the data was collected. A discussion of the data analysis procedures is then undertaken and is followed by a review of the reflexive practice, ethical considerations and limitations to the research.

The findings chapter (Chapter 4) begins with a review of the findings of the exploratory study by identifying the benefits of social networks to the biopharmaceutical sector and the barriers to the knowledge transfer between organisations. It then considers the findings of the first research question which evaluates the use of social networks when sourcing information before it considers the findings of the second research question on the use of templates in the knowledge

transfer process. The final research question is addressed and reviews the findings related to the micro-foundations of valuing new knowledge.

The last chapter presents the discussion and conclusions (Chapter 5) and maintains the structure around the research questions. This chapter builds upon the previous findings chapter and reviews the findings in light of previous empirical research and theories. It provides an overview of the most important findings of the study in relation to the extant literature; discusses the implications for management practice and provides suggestions to overcome the dilemmas that biopharmaceutical managers have when balancing the freedom to social network with the potential loss of IP. The chapter concludes with a holistic consideration of the study by critically evaluating the creditability of the research before proposing further research in the area.

An appendix follows and contains example data and supporting materials which have been referred to throughout the thesis.

2 Literature Review

The literature review is structured around the three research questions that have been presented in the introduction chapter. The chapter also reinforces the interrelated nature of the theories underpinning the research objective that seeks to understand how scientists externally source, value and transfer knowledge. These theories are investigated through the study of the micro-foundations of external knowledge transfer routines.

The literature review starts with a consideration of the theory that underpins the first research question by providing an overview of knowledge transfer and its potential impact on organisational learning and innovation in the organisation. It then examines the concept of absorptive capacity and how it aids knowledge transfer. The third major literature stream relating to the first research question is social networks. This is reviewed through the social capital framework and will review the structure, relationships and cognitive influences of social capital on knowledge transfer. This chapter will critically review the theories behind each topic, such as the importance of trust in relationships and knowledge overlap in the cognitive dimension of the knowledge transfer process.

From Section 2.5 onwards, the literature review considers the extant theory behind the second two research questions by examining the micro-foundations of organisational routines. It starts by introducing organisational routines and the use of artefacts; and the use of templates in the transfer of knowledge which is the subject of the second research question. It also provides the theoretical platform for the study of external knowledge transfer routines by considering problem solving routines that are used as a form of 'proxy' for knowledge transfer in this study. This is followed by a critical review of information seeking routines, which along with problem solving routines are fundamental to knowledge transfer.

The literature review then focusses on the final research question by critically evaluating the extant theory of external absorptive capacity meta-routines and the recognition of value in new knowledge. A recognition of the merits of new knowledge constitutes the first stage of absorptive capacity and is therefore a vital antecedent in the transfer of knowledge. The author summarises the literature review chapter by proposing a model which illustrates the interplay

between external knowledge transfer meta-routines, social capital and the knowledge acquisition stage of absorptive capacity.

2.1 Knowledge transfer through social networks (research question 1)

Research into organisational innovation has documented the important role that networks play in the sharing and the creation of new knowledge (Cross & Parker, 2004). Studies support the concept that the use of external knowledge and resources will benefit innovative performance (Katila, 2002; Owen-Smith & Powell, 2004; Witzeman, et al., 2006) and will lead to higher profitability, market value and improved sustainability (Czarnitzki & Kraft, 2004; Laursen & Salter, 2006). Knowledge sharing between organisations provides the opportunity for ‘kaleidoscopic thinking’ which provides innovative forms of new knowledge (Kanter, 1988).

Organisational networks may be subdivided into two forms; those which are formal and include organisational structures such as joint ventures, strategic alliances and other forms of contractual collaboration and social networks which tend to be informal by nature and consist of relationships that are based on mutual interest and personal history (Jeffs, 2008). Research has found that the use of both formal and informal cross-functional networks can provide diversity in new forms of knowledge (Jansen *et al*, 2009). Inter-organisational networks provide individual members a means to recognise another actors’ know-how and how this relates to their own work and to synthesise it for their own and their organisation’s benefit (Zhou & Li, 2012).

Organisational structures (Borgatti & Cross, 2003), social networks (Inkpen & Tsang, 2005) and organisational culture (Bhagat *et al*, 2002), provide the context for successful inter-organisational knowledge transfer. The organisational pervasiveness of social networks in the innovation process has not always been recognised in the extant literature and will therefore be investigated in this study (Adams, Bessant, & Phelps, 2006; Bernstein & Singh, 2006). The influence of organisational culture and structures may have some relevance to the exploratory study which investigates the extent of external knowledge transfer in pharmaceutical companies and smaller biopharmaceutical companies. Organisational cultures have also been shown to impact on knowledge transfer activities. For example, bureaucratic and risk adverse organisational cultures that emphasise rules and controls have been found to achieve less knowledge transfer (Mintzberg, 1979; Powell, 1996), whereas organisations that support risk-

taking by encouraging the exchange of new knowledge and ideas realise greater levels of knowledge transfer (Smith, Collins, & Clark, 2005; Weick & Westley, 1996).

Some authors have suggested that it is easier to transfer knowledge between some forms of organisation than others; however the results from work in this area are mixed. A number of studies claim that organisational size has a positive effect on the extent of knowledge transfer (Dhanaraj *et al*, 2004; Laursen & Salter, 2006); whilst other research has found non-significant (Tsang, 2002) or negative correlation between size and the extent of knowledge transfer (Makino & Delios, 1996). Similarly in relation to the older pharmaceutical companies and newer biopharmaceutical companies; no correlation has been found between the age of an organisation and its ability to transfer knowledge (Gray & Meister, 2004; Yli-Renko, Autio, & Sapienza, 2001). The mixed results from these studies tend to indicate that the degree of knowledge transfer will be dependent on other factors such as the type and nature of the industry.

The ability to successfully manage and use of any form of collaborative network to the organisation's advantage is considered to be a 'relational capability' (Dyer, Kale, & Singh, 2001). A strong relational capability is demonstrated in firms which have open search strategies and which search widely and deeply (Swan *et al*, 2007). It has however been demonstrated that this occurs only to a point beyond which additional search becomes counterproductive (Laursen & Salter, 2006). Organisational searches may be optimised to increase the diversity of sources which can stimulate new combinations of technology and knowledge (Nelson & Winter, 1982). Indeed it has been found that industries that require high levels of technological investment, such as the biopharmaceutical industry (Powell, Kogut, & Smith-Doerr, 1996), need to search more widely than those with less of a technological opportunity and often cut across professional and organisational boundaries in order to achieve this (Christensen, 2000). It has, however, also been suggested that whilst diverse knowledge may stimulate creativity, without sufficient synthesis and application diverse knowledge is likely to support only incremental rather than radical innovation (Laursen & Salter, 2006).

2.1.1 Knowledge transfer as a benefit to organisational learning

Organisational learning occurs when knowledge is transferred from a source to a recipient (Senge, 1990). Research in the field of organisational learning has been extensive and has considered processes through which knowledge is created (Argyris & Schon, 1996; Nonaka & Takeuchi, 1995), the management of knowledge (Davenport & Prusak, 1998), the development and implementation of solutions to organisational problems (Kamoche, 1997) and the value of know-how and experience (Kolb, 1976). This author follows the lead of a number of researchers and makes the assumption that the main objective of a technological company is to create valuable knowledge (Macher & Boerner, 2012; Nickerson & Zenger, 2004).

The creation of organisational knowledge in the pharmaceutical industry has been shown to be dependent on the exchange and combination of existing information, knowledge and ideas (Kogut & Zander, 1996; Sundgren *et al*, 2005). For knowledge sharing to occur it is generally accepted that two-way dialogue and articulation is important in order to make knowledge explicit and relevant (Hakanson, 2007). Implicit in this notion is the idea that individuals possess different types and levels of knowledge, and that they are able and willing to engage in communication in order to combine their knowledge and to learn from one another (Smith, Collins, & Clark, 2005). It has therefore been suggested that knowledge transfer should be considered to be a process of creation, not just an act of transmission and reception (Szulanski, 2000). Knowledge creation relies on socialisation and interaction, features that are prerequisites to 'mode 2' knowledge production, as opposed to the 'science push' characteristics of 'mode 1' (Gibbons *et al*, 1994).

Industries that rely heavily on experiential tasks, such as those in the science and engineering sectors, have demonstrated two beneficial forms of organisational learning, analogical learning and observational learning (Nadler, Thompson, & Van Boven, 2003). The use of analogies in a group within the pharmaceutical industry has been shown to be a stimulus to creative thought; Dunbar (1997) has called this process '*distributed reasoning*'. The use of analogy is beneficial to learning if the 'student' can understand a novel situation by using knowledge gained from a previous experience in a different situation and by identifying common relational structures (Pirolli & Anderson, 1985) (Ross & Kilbane, 1997). Observational learning works on the

principle that by watching another undertake a task, the 'student' is better prepared to undertake the task themselves as they gain access to tacit knowledge (Nadler, Thompson, & Van Boven, 2003). Tsoukas (2003) suggests that in order to achieve this, an individual shifts their awareness between the tools and the task, whilst reflecting on their experiences, theorising the circumstances and discussing them with others.

2.1.2 The influence of knowledge characteristics on its transfer

The forms of knowledge that reside in organisations may be categorised in the aggregate form as 'intellectual capital' (Youndt, Subramaniam, & Snell, 2004). Categories of intellectual capital include 'human capital', which is the knowledge and skills residing in individuals (Schultz, 1961); 'organisational capital' which is the codified knowledge held within the organisation in databases, patents, manuals, systems, processes, templates and SOPs (Youndt, Subramaniam, & Snell, 2004); and 'social capital' which is knowledge embedded in and available through individual networks (Nahapiet & Ghoshal, 1998). Social capital is of particular interest in the use of social networks and is used as a framework in this study.

Other organisational forms of knowledge include 'transactive knowledge', or 'who knows what', which is reported to be beneficial in the use of social networks, 'procedural knowledge' or 'know-how' which is closely related to knowledge that is found when implementing organisational routines, and 'declarative knowledge' which may be codified in organisational data (Moorman & Minor, 1998; Reagans, Argote, & Brooks, 2005). Research has emerged that considers the characteristics and context of knowledge and how these affect the ability to transfer it (Argote, McEvily, & Reagans, 2003; van Wijk, Jansen, & Lyles, 2008). Simple knowledge, for example, is easier to transfer and absorb than complex or ambiguous knowledge. Complex knowledge may be characterised by the number of interdependent technologies, routines, individuals and resources linked to a particular knowledge or asset (Simonin, 1999). Transferring knowledge between different firms (inter-firm) is also generally more difficult than transferring knowledge between sub-units (intra-firm) in the same organisation (Inkpen & Tsang, 2005).

Studies such as these have increasingly supported the notion that knowledge transfer is not just a task or act, but a process that can be inhibited by the level of 'stickiness.' Stickiness may occur as a result of the degree of intimacy between the source and recipient (Hansen, 1999), the

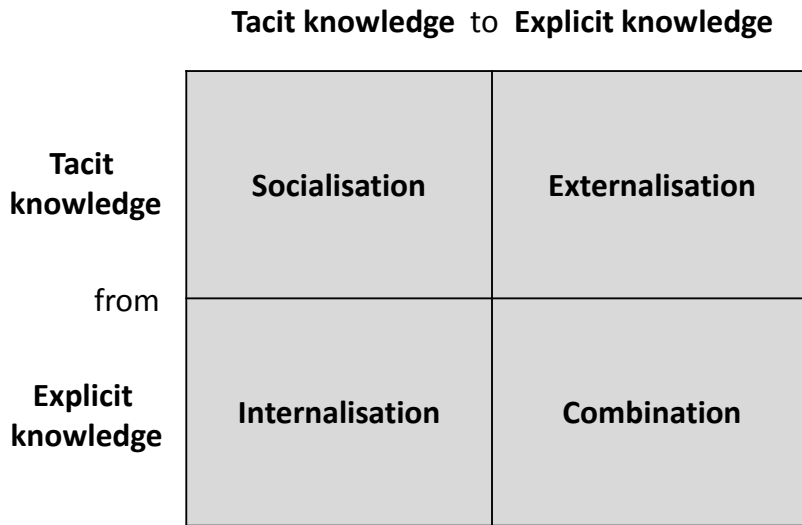
motivation and reliability of the source (Zander & Kogut, 1995) and the recipient (Hayes & Clark, 1985), the recipient's absorptive capacity (Cohen & Levinthal, 1990) and a willingness to learn (Argote, 1999). The major factor that influences the level of stickiness is most likely, however, to be the degree of tacitness of the transferred knowledge (Szulanski, 2000).

Knowledge tacitness is often considered to be a fundamental feature of knowledge based skills; if something is tacit then it is likely to be difficult to identify and transfer. Both explicit and tacit forms of knowledge may be considered to be graded along a continuum, with extreme forms of inaccessible tacit knowledge at one end and easily accessible, explicit knowledge at the other extreme (Gourlay, 2006; Nonaka & von Krogh, 2009). The explicit end of the spectrum has been likened to information, as it is so easy to transfer (Johnson, 2007). However, even the explicit knowledge end of the spectrum may be grounded in tacit knowledge as tacit knowledge is required in order to understand explicit knowledge (Hildreth & Kimble, 2002).

Knowledge does not necessarily have to remain in a static state but can be converted from one form to another, which may in turn facilitate the knowledge transfer process. The most difficult forms of knowledge conversion are from tacit to tacit and from tacit to explicit (Nonaka, 1991; Polanyi, 1966). It has been suggested that due to the difficulty in converting these forms of knowledge that conversion is best achieved by face-to-face interaction. However it has also been proposed that this may help the process, more from a perspective of building trust and a shared understanding, rather than merely facilitating the transfer of information (Johnson, 2004).

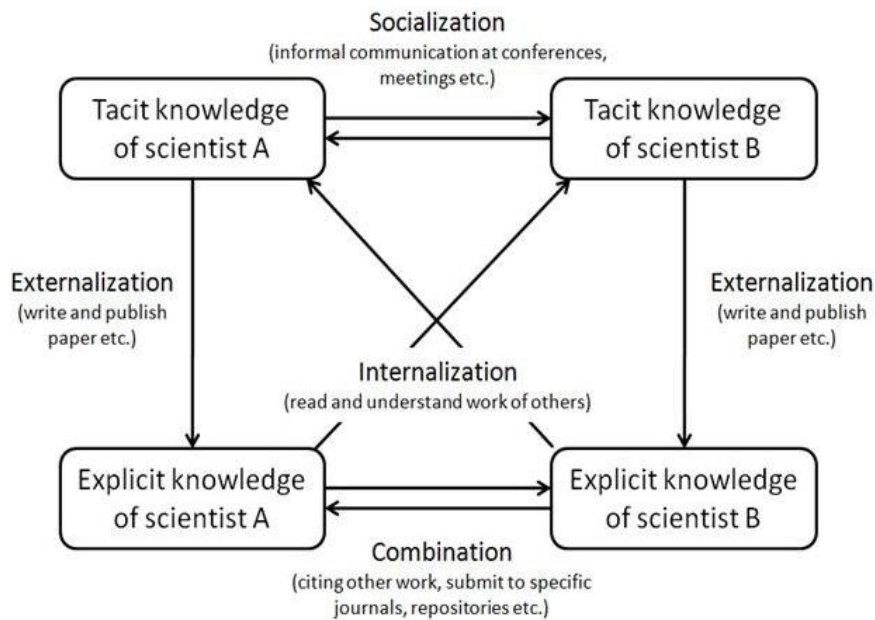
New knowledge is most effectively created when there is an inter-conversion between tacit and explicit knowledge (Hughes & O'Regan, 2009). This conversion has been demonstrated in a number of models (e.g. Choo, 1998), the most cited being the SECI model (Nonaka, 1994). The SECI model includes the concepts of socialisation (tacit to tacit), externalisation (tacit to explicit), combination (explicit to explicit) and internalisation (explicit to tacit). The conversion from tacit to explicit knowledge has been recognised by Nonaka as critical to the success of organisations (Nonaka, 1994). Nonaka's SECI model is illustrated in Figure 2.1

Figure 2.1 The SECI Model of knowledge conversion (Nonaka, 1994)



As a relevant example, the process of scientific knowledge creation and conversion has been mapped onto the SECI framework and is illustrated in Figure 2.2. For each of the two scientists (A and B) both tacit and explicit knowledge may be externalised through publishing, working together and socialisation (Bernius, 2010)

Figure 2.2 The process of scientific knowledge conversion (Bernius, 2010)



Whilst widely respected, Nonaka's framework has been criticised on a number of levels. Adler (1995), for example, is concerned with the static nature between the tacit and explicit forms of knowledge in what should be a dynamic matrix. Others have stressed the importance of the context of the 'work task' on each of the modes of knowledge transfer (Becerra-Fernandez & Sabherwal, 2001). The model has also attracted criticism as it presents a highly individualistic impression of knowledge and downplays the concepts of organisational, collective or social knowledge that are inherent in organisations (Spender, 1996).

Blackler (1995) takes a different approach in his knowledge framework which emphasises the collective view of knowledge (embedded knowledge), but highlights the level of explicitness as an additional factor (encoded knowledge). This model enables knowledge to be viewed differently in different types of organisations, for example the bureaucratic organisation where knowledge may be embedded in routines, and the knowledge intensive firm which might rely more on the individuals' (embrained) knowledge or the communication intensive form of organisational (encultured) knowledge.

2.2 Absorptive capacity

Absorptive capacity has been previously identified as a key concept in knowledge transfer. This section provides an introduction to the theoretical concept; the micro-foundations of external absorptive capacity is critically reviewed later in this chapter.

The concept of absorptive capacity has been built on theory relating to the economics of competition and innovation, the psychological perspectives of learning and managerial cognition and the resource perspectives of the knowledge based-view and dynamic capabilities (Volberda, Foss, & Lyles, 2010). An organisation's 'absorptive capacity' has been most commonly defined with reference to the original and seminal paper, as the "*ability to recognise the value of new information, assimilate it and apply it to commercial ends*" (Cohen & Levinthal, 1990, p. 128).

Absorptive capacity therefore represents an organisation's capacity to create new knowledge by addressing the competencies that are required for absorbing external ideas (Christensen, Olesen, & Kjaer, 2005). This may be achieved through the scanning of new knowledge by gatekeepers and boundary spanners (Volberda, 1996).

Managerial interventions such as investing in R&D (investing in absorptive capacity) will enhance an organisation's ability to understand and learn, and this has been demonstrated in the pharmaceutical industry (Cockburn & Henderson, 1998). It is suggested that an organisation's ability to absorb external information is most likely to be influenced by the path dependent and tacit nature of the firm's prior related knowledge (Puranam, Singh, & Chauduri, 2009). This enables the organisation to more accurately predict technological advances, such that they may be positioned to optimally exploit opportunities (Benson & Ziedonis, 2009) and to help them to appropriate knowledge spill-overs from external sources (Cohen & Levinthal, 1989). In support of this proposal, research has found that organisations with extensive prior social relationships and appropriability regimes are more effective at the identification and use of external knowledge (Torodova & Durisin, 2007)

Absorptive capacity works at the individual, group and organisational levels. Individuals are vital to the construct as they ensure that knowledge sharing and value recognition occurs, as well as providing the links between individuals within an organisation (intra-organisational), or between organisations (inter-organisational). The organisational level of absorptive capacity relates to the routines and artefacts which support a shared understanding at the individual level (Lane, Koka, & Pathak, 2006; Matusik & Heeley, 2005). The individual is critical to the organisational level of the construct, as it has its roots in the understanding of individual cognition, interaction and motivation (Cohen & Levinthal, 1990).

Individual (Lane, Koka, & Pathak, 2006) and managerial cognition (Eggers & Kaplan, 2009) have been recognised as a critical internal drivers of absorptive capacity. For example it has been hypothesised that the cognitive dimension of social capital contributes to potential absorptive capacity (Zahra & George, 2002) and mediates the influence of the relational aspects of social capital (Upadhyayula & Kumar, 2004). The micro-foundations of individual actions and motivations with regards to the absorptive capacity construct have been under researched to date (Volberda, Foss, & Lyles, 2010) and will be discussed later in the literature review.

2.2.1 Absorptive capacity and prior related knowledge

The importance of prior related knowledge (and knowledge overlap) as an aid to the transfer of knowledge is central to Cohen and Levinthal's early model (1990) and has rarely been challenged (for an exception see (Van den Bosch, Volberda, & De Boer, 1999)). Researchers disagree on how prior related knowledge is stored and retrieved but it has been proposed that from an organisational perspective it might include routines, and from an individual's perspective it may include stories, cultural norms etc. (Nonaka & von Krogh, 2009). There is however a limited understanding at the level of the individual and how they use prior knowledge to absorb knowledge from external sources (Scildt, Keil & Maula, 2012; Volberda, Foss, & Lyles, 2010).

Lane and Lubatkin have investigated learning dyads between the pharmaceutical industry and biotechnology companies. Their research suggests that scientists with similar training, backgrounds and basic scientific knowledge are better able to learn from each other and propose that the dyadic relationship may be one of 'teacher and student' (Lane & Lubatkin, 1998). They have found support for the idea that the absorptive capacity of a 'student firm' will depend on the nature of the knowledge, the similarity of the teacher and student firm's structure and processes. It has also been suggested that the similarity of organisational problems may aid knowledge transfer by providing knowledge overlap (Van den Bosch, Volberda, & De Boer, 1999).

2.2.2 Models of absorptive capacity

Early research indicates that absorptive capacity consists of three distinct dimensions, acquisition, assimilation and exploitation (Cohen & Levinthal, 1990). The acquisition stage refers to the process of obtaining of new knowledge, assimilation to the combination with existing organisational knowledge, and exploitation refers to the use of the new knowledge for the benefit of the organisation.

Lane *et al* (2001) have also based their model on three absorptive capacity dimensions but use the terminology of recognition, assimilation and utilisation. Analysis of these dimensions indicates that recognition and assimilation impact on knowledge transfer, whilst the utilisation process positively correlates to a firm's performance. Zahra and George (2002) extended Cohen

and Levinthal's (1990) three stage absorptive capacity model by adding a transformation stage after the assimilation stage and by putting a dynamic capabilities slant on the framework. This was achieved by introducing the separate concepts of 'potential' (acquisition and assimilation) and 'realised' (transformation and exploitation) forms of absorptive capacity (Zahra & George, 2002). It is suggested that both the potential and realised forms of absorptive capacity require relational structures and knowledge sharing routines to support the evaluation, acquisition, assimilation, transformation and exploitation of knowledge (Doz, 1996; Schildt, Keil & Maula, 2012).

However Torodova and Durisin (2007) propose a return to Cohen and Levinthal's model (1990) as they claim that Zahra and George's model is missing some key implications. In particular they re-instate the 'recognising the value' stage in the process, in line with research on the 'attention-based view' of the organisation (Occasio, 1997) and research into learning and innovation in dynamic environments (Henderson & Clark, 1990). The importance of 'recognising the value' of new knowledge is the focus of the third research question in this study and will be critically reviewed later in the literature review.

In their recent review of absorptive capacity Volberda, Foss and Lyles (2010) summarised the antecedents, process dimensions, contextual factors and outcomes of absorptive capacity in an integrated framework. Those that are related to external knowledge transfer include the use of informal social networks, knowledge characteristics and cognitive factors such as knowledge overlap and prior related knowledge. These topics are considered throughout the literature review.

2.3 The use of social networks

The concept of networks of actors working in virtual and informal collaboration has been around for many years; perhaps most prominently building on the work of Kuhn (1962) and Crane (1969). Crane recognised the importance of *invisible colleges* in bringing together less well published scientists with scientists that published to a greater extent; this was found to provide benefits which included short-cuts to relevant information (Crane, 1969). Becher (1989) also contributed to this field by coining the term *academic tribes* in order to describe ‘territories’ within academic disciplines. It was argued that these territories extended into other areas of professional and personal life and influenced whether researchers operated alone or in large groups (Becher & Trowler, 2001).

Other research in this area has focussed on social interaction and organisational learning in the form of *communities of practice* (CoP) (Brown & Duguid, 2001; Lave & Wenger, 1991). The CoP approach emphasises the practical application of work as a means to share knowledge between community members which by definition share a common identity (Gertner, Roberts & Charles, 2011). Wenger (1998, pp. 72-84) considered that coherence was maintained in a CoP by the establishment of a common norms, having a joint purpose and by negotiation of meaning through practice.

Whilst these concepts are still widely cited they have arguably been subsumed into the wider research portfolio of social network research. A social network is a human structure which consists of actors connected by dyadic relationships (Wasserman & Faust, 1994, p.20). Possibly in response to popular websites dedicated to social networking, more current definitions have emphasised the informal, ad-hoc basis of social networks. Social networks have more recently been defined as self-organising and ‘actor-oriented’ collaborations, with limited or no hierarchical structure (Fjeldstad *et al*, 2012).

When studying social networks, researchers commonly link knowledge transfer to organisational performance (Adler & Kwon, 2002; Cummings, 2004; Wu, 2008; Yli-Renko, Autio, & Sapienza, 2001); and to social capital (Flap & Boxman, 2001; Inkpen & Tsang, 2005; Nahapiet & Ghoshal, 1998). The extant research generally recognises that the degree of social integration will

influence an actor's ability to obtain social information and to seek technical knowledge (Xu, Kim, Kankanhalli, 2011).

The concept of social capital provides a useful means to integrate the factors and dimensions of the multi-faceted information seeking and knowledge transfer processes. It can do so by providing a model for the study of social structures (Burt, 1997), the relationships between individuals (Kallio, Harmaakorpi, & Pihkala, 2010) and information seeking behaviour (Johnson, 2004).

2.3.1 The concept of social capital

Since the early 1980s social capital has been considered by many researchers to be a resource that is located in relationships between individuals that is used to their own advantage (Gabbay & Leenders, 1999; Maurer & Ebers, 2006). As Burt (1992) recognises, depending on their social connections actors can extract value, often in the form of learning, from their relationships. Adler and Kwon (2002, p.17) suggest that social capital may simply be the '*goodwill [that is] available to individuals or groups.*' However perhaps the most commonly cited definition of social capital is that of Nahapiet & Ghoshal (1998, p. 243) who built on Bourdieu and Wacquant's (1992) definition and consider social capital to be: '*The sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit.*'

Social capital has been studied at a number of levels including that of the individual (Burt, 1997; Coleman, 2000) the group (Burt, Hogarth, & Michaud, 2000) the organisation (Baker, 1990; Pennings & Lee, 1999) and at the inter-organisational level (Chung, Singh, & Lee, 2000; Inkpen & Tsang, 2005). Following the work of Tsai and Ghoshal (1998) and Maurer and Ebers (2006), this study will investigate knowledge transfer from an individual or micro perspective, on the basis that a firm's social capital most likely represents an aggregate of an individual's social capital (Bourdieu, 1985).

Authors have characterised the constituent parts of social capital in different ways. For example, Koka and Prescott (2002) have proposed three different dimensions; information diversity (technological, country and holes); information volume (centrality, number of partners and ties)

and information richness (multiple and repeated ties). This suggests that each dimension of social capital provides a different information benefit. Empirical research has, in large part supported Nahapiet and Ghoshal's (1998) proposal that social capital consists of three constituent components which are listed below.

1. **The structural dimension** which provides the physical social network for knowledge transfer to occur. Characteristics of the structural dimension include size, age and degree of decentralisation (Tsang, 2002) and the configuration of the network which is defined by measures such network density, hierarchy and connectivity (Andrews, 2010; Fleming, Mingo, & Chen, 2007; Smith, Collins, & Clark, 2005)
2. **The relational dimension** which refers to the inter-personal activities of the individual actors and their ability to develop and maintain social networks. Characteristics of relationships include the norms of trust and obligation, power and dependency (Zheng, 2008)
3. **The cognitive dimension** which provides the mental capacity for knowledge transfer and refers to shared meanings and the interpretation and understanding of knowledge (Ibarra, Kilduff, & Tsai, 2005; Nahapiet & Ghoshal, 1998).

Whilst recognising that there is significant debate over the circular and 'tautomeric' nature of social capital research, and the 'elastic' constituent components of social capital (Chen, Chang, & Hung, 2008; Lappe & DuBois, 1997; Sobel, 2002), social capital does at least provide a useful framework to categorise the influences on the use of social networks for knowledge transfer (Dasgupta, 1999). The three dimensions of social capital that were proposed by Nahapiet and Ghoshal's (1998) are now considered in turn.

2.3.2 The structural dimension

Burt (2000, p. 32) has stated '*that people who do better are somehow better connected,*' illustrating the concept that individuals with a large number of quality ties accrue positive benefits for themselves and their organisation. Technical embeddedness has also been found to have a positive effect on organisational performance and the development of products (Andersson, Forsgren, & Holm, 2002). The density and complexity of collaborations in the biopharmaceutical sector has also been directly related to the broad range of technologies that the

industry relies upon (Owen-Smith *et al*, 2002). Other characteristics of the structural dimension of social capital and social networks include the centrality in a network, the strength of ties, the redundancy of knowledge in the network and the boundary spanning activities between networks.

2.3.2.1 The centrality and the degree of embeddedness in a network

The degree of embeddedness in a network describes the level of overlap between work-related transactions and social relations (Granovetter, 1973). A high degree of embeddedness has been shown to increase organisational survival, organisational learning and the speed at which new products are brought to market (Fleming, Mingo, & Chen, 2007; Gulati, Nohria, & Zaheer, 2000). Although it has been recognised that there is a danger of over embedding which can lead to inertia and a reduction in opportunities (Uzzi, 1997).

An actor is often embedded in social networks which comprise existing personal and professional contacts which are drawn from an individual's experience. These are used as and when they are required, a characteristic that has been called 'network bricolage' (Baker, 1990; Levi-Strauss, 1966). Different network positions represent different opportunities to access new knowledge; the more central the position the more likely the organisation will have access to appropriate knowledge resources (Tsai, 2001). Network centrality and cooperation experience have been positively associated with growth in young biotechnology firms and is thought to be an important factor in their development (Powell, 1996).

There are well established information benefits in being central to a large number of direct ties. (Putnam, 1993). Granovetter (1973) has suggested that these information benefits occur in three forms; 'access' where networks provide an efficient information screening system; 'timing' which refers to personal contacts providing information quicker than those who do not have such contacts; and 'referrals' which include recommendations and reputational endorsement, thereby influencing both the motivation and the anticipated value for an exchange. These features are all crucial to the use of social networks when seeking information. It has however been shown that being central to a network does not always result in higher organisational performance; it would seem that there is a cost associated with maintaining coordination benefits (Tsai, 2001).

Adler and Kwon (2002) claim that there are three potential flaws in social capital which may occur when an organisation is over-embedded. Over investing in specific relationships at the detriment of other relationships, strong localised ties which may restrict outlooks due to the formation of cliques, and finally the inhibition of the free flow of information or ideas by the nature of solidarity. These may all impact the knowledge transfer capability of the firm. The degree of embeddedness is also likely to evolve as an organisation grows. Business start-ups may benefit from strong ties in the early stages of their formation but in later stages they may become over-embedded which can inhibit the sensing of opportunities at later stages of organisational development (Gargiulo & Benassi, 1999; Maurer & Ebers, 2006).

2.3.2.2 The strength of ties and redundancy of knowledge

Research has shown that people are more likely to have strong social ties with people that are similar to themselves, in particular with regard to gender, race, education and age (Brass, 1995; Ibarra, 1995). Granovetter (1973) proposed the 'strength of ties' concept, which he claims influences an organisation's ability to transfer knowledge. He classified strong ties as being regular connections in dense networks and weak ties being more ad-hoc, infrequent and informal forms of communication. Strong ties tend to link people who have access to the same resources and are part of the same social strata (McPherson, Smith-Lovin, & Cook, 2001).

Dissimilar knowledge sets may provide useful 'non-redundant' knowledge which is a critical factor in problem solving networks (Chang & Harrington, 2007). There has however been some debate over the best source of this non-redundant knowledge. Researchers have found that strong ties are less likely to contain novel information when compared to weak ties (Moran, 2005; Perry-Smith, 2006). So when seeking new resources, actors need to use weak ties that possess different resources to their own (Johnson, 2004). Although other researchers have argued that strong ties aid the transfer of complex and tacit knowledge, even if they do constrain the search for novelty (Hansen, 1999; Obstfeld, 2005).

Burt (1992) has further developed the brokerage argument by emphasising the importance of sparse network structures and the disconnectedness of actors, by proposing the 'structural holes' theory. This theory proposes that firms or individuals that are embedded in sparse networks (rich in structural holes) and with few redundant contacts, often occupy a brokerage positions that are

well positioned to create new combinations from novel knowledge. In order to combine the knowledge transfer advantages of both forms of alliance structure, Capaldo (2007) proposes a dual network which comprises of both dense and sparse networks. This ‘organisational ambidexterity’ is claimed to aid both the exploration and the exploitation of new innovations by mobilising differing coordination and integration activities.

2.3.2.3 Boundary spanning between networks

Research into the transfer of knowledge in social networks has recognised that ‘gatekeepers’ and ‘boundary spanners’ can act as mediators between disparate clusters or networks by acting as an interface between the organisation and the external source (Allen & Cohen, 1969; Tushman, 1977). Gatekeepers have the ability to bridge contextual differences between actors (Cohen & Levinthal, 1990), by providing technological and business insights (Allen, Tushman & Lee, (1979). They may also provide a level of defence from information overload and therefore play an important role as information filters and uncertainty absorbers (Aldrich, 1979). Gatekeepers are often established figures in the organisation; whilst they may not have formal recognition of their position and authority, they are often in the best position to identify a new practice and champion it internally (Lewin, Massini, & Peeters, 2011).

It has been suggested by Hamel, Doz & Prahalad (1989) that organisational measures should be in place to restrict informal boundary spanning activities due to the possible loss of confidential information. However Bouty (2000) counters this by arguing that trying to stop ‘out-going’ information will inevitably inhibit the reciprocal nature of information exchange and thereby reduce the volume of incoming information. As has been previously discussed, the potential loss of intellectual property is a major concern to the biopharmaceutical industry and is likely to act as an inhibitor to knowledge transfer and therefore innovation.

2.3.3 The relational dimension

The structural dimension of social networks has been established as a key factor in providing access to novel sources of information. However these network structures exist only through the actions of individual actors and the relationships that they develop. The relational dimension of social capital is therefore an important antecedent to the development and use of social networks. There are a number of factors that define whether relationships will be developed and how well they function as vehicles for knowledge transfer. These may be summarised as identifying with a social group, the influence of power and trust in relationships and the importance of obligation in the management of relationships and will be reviewed in the following sections.

2.3.3.1 Identifying with a social group

Relationships develop between actors that have something in common, which results in networks of contacts which may belong to a single social group. Becoming a member of a social group becomes viable when the group represents the real or subjective features that are important to the individual and can bring a sense of self-worth and an understanding of their place in their social world (Hinds & Mortensen, 2005). Indeed groups that have valuable tangible or intangible resources are generally considered to be a source of positive social identity when compared to those that do not (Tajfel & Turner, 1979).

The common group identity theory (Gaertner & Dovidio, 2000) recognises the benefits of belonging to a superordinate group, which may be an organisational department, business unit, organisation or a more informal social group such as previous work colleagues. Benefits of belonging to a group include, resolving conflicts (Hinds & Mortensen, 2005), helping others to complete tasks (Dovidio *et al*, 1997) and sharing knowledge (He & Wei, 2009). ‘In-group’ members are more likely to be rated as trustworthy, valuable, honest and loyal (Hewstone, Rubin, & Willis, 2002). This does not mean however that knowledge obtained from a source would be relied upon to the exclusion of the value characteristics of the knowledge, but that it is more likely to encourage knowledge transfer (Foreman, Ghose, & Wiesenfield, 2008).

The sense of belonging to a superordinate group appears to function in a manner that is similar to that found when working in a team. Teams that have worked together for some time commonly

develop shared mental models, which act as ‘transactive memory systems’ for encoding, storing and sharing group knowledge (Lewis, Lange, & Gillis, 2005). Recent research has identified that knowledge diversity negatively impacts on shared mental models; but this may be moderated by the establishment of explicit roles which serve to establish communication norms and reduce negative relationships (Paletz & Schunn, 2010). This is particularly important when ‘power asymmetry’ puts a strain on the relationship (Easterby-Smith, Lyles, & Tsang, 2008).

2.3.3.2 Power and trust in relationships

Szulanski suggests that one of the most critical barriers to transfer of information within organisations is the existence of arduous relationships between individuals (Szulanski, 1996). Power asymmetry occurs when the dominance of the donor and the relative dependency of the recipient puts the donor in a superior negotiating position (Diestre & Rajagopalan, 2012; Easterby-Smith, Lyles, & Tsang, 2008). Authors have proposed that difficult relationships such as those created by power asymmetry may be offset by trust, the recognition of norms, obligation and identification with the other party (Nahapiet & Ghoshal, 1998). Power asymmetry may explain why some organisations are better able to exploit new knowledge through the manipulation of the resource allocation process (Dougherty & Hardy, 1996; Lawrence *et al*, 2005). Power relationships external to the organisation may also influence the exploitation of new knowledge as demonstrated with relationships with customers (Daneels, 2003), suppliers, alliance partners and other external stakeholders (Hill & Rothaermel, 2003).

Trust is one means through which power may be moderated and is one of the most frequently cited variables that are used to support the relational dimension of social capital (Wu, 2008). Although, some authors consider that trust and social capital are commensurate with each other; and that trust may occur as a result of social capital rather than be an integral component of it (Dibben, 2000; Zheng, 2008).

Trust may function as a form of relational governance which constrains against ‘free-riding’ and the likelihood of knowledge spill-overs (Yli-Renko, Autio, & Sapienza, 2001). It is believed to lower transaction costs, settle disputes, open communication, collaboration and knowledge sharing (Brelade & Harman, 2000; Dakhli & De Clercq, 2004) and to foster creativity (Subramaniam & Youndt, 2005). McEvily, Perrone, & Zaheer (2003) argued that trust

encourages knowledge sharing by increasing the disclosure of knowledge by others by being open with one's own knowledge; and has been described as a belief that the "*results of somebody's intended action will be appropriate from our point of view*" (Misztal, 1996, p.9)

Trust may be created through rational choice based on information regarding the credibility and competence of the relational partner (Dakhli & De Clercq, 2004; Simons & Peterson, 2000; West & Anderson, 1996). It may also be developed through a belief in good intentions, openness and reliability, and is developed over time and through a history of interaction (Bolino, Turnley, & Bloodgood, 2002; Moran, 2005; Nahapiet & Ghoshal, 1998). Inter-organisational trust provides a sense of security, knowing that knowledge gained through a relationship will not be exploited beyond what has been tacitly or explicitly agreed (Dhanaraj *et al*, 2004). Without it the donor may perceive a risk of leakage or unintended knowledge transfer which could negatively affect their competitive position (Norman, 2002); an important consideration when considering the potential loss of intellectual property.

There are a number of classes of trust in organisational relationships. Lewis and Weigert (1985) defined two forms of trust which are created from a relational perspective. These are based on 'cognitive decisions' which are supported by evidence, and 'affect based' trust which is founded on the emotional bonds between people. Rousseau *et al* (1998) have developed a model of three types of trust, 'deterrence based trust' which is concerned with possible sanctions if trust is breached, 'calculus based trust' which is based on rational considerations of benefits of economic exchange and 'relation-based trust' which is grounded in previous experience and positive emotions. Most models of trust emphasise the cognitive, emotional and economic dimensions of trust in relationships. The deterrent and economic dimensions of trust are related to the contractual obligations that are enforced in the case of intellectual property misuse.

There is a significant body of work that demonstrates the importance of trust in problem solving, knowledge transfer and innovation activities. For example it has been found that actors are more flexible in their thinking and more creative in their joint problem solving when there was more trust and less hostility in the relationship (Carnevale & Probst, 1998; Uzzi, 1997). It has also been suggested that trust plays a key role in the transfer of tacit knowledge (Levin, Cross, & Abrams, 2002) and is likely therefore be an important factor in this study.

2.3.3.3 Norms and obligation in relationships

Relationships are governed by social and cultural norms. Coleman (1990) proposed that norms exist when the right to control an action is determined by the group rather than the individual. Norms of co-operation can be an organisational benefit which establishes a strong foundation for the creation of intellectual capital (Kramer & Goldman, 1995; Smith, Collins, & Clark, 2005).

Organisational norms may be in the form of a shared goal, which if channelled appropriately can increase collaboration, promote mutual understanding, facilitate knowledge transfer and stimulate idea generation (Kratzer, Leenders, & van Engelen, 2006; Garcia-Morales, Moreno, & Llorens-Montes, 2006). Research has identified that a culture of open disclosure of information, openness to criticism and a tolerance of failure are important precedents to successful knowledge intensive firms (Starbuck, 1992). However, not all norms that promote knowledge sharing are positive as they may lead to ‘groupthink’ (Janis, 1982) which in time may become a pathological rigidity (Leonard-Barton, 1995). Researchers are still debating whether norms generate trust or trust generates norms (Zheng, 2008); however, this ‘chicken and egg’ situation does not detract from the influence of cultural and social norms on knowledge transfer.

Obligations may be distinguished from norms, as obligations are “*an act or course of action to which a person is morally or legally bound; a duty or commitment*” (Anon, 2011). Obligations may also be recognised as a reflection of the commonly held view that exchange often brings an element of future commitment. This commitment may not be explicitly stated but may be assumed through the social or cultural norms that govern the relationship. Fairclough (1994) further distinguished between formal, professional and personal obligations where the personal obligation was often perceived as more important and went beyond the contractual obligation; thus reinforcing the personal commitment to the relationship.

2.3.4 The cognitive dimension

Relationships may provide the ‘glue’ which ‘cements’ the structure of the social network, but the actor’s cognitive abilities, which is represented by the third dimension of social capital, enable the transfer of knowledge (Hansen, 1999) (Uzzi, 1997). According to Hazelton and Kennan (2000) there are four communication functions aligned with the cognitive attributes of social capital, namely information exchange, problem solving, behaviour regulation and conflict management. Whichever form of communication is undertaken, social exchange requires at least some sharing of context between the partners (Boisot, 1995; Boland & Tenkasi, 1995). The influence of a shared language and ‘knowledge structures’ and the degree of knowledge overlap, have been attributed to influencing understanding in the knowledge transfer process. These factors will be considered in the following sections.

2.3.4.1 Shared language and knowledge structures

It has been recognised that language influences the perception of our environment through perceptual categories which filter awareness according to experience (Pondy & Mitroff, 1979), and this may influence an actor’s ability to search or identify new information within their social network. The extent that a shared language exists will also influence the ease and ability to communicate; for example where there is limited commonality of language, this is likely to restrict access to information and knowledge. The term ‘combination capability’ was coined by Nonaka and Takeuchi (1995) to describe this effect.

The concept of knowledge structures are central to information processing and represent knowledge that is organised around a factor or a stimulus (Fiske & Taylor, 1984, p. 149). A knowledge structure is an individual’s ‘mental template’ that is created to provide form and meaning to the information environment, and are thought to simplify complex worlds and screen out irrelevance (Fiske & Taylor, 1991; Starbuck & Milliken, 1988). There are liabilities to such structures however, and these include the possibility of stereotypic thinking, ignoring discrepant information, disconfirmation of existing knowledge structures and inhibiting creative problem solving (Gioia, 1986). As stated by Starbuck and Milliken (1988, p. 40) “*one thing an intelligent executive does not need is totally accurate perception*”. They argue that an executive requires a perceptual filter which amplifies relevant information and attenuates irrelevant information, or as

Walsh (1995) claims, they need to discover the benefits of simplicity. Mental templates will later be considered in connection with information seeking behaviour.

Once information is presented, an understanding needs to occur before successful knowledge transfer is achieved. The term 'sense-making' has been widely used to describe this process as it enables an actor to filter and to form an impression of the subject into something that is more tangible (Weick, 1995). Sense-making is therefore an important means by which to assist comprehension and provide an understanding through the interaction with others (Balogun & Johnson, 2004; Brown, 2000).

2.3.4.2 Knowledge overlap

Knowledge overlap between the transmitter (source) and receiver (seeker) is a key antecedent in knowledge transfer. Theory on organisational learning suggests that a small 'cognitive distance' is beneficial for learning and innovation. Cognitive distance is a term that describes the degree of overlap between two actors' cognitive structures and is a measure of cognitive diversity (Oliver & Montgomery, 2008). It is suggested that learning and creativity may be optimised if there is a complete overlap of mental models because under these conditions communication and understanding becomes easier (Banks & Millward, 2000). Conversely a large cognitive distance has been identified as a hurdle for achieving solidarity in an emerging group as it can lead to communication problems and mis-understanding (Oliver & Montgomery, 2008). An important aim of organisations is therefore to reduce cognitive distance in order to enable the transfer of knowledge and the achievement of goals (Gilsing & Nooteboom, 2005).

However, research into the performance of teams suggests that a small cognitive distance is not always beneficial as it might lead to a duplication of knowledge and a reduction in communication (Rahe, 2009). Other studies suggest that optimal team performance occurs when mental models are different but connected in such a way that knowledge is still able to flow and overlap in some areas (Banks & Millward, 2000). This finding is in accordance with research into diverse groups which are usually found to be more creative than homogenous groups. Despite the wider cognitive distance between the members, it would appear that they are capable of forming a wider and more complex knowledge base if they can form a common understanding (Harrison & Klein, 2007). This relatively small overlap of knowledge provides enough of an

understanding of a project's aims whilst each actor recognises, interprets and applies knowledge in their unique way.

A related area of research into cognitive distance is 'cognitive friction,' where diverse actors, by background, education and culture, have a common understanding through similarities in knowledge base, task, project or other organisational aim (Hautala, 2011). It is suggested that cognitive friction can be a source of creative innovation in organisations.

2.3.5 Building social capital in organisations

It has been recognised that social capital rather than technology is a significant driver of knowledge transfer in organisations (Huysman & DeWit, 2002). It is also suggested that social capital may be managed within an organisation through its knowledge systems; although how this may best be achieved is a topic of much debate. Nahapiet and Ghoshal (1998) have suggested that the micro-foundations of organisational routines is an important factor in the development of social capital. Hence, the application of the three dimensions of social capital to organisational practice might provide a framework to assess potential collaborations (Davenport *et al*, 2003). One attempt at this is illustrated in Table 2.1 which employs the terms, 'competence', 'confidence' and 'compatibility' as organisational characteristics which may be related to the theoretical dimensions of social capital.

It is suggested by the authors, that an applied version of Table 2.1 may be used to support social capital in organisational networks and, in particular, when assessing early stage relationships for their degree of competence and compatibility (Davenport *et al*, 2003). Whilst this may not prove to be practicable, it does at least provide an insight into the possible management and development of social capital as a means of knowledge transfer.

Table 2.1 Social capital terminology and the analogous terminology for an organisation

Nahapiet and Ghoshal's (1998) terminology	Organisational terminology
<p>Structural dimension</p> <ul style="list-style-type: none"> • Network ties • Development of networks 	<p>Competence</p> <ul style="list-style-type: none"> • Track record/history • Endorsements • Reputation
<p>Relational dimension</p> <ul style="list-style-type: none"> • Trust • Norms • Obligations 	<p>Confidence</p> <ul style="list-style-type: none"> • Motivation • Responsiveness • Reliability • Tolerance
<p>Cognitive dimension</p> <ul style="list-style-type: none"> • Shared codes and languages • Shared narratives • Knowledge overlap 	<p>Compatibility</p> <ul style="list-style-type: none"> • Shared practices • Shared techniques and tools • Shared protocols

Having considered how the characteristics of knowledge and how the three dimensions of social capital may influence knowledge transfer, the literature review now turns its attention to organisational routines which underpin the theory that is related to all three research questions. This section of the literature review starts by critically reviewing the background literature on organisational routines; followed by the use of templates in knowledge transfer which is the subject of the second research question.

2.4 The micro-foundations of external knowledge transfer routines (research question 2)

Organisations can differentiate themselves through the routines that they use and may therefore be considered to be a source of innovation and competitive advantage (Barney, 1991) (Nelson & Winter, 1982). Routines are considered to play an important role in the building of uniqueness as they channel the behaviours, objectives and actions of the organisation towards specific goals, and enable the capture and sharing of organisational knowledge (Levitt & March, 1988) (McGrath & Argote, 2001). They achieve this by serving as a template or heuristic which provides a guide to how the process should be conducted (Becker, 2004; Witt, 2011). It is for these reasons that organisational routines are considered to be an important form of dynamic capability, as they have been shown to influence organisational learning, flexibility, adaptation to external forces and most importantly for this study, the transfer of knowledge between organisations (Dosi, Nelson, & Winter, 2000; Rerup & Feldman, 2011).

Within organisations, routines have been shown to simplify and speed up repetitive tasks and decision making (Gavetti, Levinthal, & Ocasio, 2007). This optimises collective mental effort (Hansen & Vogel, 2010; Simon, 1947, p. 100) and preserves an actor's information processing and decision making capabilities (Backer & Knudsen, 2005; Baumol, 2002). The micro-foundations of organisational routines constitute the small steps that an individual takes in order to fulfil a routine. This emphasis on the individual provides an indispensable causal role of how routines and capabilities originate (Felin & Foss, 2005).

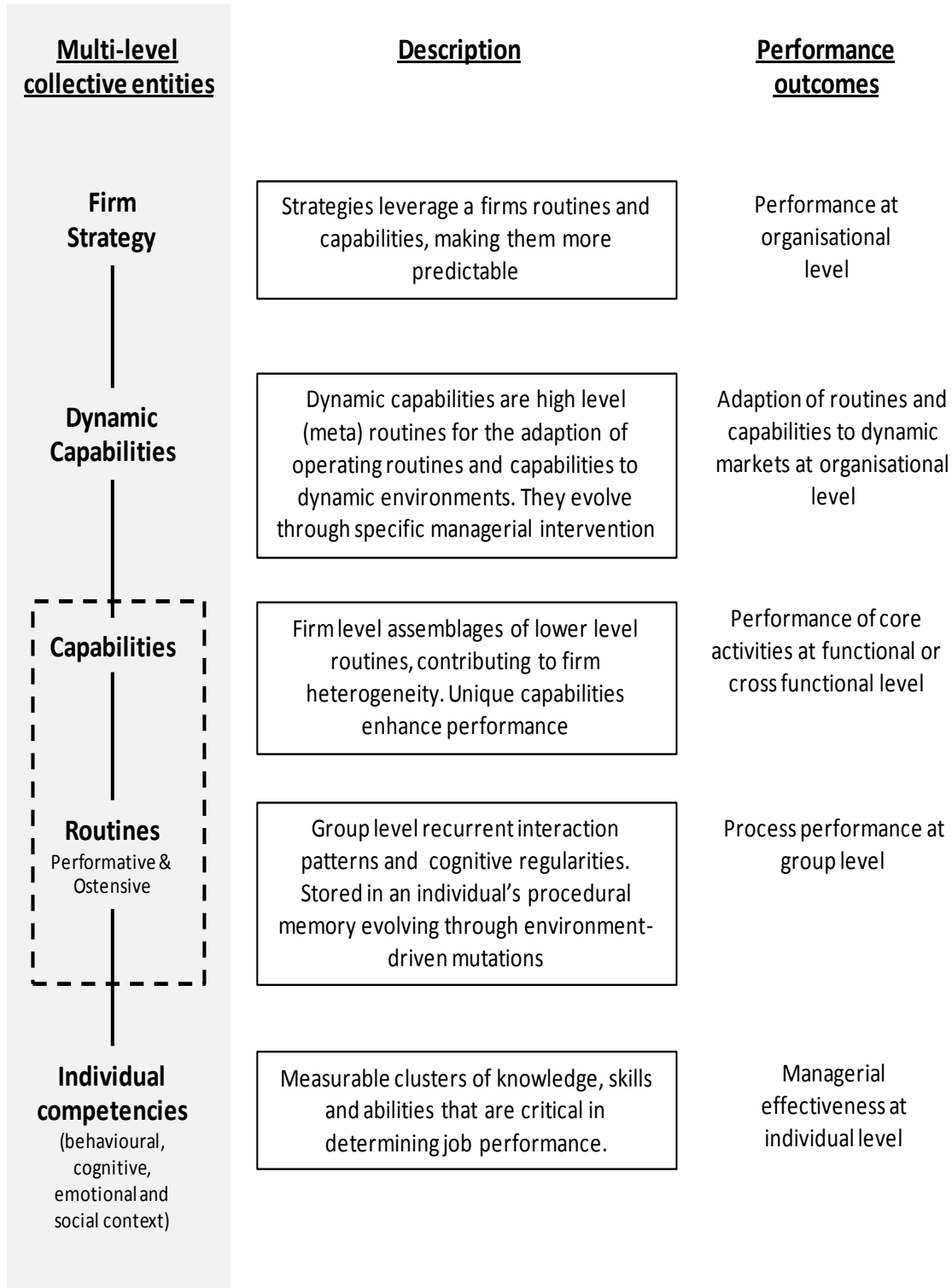
Routines have been variously described as '*ways of doing things*' (Winter, 1986, p. 165); '*ordered sets of actions*' (Pentland & Reuter, 1994) and as '*one ontological layer above habits*' (Hodgson, 2008, p. 18). A broader definition that has most recently been adopted by researchers studying organisational routines is '*a repetitive, recognizable pattern of interdependent actions, involving multiple actors*' (Feldman & Pentland, 2003, p. 96). This definition provides researchers the flexibility to focus on the dynamic nature of interactions between multiple actors, rather than just the specific patterns in routines (Howard-Grenville, 2005); a factor that is important in this study.

The influential nature of organisational routines has resulted in them being considered as the central unit of analysis of management research (Becker, 2007). It is therefore not surprising that the concept of routines has been applied to a wide number of research areas including resources (Amit & Schoemaker, 1993; Barney, 1991); organisational behaviour (Argote & Greve, 2007; Cyert & March, 1963); problem solving (March & Simon, 1958); knowledge management and information seeking (Argote & Darr, 2000; Campbell & Gingrich, 1986; Nonaka & Takeuchi, 1995); dynamic capabilities (Eisenhardt & Martin, 2000); evolutionary economics (Nelson & Winter, 1982); organisational learning (Argyris & Schon, 1978; Levinthal & March, 1993; Zollo & Winter, 2002); organisational memory (Walsh & Ungston, 1991) and innovation and change (Gavetti & Levinthal, 2000; Leonard-Barton, 1992; Tushman & Anderson, 1986). This vast body of research demonstrates that few routines operate independently and often overlap with other routines in other areas of the organisation (Naduzzo, Rocco, & Warglien, 2000). This complexity creates methodological hurdles for the isolation and evaluation of routines.

An additional form of complexity for the researcher is the profusion of converging terms relating to routines, capabilities and competencies. In order to position organisational routines with capabilities and competencies, a typology of routines and capabilities has been proposed by Salvato and Rerup (2011, p. 471) and is illustrated in Figure 2.3.

Using Salvato and Rerup's terminology, an organisational capability may be described as '*an ability to realise a routine*' (Abel, Felin, & Foss, 2008, p. 500) and these typically function as a collection of routines characterised by a firm-level purpose (Dosi, Nelson, & Winter, 2000). This level of capability can create, enhance or modify lower order capabilities and act as 'meta-routines'. This study is focussed at the routines and individual competencies level of Salvato and Rerup's (2011) hierarchy, otherwise recognised as the micro-foundational level, but the findings will contribute to the understanding of meta-routines at the capability level.

Figure 2.3 Routines and capabilities (Salvato & Rerup, 2011, p. 471)



2.4.1 Organisational routines and their characteristics

Routines consist of rules, heuristics and norms that are operationalised throughout the organisation, and these vary from simple rules such as local problemistic search (Cyert & March, 1963) to higher meta-routines that moderate changes in lower routines (Lewin, Massini, & Peeters, 2011). Heuristics are ‘rules of thumb’ which are used to form judgements, make decisions and to solve problems (Bingham & Halebian, 2012; Kahneman, Tversky, & Slovic, 1982). Meta-routines include problem solving procedures which can improve existing routines or create new ones (Adler, Goldoftas, & Levine, 1999) and through information seeking behaviour influence knowledge validation and creation (Ghosh & Sobek II, 2012). Well documented rational examples of problem solving meta-routines include the ‘plan-do-check-act’ wheel (Deming, 1986) and the ‘define-measure-analyse-improve-and-control’ cycle that are used in the Total Quality Management and Six Sigma philosophies.

Organisational routines may be interpreted in two different but complementary ways. Through the behavioural regularities in the analytic process that is to be followed, or by the cognitive regularities which refer to abstract patterns or understandings that are adopted as a guide when following the routine (Cyert & March, 1963). Feldman and Pentland also visualise routines in two dimensions, referring to the ‘ostensive’, which is the idealised or schematic narrative routine, and the ‘performative’ action based or enacted routine (Feldman & Pentland, 2003; Pentland & Feldman, 2008). The ostensive part of a routine shapes the actor’s perspective of what the routine is and may exist as a codified or ‘tacitly implied norm’ (Cohen & Bacdayan, 1994). The ostensive component is a creative resource that allows actors to build their understanding, guide and describe their actions, and to recognise and organise diverse parts of the performance as a complete routine (Pentland & Feldman, 2007). The performative component of the routine broadly follows the guidelines defined by ostensive criteria. In practice however, the performative component of a routine is often improvised by using the components of the routine from a repertoire of possibilities; with the design and execution of activities converging (Baker, Miner, & Eesley, 2003). This has been likened to a musical score that is improvised by the musician, where the particular courses of action are always novel (Orlikowski, 2000; Weick, 1998). In time, the performative and ostensive components of routines have a

symbiotic relationship where the performative aspects modify the ostensive routines, which in turn constrain the performative routines (Rerup & Feldman, 2011).

Despite this feature, routines have often been considered to be a source of organisational inertia, with the modification of routines providing a means of organisational change (Cohen & Bacdayan, 1994; Naduzzo, Rocco, & Warglien, 2000). This may be because routines are often documented in the form of SOPs; but even in these cases there are always additional unwritten social expectations that actors will need to be familiar with in order to complete the routine (Howard-Grenville, 2005). It is also unlikely, if not impossible, to specify a routine in sufficient detail that it is robust in all circumstances (Taylor, 1993). The perceived inflexibility of routines has therefore been based on the consideration of agency, if the routine is perceived as a programme written by others and implemented without modification then it is more likely to be considered to be inflexible; whereas in reality organisational routines are conducive to human agency in the act of performing the routine (Emirbayers & Mische, 1998).

Nelson and Winter (1982) recognised this anomaly and reinterpreted the notion of routines from meaning the repetitive form of activities, to that defining the collective skills and capabilities of organisational members. They suggested that organisational routines were more like ‘genetic material’ which provides an analogy to the persistent collective knowledge of the organisation. More recent research has also proposed that whilst routines do exhibit repetitive patterns of action they are certainly not rigid, mundane in content or isolated from thought or feeling (Cohen, 2007; Feldman & Pentland, 2003). It has been suggested that the enactment of routines is often fragmented by the actors who ‘dip in’ and use ‘chunks’ of routines without performing a complete sequence (Allatta & Singh, 2011; Cohen *et al.*, 1996). It is suggested that these ‘chunks’ constitute action steps, and the sequences that the actors implement might be chosen from a limited list which predisposes a particular response (Ashmos, Duchon, & McDaniel, 2000).

It is therefore not surprising that the same routine can provide a variety of actual performances depending on the actor’s cognition and the socio-emotional context (Gersick & Hackman, 1990; Howard-Grenville, 2005). These characteristics have resulted in some authors using alternatives to the word ‘routine;’ such as ‘custom’ and ‘disposition’ with the aim of highlighting the mindful

and dynamic nature of routines (Hodgson & Knudsen, 2004; Weick & Sutcliffe, 2006). This inherent flexibility and mindfulness in using routines is likely to be particularly applicable to the solving of complex scientific problems in this study.

2.4.2 Routines, cognition and automaticity

The degree of consciousness with which an actor enacts a routine has contributed to a long running debate in the academic literature. The debate is set between those who claim that routines are applied and used automatically, using long term memory and existing tacit knowledge (Cohen, 1991; Dosi, Nelson, & Winter, 2000; Narduzzo & Warglien, 2008; Postrel & Rumelt, 1992); and those who claim that routines are not mindless but are constantly modified through cognitive processes (Costello, 2000; Feldman & Pentland, 2003; March & Simon, 1958; Perren & Grant, 2000).

The concept of 'mindfulness' comes from the psychology literature and in the context of organisations is considered to be the non-automatic behaviour, characterised as active awareness to external cues, and is similar to recent definitions of dynamic capabilities (Schreyogg & Kliesch-Eberl, 2007). Although routines may be based on mindless behaviour, it should not imply a lack of thinking; and whether applied instinctively or with the application of thought, the actor may or may not require an understanding of the knowledge basis or rational behind it (Levinthal & Rerup, 2006). Other authors have proposed that available routines (less-mindful behaviour) provide managers with a selection of possible actions; whereas managerial attention (mindful behaviour) is essential in the selection of the routines to be used (Salvato, 2009). Studies have shown that the degree of automaticity and the maintenance of existing routines are strongly influenced by time pressures. Actors will tend to repeat tried and tested routines when under time pressures, even if they had previously decided to modify their behaviour (Betsch *et al*, 2004; Garapin & Holland, 1999).

Behavioural researchers claim that actions become automatic through repetition, and in a similar way to habits, past behaviour may become the predictor of future behaviour (Aarts & Dijksterhuis, 2000). This process is considered to be affected by bias and heuristics, which may also affect the ability to recall a routine from memory (Narduzzo & Warglien, 2008). It is however more likely that an individual will be able to recall a routine when it is linked to a vivid

story rather than to abstract information, when the recall refers to a personal experience or the experience of someone with which they share an identity (March, 1994). The recall of a memory that is linked to a vivid story will be helpful in the application of the critical incident technique that is used in this study.

2.4.3 Creation, modification and replacement of routines

Research has demonstrated that organisations recognise changes in their environments and adapt routines in accordance to these and the actions of their competitors (Lazaric, 2011; Occasio, 1997). It has been suggested that organisations with less experience are less likely to use detailed information filters, routines and heuristics, in comparison to more experienced (older) organisations (Argote, 1999; Mayer & Salomon, 2006). This may result in an attenuated ability to solve problems, selecting collaborative partners and in transferring tacit knowledge (Macher & Boerner, 2012; Parmigiani & Mitchell, 2009). Changing routines in response to environmental changes suggests that modification is an important dynamic capability which can be utilised to adapt routines when an opportunity presents itself (Teece, Pisano, & Sheun, 1997; Zollo & Winter, 2002). Hence, whilst organisational routines are perceived as a repetition of the past, the actual performance of the routine may adapt to contexts that reflect on-going changes and future possibilities (Feldman & Pentland, 2003).

It has been proposed that any variation in a routine is likely to occur either due to a misinterpretation of the routine, the need to adapt a routine to fit a particular problem (problemistic search) or an intentional modification to improve the routine or its outcome (Nelson & Winter, 1982). It has also been suggested that organisational routines may emerge informally and without planning or design, and may even occur through spontaneous sequences of actions which are repeated in recurrent situations. On these occasions the influence of management in the design of the routine tends to be marginal (Witt, 2011). However, other research suggests that both individuals and organisational leaders can play an important role in the creation and use of routines (Lewin, Massini, & Peeters, 2011); although it is unclear how this is achieved (Massini, 2010).

It has been previously assumed that whole routines are replaced once they are deemed not fit for purpose (Baum & Ingram, 1998; Kim & Miner, 2007), however it has been more recently

established that incremental change occurs and typically only parts of the routine are modified (Rerup & Feldman, 2011). Hence, performance improvements may come about by not just selecting new routines and capabilities, but also through modifying the micro-mechanisms by which routines influence performance (Abel, Felin, & Foss, 2008; Barley & Tolbert, 1997; Salvato, 2009). Due to the diverse nature of problems, information seeking and problem solving meta-routines are regularly modified and adjusted in relation to the characteristics and context of the problem.

Research in the area of organisational routines has identified a paradox in which some routines appear to be fairly stable over time whereas others seem to frequently change. In order to provide some explanation of why some routines change more than other routines, routines have been categorised as being either ‘embedded’ or ‘peripheral’ to organisational structures. Authors argue that routines that are on the periphery are easier to change than those that are embedded (Gersick & Hackman, 1990). Two further typologies have been applied to those routines which are said to be on the periphery. Those that are applied in the present context may be classed as ‘pragmatic routines’ and are thought to change rapidly as a result of emergent variation and are therefore more responsive to changes in current situations. Whilst those that apply to future projects have been labelled as ‘adaptive routines’ and are relatively easily adapted to new uses to the extent that many variants may co-exist simultaneously (Howard-Grenville, 2005).

2.4.4 The use of templates in knowledge transfer

In the same vein as routines, the role of artefacts within organisational processes and in particular their role in knowledge transfer, can provide an organisation with a distinctive source of competitive advantage (Winter & Szulanski, 2001). Organisational knowledge may be codified in the form of artefacts such as templates, procedures, scripts, SOPs, software, databases etc. (Nelson & Winter, 1982). Formal rules, SOPs and templates support the implementation of an organisational routine by providing guiding principles. Typically they will contain both critical and non-critical aspects of a routine and supply details on the sequence and actions of the routine, and how individual components are interconnected for the actual performance (Nelson & Winter, 1982). In this way artefacts can work as an external organisational memory, by helping actors to solve problems and by sharing the cognitive burden (Nelson & Winter, 1982).

Templates are considered to aid the knowledge transfer process by playing the role of referent document, which is thought to reduce implementation difficulties and encourage the adoption of the routine (Armenakis & Harris, 2002; Jensen & Szulanski, 2007). It is for this reason that some authors consider that research on artefacts can provide valuable insights into the micro-dynamics of routines (D'Adderio, 2011). Templates can provide a useful vantage point through which to study the evolution of routines (Pentland & Feldman, 2005) and can provide insights into the coding and decoding process in the production of the templates and routines (D'Adderio, 2003). In the language of 'Actor Network Theory' it is proposed that templates may be acting as a form of *immutable mobiles* in that they may be shared, reproduced and are left relatively unchanged, but may nevertheless impact on the co-creation of knowledge (Law & Singleton, 2005, p.335; Latour, 2005).

Like organisational routines, artefacts are often taken to support the automated and mindless actions of a routine, as a formalised recognition of what actions should occur (Cohen *et al*, 1996) but this perspective is increasingly being challenged (Cohen, 2007; Pentland & Feldman, 2008). Many authors now consider that human actors operate with differing degree of discretion when interpreting rules or procedures, thereby treating artefacts as descriptive rather than prescriptive (Daft & Weick, 1984). Some even claim that strict adherence to formal templates decreases performance (Kostova & Zaheer, 1999) and can stifle learning and innovation (Winter & Szulanski, 2001).

2.4.4.1 A typology of templates

Baden-Fuller and Winter (2008) and others have attempted to further clarify the role of artefacts by distinguishing between two forms; those representing *templates* and others which represent *principles*. In their view templates are based predominantly on observation and direct copying, often without a detailed understanding (*why*) of the underlying concepts; in effect the templates are there to be reproduced. An extreme version of this is a 'prescriptive' document (Callon, 2007) or what has been previously called 'copy EXACTLY!' with reference to Intel's protocol for the reproduction of policies that support the manufacture of semi-conductors (McDonald, 1998). The document that refers to 'principles' is however more descriptive and the focus is on an explanation of *why* something should be done and the reasons that it should be done. In other

words it clarifies the objectives and reasoning but does not stipulate the means to achieve it. Templates formed on 'principles' require less detailed codification as a robust understanding of the principle, as 'common sense' maybe sufficient for the recipient to find their own means to a successful implementation.

Baden-Fuller and Winter (2008) propose that there is a continuum between these two extreme poles. Both approaches may be supported by codification, and in the case of templates these may detail each of the steps and how to accomplish them (Baden-Fuller & Winter, 2008). However it is also evident that most codified accounts have a tendency to omit important tacit skill-based constituents. It is for this reason that it is rare that a true replication can be accomplished by just using the template (Collins, 1991), as most tacit knowledge has to be recreated by the receiver (Kogut & Zander, 1992; Nelson & Winter, 1982).

Nevertheless, some organisations will rigorously utilise templates at the exclusion of principles in order to assure compliance (Winter & Szulanski, 2001). Management researchers that have attempted to categorise situations where principles or templates might be used. These studies have identified that the context, the relative importance of process control, the background knowledge and the motivation of the replicator, all act as influences on the form of template/principles that might be used. In summary, they have found that principles are favoured over templates when the context is unclear or changeable, the processes are difficult to monitor, the understanding and tacit experience of the replicator is high and that the actor is fully engaged and willing to be flexible (Argote, McEvily, & Reagans, 2003; Baden-Fuller & Winter, 2008).

2.4.4.2 The development of templates

Like routines, templates are known to evolve over time in line with the demands of the routine and in response to different contexts. Through this process the guidance provided by historical templates is eventually discarded in favour of a new template which better fits the latest scenario. However, differences in environmental conditions and subsequent modifications of the template to suit local circumstances may also create new problems, which will have to be solved through trial and error (Winter & Szulanski, 2001).

Templates may be produced through a process of articulation, codification and standardisation (Nonaka, 1994), and the end result should be a practiced routine that is documented and made explicit for others to use (D'Adderio, 2008). It has however been claimed that moving from templates to performances and vice-versa, not only entails a process of codification and de-codification, but also requires a socio-technical transformation that involves both actors and artefacts (D'Adderio, 2011). Transferring templates from one source or context to another may also require the learning of a language in which to code routines, the creation of supportive cognitive artefacts and translation of high level description into practice (Hutchins & Hazelhurst, 1991, p. 674). The replication of a template is therefore directly underpinned by the individual's absorptive capacity and common training which gives rise to a mutual understanding (Cohen & Levinthal, 1990; Zahra & George, 2002).

Templates tend to emphasise explicit knowledge at the expense of tacit knowledge (Hansen, Nohria, & Tierney, 1999), and this is likely to compromise knowledge creation (Herschel, Nemati, & Steiger, 2001). As demonstrated through the SECI model (Nonaka, 1994), converting tacit knowledge to explicit knowledge is time consuming and problematic (Davenport & Prusak, 1998). It has been suggested that to help overcome this problem, structuring mechanisms might help (Herschel, Nemati, & Steiger, 2001). In a study on knowledge exchange protocols (templates) in the health services, Herschel, Nemati and Steiger (2001) identified that by structuring the patient-clinicians dialogue and the clinician's thoughts and actions, tacit knowledge was externalised and easier to share. They concluded that when structure is used in the tacit knowledge sharing process, and used specifically as a narrative recall procedure, it was the most effective means of enabling knowledge transfer.

Differences between the template and the performance of the routine cannot be sustained and will require a change in the template to match the performance or vice-versa. Resolving these problems may involve frequent comparisons between practice and the template, and may entail exchanges between the recipient and the source (Nelson & Winter, 1982). D'Adderio (2008) has proposed that the template may be modified through a cycle of framing (prescribing), overflowing (interpreting) and reframing (modification). This was exemplified by the use of a virtual prototype which underwent iterative cycles of 'translations' as different stakeholders, including suppliers and customers, contributed to its development (D'Adderio, 2001).

The modification of a prototype in response to external influence is a process that has also been proposed by Jensen and Szulanski (2007) in the form of ‘intermediate templates’. Their findings suggest that pilot call centres may act as intermediate templates, as they were used as a ‘test-bed’ of the knowledge embedded in the templates before a wider-scale implementation was initiated. They conclude by suggesting that intermediate templates may play an important role in knowledge transfer.

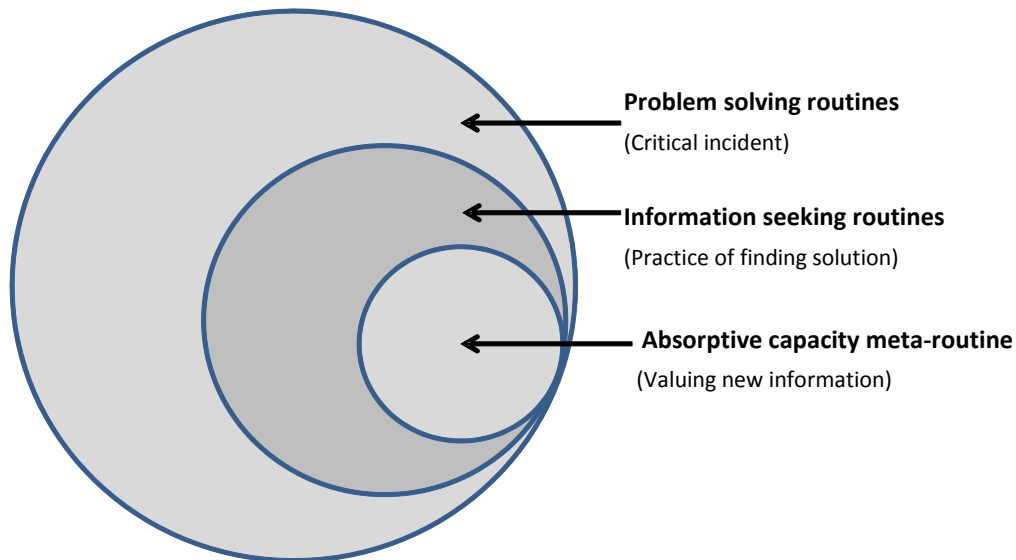
It is clear from these studies that templates have an inherent role to play in the codification and transfer of organisational knowledge. The modification of templates in line with organisational routines enables organisational knowledge to be dynamically captured and transferred. The micro-foundations of this process are the subject of the second research question.

2.5 The inter-dependence of knowledge transfer routines (research question 3)

In order to provide supporting theory for the first and last research questions, three organisational routines have been selected for particular attention. These include problem solving and information seeking routines, and meta-routines which support external absorptive capacity. Problem solving is used in this study as practical exemplars of knowledge transfer through social networks and is the subject of the critical incidents of the research participants. As a fundamental component of problem solving; information seeking routines are applied when searching for data or solutions within social networks. The absorptive capacity model was introduced earlier in the literature review as a concept to describe knowledge transfer and the innovation process. In this section, it will be considered from an external absorptive capacity meta-routine perspective with a particular focus on valuing external knowledge, which is the subject of the final research question.

In order to more clearly represent the relationship of organisational routines that are involved in knowledge transfer they have been represented in Figure 2.4. Figure 2.4 illustrates the nested nature of these routines demonstrating that valuing information is a factor in information seeking behaviour, which is in turn a major component in problem solving routines; each will be considered in turn.

Figure 2.4 A representation of the inter-relationship of the knowledge transfer routines



2.6 Problem solving routines

The ability to identify, analyse and solve organisational problems is a core skill which aids learning, develops knowledge, identifies opportunities in the environment and directs resources towards the accomplishment of goals (Alvarez & Barney, 2005; Giroux, 2009; Shane, 2003). Heterogeneity in problem solving routines has been found to be an important antecedent of novel solutions (Amabile, 1988). Indeed it has been argued that learning capabilities and problem solving skills are fundamental to knowledge creation and are so similar as not to warrant separate investigation (Cohen & Levinthal, 1990). The difference between them lies in the assumption that problems lead to solutions and the creation of new knowledge; while learning capabilities assimilate existing knowledge in the creation of new knowledge.

Problem solving routines are interdependent with information seeking, attention based and decision making routines. Indeed, decision making has been described as thoughtful problem solving (Newell & Simon, 1972). Not surprisingly decision making processes are often broadly equivalent to problem solving processes, in part because they define problems as opportunities and include the stages of sensing, exploration, generating, evaluating and the final selection of a solution (Huber, 1986). Problem solving has been studied in a variety of contexts, including studies of strategic action (Sutcliffe & Weber, 2003) and problem solving in different environments (Carroll *et al*, 2001). Throughout the extant research the importance of communication and the development of social assets has been highlighted (Hansen & Nohria, 2004; Starr & MacMillan, 1996) with professional or personal relationships providing a valuable forms of assistance (Funke & Frensch, 1995). Problem solving is therefore co-dependent on the use of social networks and the transfer of knowledge.

A manager cannot simply choose which new knowledge to acquire, but must instead choose between problems that might yield valuable knowledge (Nickerson & Zenger, 2004). An experienced employee might therefore be expected to develop trouble-shooting and problem-solving skills that enable them to create a range of valuable routines that support knowledge transfer, learning and innovation (Leiblein & Madsen, 2009; Rulke & Galaskiewicz, 2000). It is for these reasons that the problem solving routines have been chosen in this study as a proxy for knowledge transfer. By clearly defining the form of knowledge transfer approach, boundaries

can be placed on the type of knowledge transfer that is investigated, participants can have clear guidance in choosing critical problem solving incidents, and the researcher can establish links to the micro-foundations of the absorptive capacity construct.

2.6.1 Micro-foundations of problem solving

The likelihood of success or failure is fundamental to the enactment of the problem solving process (Kallenhauge, 2010). The problem solver will typically seek and evaluate alternatives with the aim to select the best or most optimal solution to address the problem (Bazerman & Moore, 2009). The use of ‘provisional narratives’ and analysis of the problem by ‘problem decomposition,’ have been identified as a means of generating multiple interpretations and defining or ‘framing’ problems (Boje, 2001; Bowey & Easton, 2007; Uzzi, 1996). Framing a problem by these means will allow for the development of a proposition or a set of potential solutions which may be adapted to fit the problem (Bartel & Garud, 2009) and has been recognised as the most important aspect of knowledge creation (Hargadon, 1999).

Once the problem is framed, a solution which is feasible and appropriate has to be crafted and stakeholders may have to be convinced that the solution is suitable (Cross & Sproull, 2004). Complex problems in particular may require a pragmatic perspective to be taken, which creates ‘actionable knowledge’ or knowledge that progresses the cause of the problem to the next stage (Carlile, 2002; Cross & Sproull, 2004). It has for example been shown that if given the freedom to seek help at any stage in the problem solving process, most decision makers tend to initially undertake an information search in order to build ‘internal information’ before seeking ‘external information’ in the form of advice (Van Swol & Ludutsky, 2003).

Research suggests that when actors are faced with a problem they typically adopt short term steps in order to overcome the immediate crisis, less commonly this may be followed by a second step which more fully investigates the root causes to the problem (Tucker & Edmondson, 2003). The short-term step has been termed ‘first-order problem solving’ and the more in-depth investigation for a long-term fix of the problem has been termed ‘second-order problem solving’ (Tucker & Edmondson, 2003). These steps may be considered to be analogous to Repenning and Serman’s (2002) first order and second order improvement or Argyris and Schon’s (1978) single and double loop learning. It has also been argued that effective meta-routines can facilitate

second-order problem solving which is important to achieve sustainable learning in the organisation (Ghosh & Sobek II, 2012; Hayes, Wheelwright, & Clark, 1988).

Das (2003) has identified that individuals that are faced with problems often recognise similarities with previous problems. However when there is no previous experience to draw upon, 'divergent thinking' may be required (Christensen & Schunn, 2005). Information search and analogy are often associated with divergent thinking and can help problem solvers to overcome mental blocks. Other forms of divergent thinking may use inference which proposes an explanatory hypothesis (abduction) (Josephson & Josephson, 1994), by forecasting a solution to a hypothesis (deduction) or by drawing conclusions from findings (induction). Together abduction, deduction and induction can provide the means to solve problems by creating a cycle of learning (Rudolph, Morrison, & Carroll, 2009). Over time these cognitive resources can provide a range of mutually supportive routines (Cohen, 2007) which may be used to optimise problem solving, information seeking behaviour and knowledge transfer.

2.6.2 Problem solving models

Early process-orientated models of problem solving proposed that problem solvers consider one hypothesis at a time, in a rational, linear and prescribed order, and only consider a new hypothesis when the first hypothesis fails to meet the expected outcomes (Bales & Strodtbeck, 1951; Klein, 1998). Early work by Dewey (1933) suggested that there were five stages to problem solving; perceiving the difficulty, defining the problem, suggesting solutions, analysing the implications of the solutions and testing the validity of them. Numerous subsequent models produced variations on this process as typified by the 'IDEAL' model (Bransford, Sherwood, & Sturdevant, 1987), and Kuhlthau's (1991) ISP-Model.

These models have common features such as a consideration of the cognitive factors of problem solving and action upon reflection. Schon (1987) pays particular attention to reflection and sees every problem as unique, whilst emphasising tacit knowledge and experience-based intuitive actions. The authors of these models propose that information seeking is easier if the problem is clearly definable or may be defined following an initial exploration (Fainburg, 2009). It is assumed that once the problem is understood and the models are followed in the prescribed order, that the problem will be effectively solved (Bales & Strodtbeck, 1951). In practice,

however, there has been little empirical support for these models (Lipshitz & Bar Ilan, 1996), suggesting that they are based on rational argument rather than practical application (Nutt, 1984).

Later problem solving models recognise that problem solvers continually reinterpret and reassess the plausibility of their diagnosis, which generates alternative diagnosis and creates numerous feedback loops (Rudolph, Morrison, & Carroll, 2009; Spink & Cole, 2005). Indeed the 'garbage can' model of organisational choice recognises that there are often accidental or random confluences of problems, solutions, participants and choices (Cohen, March, & Olsen, 1972). Hence whilst rational models of problem solving describe the distilled process of the key stages of reaching a solution, in reality problem solving is significantly messier with problems being 'solved on the fly' in an intuitive, improvised and non-linear manner (Giroux, 2009; O'Gorman, Bourke, & Murray, 2005). It has also been recognised that when the problem is overly complex, ill-understood or time is too short, the solution may be achieved through a cognitive process of 'insight' which tends to rely on a previous and subconscious experience (Durso, Rea, & Dayton, 1994; Helie & Sun, 2008).

2.6.3 Solving complex problems

Problems may be characterised by their structures. Problems at one extreme of a continuum may be tight or 'well-structured,' explicit, definable and often objectively quantifiable; at the other end of the continuum they may be loose or 'ill-structured,' ambiguous, poorly defined, with a solution that is difficult to define (Macher & Boerner, 2012; Shapiro & Spence, 1997). Many management problems are complex and ill-structured and hence cannot be solved by logic or programmable formulas (Klienmuntz, 1990). For this reason complex problems can rarely be solved by the use of rational problem solving models or by the simple use of information sources. Instead, they are more likely to be multi-staged, have a significant tacit component and therefore require a rich form of communication to solve (Azoulay, 2004; Fang & Levinthal, 2009).

Complex problem solving requires creative solutions which are commonly built from social interactions that recombine existing ideas (Amabile, 1983; Kirton, 2003). The difference between what an individual can learn through problem solving by themselves and that which can

be accomplished through socio-cultural feedback, has been termed the '*zone of proximal development*' (Vygotsky, 1987).

Newell and Simon (1972) first introduced the concept of searching for a solution through a problem space represented by two extremes (Perkins, 2000). Simple problems are represented on their model by contour lines which demarcate a 'homing' space where the solution may be found. Complex problems are characterised by a complex contoured landscape where the solution is hidden amongst clues which are often misleading. In order to navigate these contours a 'precipitating event' needs to occur which generates fresh information and direction and may be triggered as a result of a random search strategies. Kauffman's NK framework is widely used as a means of defining problem landscapes (Kauffman, 1993); where N represents the number of knowledge sets that are available in forming potential solutions to the problem and K represents the degree of interdependence or interactions between the N knowledge sets. Given a particular N and K, organisations attempt to search the landscape for high value solutions by effectively combining dispersed knowledge sets.

Searching for and choosing between optional solutions may occur through trial and error, which is otherwise called 'experiential' or 'directional search' (Nelson & Winter, 1982). Experiential search is most useful when a solution is 'decomposable' or may be broken down into sub-tasks, since the knowledge sets are independent of one another. The less decomposable the problem is, the likelihood of finding a quality solution (a high peak) decreases and there is a relative increase in the costs of experimentation and search. A more efficient means of searching for solutions for 'non-decomposable' problems is by conducting the search using cognitive beliefs or heuristics (Simon, 1991). These forms of search hypothesise about the most promising areas to search for high value solutions. A summary of the benefits of directional and heuristic searches is shown in Table 2.2.

Table 2.2 The relative benefits of search methods by problem type (Nickerson & Zenger, 2004)

	Decomposable	Nearly decomposable	Non-decomposable
Directional search	++	+	0
Heuristic search	0	+	++

In practice, cognitive search may get problem solvers in the vicinity of high value solutions after which incremental experiential search is more efficient (Hsieh, Nickerson, & Zenger, 2007). More experienced firms can therefore improve problem solving performance through experiential learning (Argote, 1999).

2.6.4 Distributed problem solving

Research has recognised that actors often use a multi-dimensional approach to solving problems through their social networks (Cross & Sproull, 2004). Social contacts may be used for different purposes. For example, those that were already established may be selected as they were seen to be more approachable for brainstorming activities, whereas others may be more appropriate for solution legitimisation. In total, five reasons for seeking information from relationships were identified (Cross & Sproull, 2004) .

- 1) **Looking for a solution** Either know-what/declarative knowledge and know-how/procedural knowledge was requested
- 2) **Referrals to other sources** Not all sources provided solutions directly; some provided referrals to other people (70%) or sources of data. These were often in the form of introductions to the sources personal contact.
- 3) **Problem re-formulation** If the problem required reformulation, sources often provided help in thinking more broadly about the problem by suggesting different perspectives. Sources also provided insights with regard to possible issues and concerns

- 4) **Validation** Provided support to the seeker by developing confidence in their solution, in particular at critical junctures of a project
- 5) **Legitimation** The use of influential contacts helped to provide support for their solution

The task that the seeker is engaged in has repeatedly been shown to influence the context of problem solving (Kim, 2009). A high level of task uncertainty has for example been found to be a characteristic of R&D projects (Katz & Tushman, 1979) and requires an increase in the diversity of sources and information to complete the task (Xu, Tan, & Yang, 2006).

The concept of ‘collective cognition’ has been used to define the collective generation of ideas by combining different individual ideas and experiences in order to solve problems. An individual’s comments are considered by others in their social group and have the potential to shape their own perspectives; hence each individual is shaped by the group’s collective views (Hargadon & Bechly, 2006). This process has been found to comprise of four interrelated activities; help seeking, in order to solve the problem; help giving, in order to assist the work of others; reflective reframing, where each actor builds upon the comments of others, and the reinforcement of the values which bind the actors together (Hargadon & Bechly, 2006).

2.7 Micro-foundations of information seeking routines

Information seeking routines are the organisational processes that are actively used for searching for data or solutions to problems and are commonly used in conjunction with problem solving and social networks (Bin, 2011). Information seeking behaviour is the purposeful actions of the acquirer with the aid of technological and social sources (Johnson *et al*, 1995, p. 275). Studies investigating source preferences have indicated that despite the advent of new technologies, people and informal social networks are the most common source that is sought (Aguilar, 1967). There is a well-established interdependence between problem solving and information seeking as represented by the nested circles in Figure 2.4.

Research in the area of information seeking behaviour suggests two components of the search strategy, the external search breadth, or the degree of concentration in source use, and the external search depth which is a measure of how extensively an individual source is used (Bin, 2011). Studies have demonstrated that with a high task uncertainty there is a tendency to undertake a depth-first approach to information seeking which is thought to reduce costs in time and effort, and is in line with findings of work on ‘attention based’ theory (Bin, 2011; Occasio, 1997). Knowledge diversity will provide a broader base of information to be shared, but also provides conflicting norms and assumptions with regards to the selection of an optimal solution (Paletz & Schunn, 2010). Studies have also shown that decision makers seek out sources that possess unique information and avoid information that overlaps with the seekers’ information (Van Swol & Sniezek, 2005). This research does however contradict the ‘undifferentiated small-groups literature,’ which has found that actors tend to reuse common rather than unique information (Wittenbaum & Stasser, 1996).

There are many contextual factors that influence information seeking behaviour and these may be classified into the *cost-based* influences which are related to accessibility and the characteristics of the source (Johnson *et al*, 2006), and seeking *benefit* from the source’s information quality (Xu, Kim, Kankanhalli, 2011). Information quality will be discussed in Section 2.8 of this chapter; cost-based influences such as accessibility and source characteristics are critically reviewed in the following sections.

2.7.1 Accessibility as an antecedent to information seeking

Early research into source preferences was predominately focussed on two schools of thought, the ‘principle of least effort’ (Gerstberger & Allen, 1968; Zipf, 1949) and the related ‘cost-benefit model’ (Anderson *et al*, 2001; Fidel & Green, 2004). The ‘principle of least effort’ assumes that the seeker uses sources that are of the least psychological and financial cost. If a source is available and accessible, it is more likely to be used even if the quality of the information is compromised (Allen, 1977, p. 185; Hardy, 1982). The cost-benefit model considers whether the expected benefits outweigh the potential costs of the search. Costs might include the financial impact and any physical constraints such as accessibility (Monge *et al*, 1985). Cost may also include the psychological effort such as ease of use, the admission of ignorance, impact on self-esteem and self-image (Lee, 1997) and future obligation (Fiske, 1991).

Whilst the principle of least effort and the cost benefit model have been successfully applied to many information seeking scenarios, researchers are now more inclined to downplay the importance of cost in relation to information seeking. Studies are increasingly finding that information quality and previous experience are more important influences than cost or least effort (Cross, Rice, & Parker, 2001; Kwasitsu, 2003; O’Reilly, 1982). This ‘perplexing finding’ (Xu, Tan, Yang, 2006) has been the catalyst for other studies that have considered the potential moderating factors of ‘social risk’ and ‘obligations’ that arise from information seeking behaviour. However, these studies have either shown no effect or have produced unconvincing and mixed results (Borgatti & Cross, 2003).

A more recent study has however suggested that whilst actors might prefer the ‘best sources,’ situation constraints may become important during information seeking and sources may then be selected on the basis of ‘ease of access’ (Xu, Kim, & Kankanhalli, 2011). Other antecedents such as experience and trust have also been shown to be influential in the moderation of perceived accessibility and the choice of source. Previous experience gained in using sources reinforces and improves the perceived accessibility leading to increased use (March & Simon, 1958), and if the source is trustworthy they may be used in preference to recognised subject experts (Mackenzie, 2002).

One of the first decisions to be made when seeking a source is to decide on whether a suitable source is available within the organisation, or whether an external source might be more appropriate. The choice may depend not only on the basis of the source's characteristics, but on the relative quality and accessibility to them (Bin, 2009). Information searching within organisations is commonly aided by defined roles and structure, but this advantage will still be balanced with a preference for contacts where informal relationships are already established. Studies have suggested that the information seeker will tend to use external sources of information if there is an increase in task uncertainty (Bystrom & Jarvelin, 1995; Katz & Tushman, 1979). These findings have however been disputed as other studies have not identified this connection (Anderson *et al*, 2001).

It has been proposed that the preference of external sources over internal sources may often be based on perception rather than demonstrated benefit. A high value attributed to sources that are outside the organisation has been shown to be due to a number of factors. The relative difficulty of access which gives the impression of scarcity (Cialdini, 2001); external sources are often more costly and this reinforces value; and information from external sources is often less transparent and less easy to scrutinise, which adds to the value proposition of the information received (Menon & Pfeffer, 2003). In addition it has been proposed that actors gain status by using externally sourced knowledge (Burt, 1992).

Interpersonal sources such as friends and colleagues are also deemed to be the most accessible types of sources (Allen, 1977, Warner, Murray, & Palmour, 1973), with later studies indicating professionals and text and internet based sources are also being used for particular types of everyday problems (Agosto & Hughes-Hassell, 2006; Rich, 2004). Whilst these characteristics may be generally accepted, access to knowledge is only beneficial if the knowledge is available at the appropriate time, hence the influence of timeliness is also a regulator in the question of access (Borgatti & Cross, 2003).

2.7.2 Source characteristics as an antecedent to information seeking

The concepts of the source preference and the relevance of the source are closely related but are not the same. They differ because source preference focuses on criteria of why a particular source was sought and therefore tends to be used at the early stage of problem solving. Source

relevance however, focuses on the criteria of how people judge the value of the source and tends to be used in the final stages of problem solving (Savolainen, 2008). This is an important distinction for this study, as the source characteristics will be evaluated from the initial selection of source(s) and also from the perspective of valuing the solution.

The source preference depends not just on the availability of the source (the principle of least effort) but the specific requirements of the problem to be solved (Savolainen, 2008). Early studies by Chen and HERNON (1982) found that sources were chosen that were familiar to the seeker and on the basis of the accuracy and understandability of the information. In a more recent study, speed and ease of use were identified with the value of information as being important for source selection (Julien & Michels, 2004). Whilst other studies have identified the reliability of information, trustworthiness, ease of communicating, knowing the seeker and understanding the seekers needs (Fisher & Naumer, 2006). It has also been suggested that a seeker will use an existing source that has similar information in order to benchmark and gauge the quality of the new source (Bin, 2011).

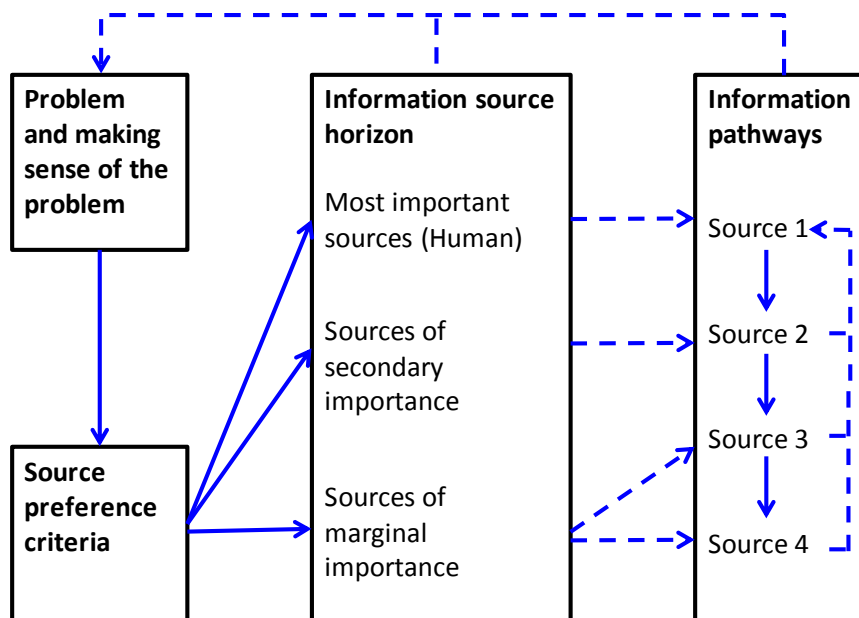
Research also indicates that knowledge, communication behaviour, communication style and cognitive ability are also important reasons why people were selected as information sources (Bin, 2009). Aspects of communication behaviour are often intangible in nature, but according to Mackenzie they include a willingness to share information, respond promptly, are approachable, the voice of reason in difficult situations, have a well-developed intuition and are often perceived as intelligent and insightful (Mackenzie, 2002).

In an attempt to put these and other source preference criteria into context two conceptual tools have been suggested. The 'information source horizon' (Savolainen & Kari, 2004; Sonnenwald, 1999) is a concept which allows the researcher to put sources on a virtual map, either nearer or further away from the seeker depending on their significance and contextual preferences. Information source horizons may be considered to be analogous to 'mental models' of information searching as they provide a means to determine and illustrate the situation-specific horizons that are unique to seeker and the problem.

Another conceptual tool is 'information pathways' which have been used to describe the sequences that seekers might use when exploring their information source horizon, thus

providing a dynamic dimension to the construct (Johnson *et al*, 2006). It has been suggested that not all pathways are unique as sometimes seekers may follow habitual and commonly used pathways in order to find the solution to a recognisable problem, a feature that supports the use of organisational routines in information seeking behaviour (Johnson *et al*, 2006). The manner in which information source horizons and information paths maybe used to solve problems is illustrated in Figure 2.5.

Figure 2.5 The interaction between information source horizons and information pathways Savolainen(2008)



The framework presented in Figure 2.5 has been used to guide empirical research which sought to determine the kinds of information sources that were used, the criteria for preference of those sources and the sequence (pathways) of sources that seekers followed (Savolainen, 2008). On average each problem solver used 3.5 sources of information for each problem solved. Human sources were the most strongly preferred, closely followed by internet sources, with printed media and organisational sources being less significant and therefore on the margins of information source horizons. Usually the first two sources were used to meet the major information requirement, with the following steps acting as additional or confirmatory steps. If

more than three steps were needed to solve a problem, human sources tended to be used to obtain advice on how to proceed. When questioned as to why human sources were preferred so strongly they were identified as being able to provide filtered, clarified and experience-based information about the specific problem. These information seeking preferences did vary depending on the type of problem and the content of information that was being sought; but it was evident that the selection of sources was driven by the expectations and beliefs concerning the solution that was provided by the information sources (Savolainen, 2008).

2.8 Meta-routines and external absorptive capacity

Following the earlier introduction of the concept of absorptive capacity this section focuses on the operationalisation of the absorptive capacity construct as an organisational routine and underpins the theory relating to the third research question.

Lewin, Massini and Peeters (2011) have advocated that the successful development of a new innovation may benefit from an optimised configuration of absorptive capacity in conjunction with better practiced internal and external socially enabling routines. In an attempt to characterise the linkage between absorptive capacity and organisational routines, a taxonomy of routines has been proposed as the basis for further research (Lewin, Massini, & Peeters, 2011). In this taxonomy, routines have been characterised as being internal or external. Internal meta-routines include those which manage variation, sharing knowledge and updating these capabilities; whereas the external meta-routines are more relevant to this study and include the identifying and recognising value of external knowledge and learning from external networks (Bresman, 2010). Figure 2.6 illustrates the proposed taxonomy and highlights mediating and moderating variables such as the socio-cultural values which influence the internal and external components of absorptive capacity (Torodova & Durisin, 2007; Zahra & George, 2002).

Figure 2.6 Internal and external absorptive capacity routines (Lewin, Massini and Peeters, 2011)

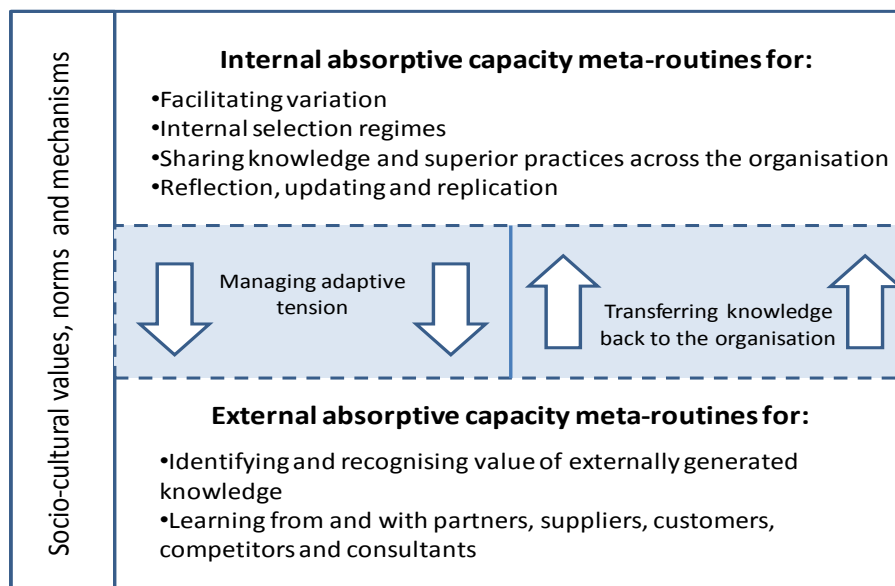


Figure 2.6 suggests that there are two meta-routines that act at the interface between the external and internal environment; creating and managing ‘adaptive tension’ and the transference of knowledge from the external to the internal environment (Lewin, Massini, & Peeters, 2011). The management of adaptive tension involves the selection of an external source and attaching some weight to the value of the external information. This meta-routine may include the setting of goals (often stretch goals) and expectations in order to stimulate change, for example by providing guidelines for the selection of a reference group or a benchmarked competitor (Massini, Lewin, & Greve, 2005). In related research, Hughes and Wareham (2010) differentiate between the combinative value of external and internal knowledge flows by using the concept of ‘knowledge arbitrage’ as a means to address the bi-directional opportunities of knowledge transfer.

Central to Figure 2.6 is the proposal that an organisation should create meta-routines for learning from external sources and for identifying and valuing externally generated knowledge (Lewin, Massini, & Peeters, 2011). Previously Torodova and Durisin have illustrated the importance of ‘recognising the value’ within the absorptive capacity model by claiming that valuing is a biased process which needs to be nurtured for it to occur at all (Torodova & Durisin, 2007). Other researchers have recognised the dangers in the lack of identification and the absorption of valuable new external knowledge through the inappropriate use of information screening filters, obsolete communication channels, embedded knowledge bases, rigid capabilities and path dependent management cognition (Gavetti & Levinthal, 2000; Helfat, 2000; Langlois & Steinmuller, 2000). The practical implications of identifying the value of information are discussed in the following section.

2.9 The micro-foundations of recognising value in new knowledge

Recognising the value of information has been identified as an important factor in models of absorptive capacity and in knowledge transfer through social networks (Kane, 2010). The process of valuing information or new knowledge is inherently complex. It may encompass different research streams on decision making, advice taking, rationality, judgement, intuition and heuristics; as well as theory regarding knowledge relevance both from an organisational and a psychological perspective. Much of this material is beyond the scope of this research and the broader research question which is to determine the practical micro-foundations of external absorptive capacity; rather than the cognitive dimensions of decision making. However, it is recognised that research that evaluates the quality or the value of knowledge is scarce outside the field of psychology (Yoo, Vonderembse, & Ragu-Nathan, 2011).

The likelihood that problem solving will be successful has been found to be determined by the quality of the solution and the algorithms of choice that are applied to the representation of the problem (Simon, 1986). The terms ‘value’ and ‘quality’ will be used interchangeably for this study, although it is recognised that in some circumstances there may be a slight difference in emphasis. Previous studies on knowledge quality have suggested that it comprises three broad dimensions (Yoo, Vonderembse, & Ragu-Nathan, 2011).

1. Intrinsic knowledge quality (accuracy & reliability)
2. Contextual knowledge quality (relevance)
3. Actionable knowledge quality (ease of application)

This section considers these characteristics in the context of how decisions are made, the role of advice taking, the influence of the source in the acceptance of a solution, and finally how judgements are made based solely on the quality of knowledge

2.9.1 Decision making and judgement

It is generally accepted that having relevant information improves the chances of finding a good solution and making a rational decision, and this is enhanced if there is a clearly defined and tangible objective. The rational choice theory is however only one dimension of decision making as it does not account for the practical situations where there are time pressures, diversity of

demands, and the subjective nature of the problems that are faced (Ericson, 2010). Managers often have to work with heavily aggregated data, partial information and seek alternatives rather than answers (Alwis, Majid, & Choudhry, 2006).

Theories of bounded rationality and 'satisficing' behaviour have provided important contributions to the behavioural school of thought in decision making. Work in this area has determined that when the consequences of decisions are unclear, optimal decision making is unlikely as making an assessment of all the outcomes is impossible (March, 1994; Newell, 2005). Limited by their level of cognition and other workplace constraints, seekers may choose not to pursue an optimal outcome but instead accept an option that is 'good enough' for their needs (Prabha *et al*, 2007; Simon, 1997).

Satisficing can act as a 'stop rule,' stopping a search once the seeker has enough information for their purposes. (March, 1994; Simon, 1997). These stop rules have been extensively studied in the information seeking literature and have been found to be influenced by numerous factors including time constraints, diminishing returns and an individual's frustration (Agosto, 2001; Morehead & Rouse, 1982). Information sufficiency is perceived to be met when the completeness and usefulness of the information is judged to be appropriate (Browne & Pitts, 2004). Qualitative stopping points in information seeking include the accuracy of the information, finding a trustworthy resource, the occurrence of a repetition of data, gathering sufficient information, reaching an understanding of the subject, achieving a representative sample, current research has been uncovered and feedback from stakeholders has been addressed (Prabha *et al*, 2007).

Information seekers may use an intuitive decision making process which is based on personal experience, and may satisfice whenever there is conflict between time factors and a sense of comfort with the information that was found (Zach, 2005). This may lead to a solution being chosen for a problem as it had been previously used in solving similar problems, rather than seeking a new and perhaps more appropriate solution. The benefits of such decisions are that they are quick and use less cognitive resources (Becker, 2005). These factors have contributed to visualising the decision making as a progression along a spectrum from a calculated, objective

and rational end to the other extreme where decisions are made on the basis of experience, biases and the context of the decision (Eisenhardt & Zbaracki, 1992; Tello, Latham, & Kijewski, 2010).

Decisions that are objective, quantitative and have right/wrong characteristics are most likely to use 'predictive' forms of judgements. Qualitative decisions are likely to be 'evaluative' and may be influenced by experience, context and personal preferences; this form of judgement cannot be objectively assessed for accuracy (Hogarth, 1980). Therefore in order to make evaluative decisions, the seeker will base their judgement on a subjective evaluation of the usefulness of the knowledge (Menon & Blount, 2003) which is likely to be based on previous experience and the likely outcomes that were predicted by the problem framing process (Kuhlthau, 2003).

Evaluative decisions may also be supported when combined with complementary information (Ellis & Haughan, 1997; Kogut & Zander, 1996). This factor is recognised in literature on 'reference class forecasting' (Kahneman & Tversky, 1979), 'case based decision theory' (Gilboa & Schmeidler, 2001) and similarity based forecasting (Lovallo, Clarke, & Camerer, 2012); all of which may be categorised as analogical forms of external benchmarking.

2.9.2 The role of advice taking when making decisions

Decisions are rarely made in isolation but are often made after consulting with others (Kerr & Tindale, 2004). Seeking advice is commonplace in the work environment and may be used to make better decisions, avoid mistakes, consider new information, structure thoughts, obtain stakeholder support and to improve the level of confidence in their decisions (Cross, Rice, & Parker, 2001; Schlosser & Gelso, 2003). Extant research has also demonstrated that advice seeking provides shared accountability for the decision that is subsequently made (Harvey & Fischer, 1997) and that combining the opinions of multiple, unconnected sources increases the accuracy of the decision as it reduces random error (Yaniv, 2004). Less confident decision makers may therefore look for more advice (Budescu & Rantilla, 2000) and when advice is provided from multiple sources and this advice overlaps, the confidence level in the decision is increased (Budescu *et al*, 2003). However this effect may also be influenced by power relationships, such as those found in hierarchical situations (Torodova & Durisin, 2007).

When advice is sought, it is more likely to be followed than from that received from unsolicited advice (Gibbons, Sniezek, & Dalal, 2003). This may be because it is seen as a threat to the

decision makers' self-esteem, as it might create the impression that they are unable to cope with the problem (Deelstra *et al*, 2003; Reinhardt, Boerner, & Horowitz, 2006). The complexity of the problem may also impact on the potential for accepting or rejecting advice; the more complex the problem, the more likely the advice will be received (Gino & Moore, 2007). However when advice is given that is very different from that given by other advisors, it is more likely to be rejected (Harries, Yaniv, & Harvey, 2004). It has also been demonstrated that decision makers weigh purchased advice more heavily than free advice (Gino, 2008). These factors are important when unsolicited advice and paid for advice is obtained when seeking information.

Studies have suggested that there are decision accuracy benefits that can be achieved through collecting advice from a diverse range of sources (Soll, 1999), and that three to six independent sources may be sufficient to achieve this (Budescu & Rantilla, 2000; Yaniv, 2004). It is likely that decision makers will in time learn how to identify which source has which type of knowledge, which advisor is most accurate and under which circumstances, and whether the source's confidence ratings are valid indicators of accuracy (Hollenback *et al*, 1995). Following the decision making process, reflection can influence future decisions by changing the perceived value or weighting of their advisors (Fischer & Harvey, 1999).

2.9.3 Influence of the source on the perception of value

It has been suggested that new knowledge is judged not just through the cognitive application of quality constructs but is also influenced by the values held by stakeholders (Torodova & Durisin, 2007, p. 777). Hovland and Weiss (1951) were amongst the earliest researchers to provide evidence that the believability of a message is strongly linked to the source of the message, more credibility was given to the content from an 'expert source' than that of the same message delivered by a 'non-expert source.'

Subsequent research has confirmed that a source's social characteristic (social capital) has a direct impact on the adoption of a solution that is independent from the solution content, demonstrating the importance of the identity of the source when assessing value (Abrams *et al*, 1990; Argote, McEvily, & Reagans, 2003; Humphrey *et al*, 2002). Hence knowledge is more likely to be thoroughly considered when the seeker and source share a social identity than if the source is from outside the seekers social group (Van Knippenberg, 1999). Giving the 'benefit of

the doubt' to 'in-group' members is therefore predicated on the expectation that knowledge will have merits (Pettigrew, 1979). Indeed it has been found in some circumstances that liking or disliking someone on a personal level was more important to the task than an evaluation of task-related competence (Casciaro & Lobo, 2008).

Advice taking and decision making (judge-advisor systems) research seeks to understand what weight the advisor's (source) advice to the judge (decision maker/seeker) may carry by estimating the level of confidence the judge has on their decision (Yaniv, 2004). The judge's final decision is often evaluated in terms of accuracy or effectiveness. Advice utilisation refers to the degree that the judge (seeker) follows the advice, whereas advice discounting refers to the extent that the advice is ignored. Source discounting occurs less when the advice is offered by an expert source with a greater perceived knowledge in relation to the decision maker (Foreman, Ghose, & Wiesenfeld, 2008; Jungermann & Fischer, 2005) and also to those sources which are greater in age, education and life experience than themselves (Feng & MacGeorge, 2006). The 'authority' of the source is also considered to be significant (Choo, 2007; Zerubavel, 1997), with the style of communication being rather less so (Kallenhaug, 2010).

2.9.4 Judgements on the value of knowledge

The value of knowledge has also been studied from the perspectives of 'quality', 'relevance' and 'knowledge demonstrability,' each of these will be considered in turn. The use of data, information and knowledge will depend to a large extent on its quality (Yu, Kim, & Kim, 2007). Data, information and knowledge have associated characteristics that in different contexts may define their quality/value. The value criteria that have been associated with data and information include accuracy, currency, accessibility, relevance, timeliness, completeness and consistency (Cappiello, Francalanci, & Pernici, 2003; Goodhue, 1995).

The quality characteristics of knowledge have been considered in a similar vein and many of the features that are associated with data or informational quality also apply to the evaluation of knowledge, such as the accuracy, currency and consistency. Other characteristics of the quality of knowledge have however been identified and include the interpretability, context, level of detail, importance, preciseness meeting needs, volatility and sharing usefulness (Kulkarni, Ravindran, & Freeze, 2007; Rao & Osei-Bryson, 2007; Soo, Devinney & Midgley, 2004).

Knowledge quality tends therefore to be more of a vague concept than either data or informational quality, possibly due to its ubiquity and variety (Poston & Speier, 2005).

In the field of information seeking behaviour, research on 'data relevance' has identified similar factors to those characterised as defining knowledge quality (Barry & Schamber, 1998). Subject relevance (validity/currency/specificity) is the most commonly cited reason for the selection of a data source (Barry, 1994; White & Wang, 1997), whereas the 'orientation' (depth/scope) and the nature of the information (accuracy/clarity/tangibility) are the second most preferred relevance criteria (Kallenhaug, 2010).

It has been suggested that knowledge may be relevant to the seeker if it can lead to new implications when applied to existing knowledge; lead to the abandonment of existing knowledge or can strengthen the existing assumptions of knowledge (Sperber & Wilson, 1986). This reinforces the notion that knowledge relevance not only triggers the transfer of knowledge but that it is also likely to have a creative influence (Xu, Kim & Kankanhalli, 2011). Knowledge relevancy is therefore likely to have both a cognitive impact and a pragmatic value in solving the seekers problem (Xu & Chen, 2006). It has also been suggested that the motivation to process information increases with the perceptions of its relevance (Petty & Wenger, 1998) but more work needs to be done to establish this conclusively.

Conceptual theoretical models use the term 'knowledge demonstrability' as a variable to characterise the observable merits of the knowledge. It is suggested that knowledge whose merits are clear is most likely to be recognised and adopted (Kane, 2010). Highly demonstrable knowledge with clear merits requires little consideration in order to recognise its value, whereas less demonstrable knowledge with obscure merits requires a more thorough consideration to recognise its value. Hence, knowledge demonstrability affects the need for knowledge consideration, whilst superordinate social identity reduces the extent that the recipient considers knowledge. Knowledge transfer is therefore more likely to occur when the demonstrability of knowledge is high and where groups share a super-ordinate identity (Kane, 2010).

Recognising the value of information has been considered by Laughlin (1980) as a task continuum, with judgemental tasks at one end and intellectual tasks at the other. At the intellectual end of the continuum are a series of routines, rules, decisions and relationships which

provide an analytical assessment framework that is based on the options that are available. The judgemental end of the spectrum may be considered to be instantaneous, emotional and possibly involve irrational decision making. Between these two ends of the spectrum are a range of possible combinations which are generally superior to either extreme (Bonabeau, 2003; Landry, 2003). The nature of the problem to be solved is likely to determine the appropriate mix of judgemental and intellectual inputs, with confident decision makers blending differing portions of each (Simon, 1997). This study is likely to reveal problems that will illustrate a variety of different positions on Laughlin's (1980) scale.

2.10 Summary and theoretical proposition

Empirical research has shown that the most important influences on selecting a source through a social network include their accessibility (O'Reilly, 1982), the source characteristics (Savolainen, 2008) and the value or relevance, quality and demonstrability of the knowledge that is transferred (Kallenhauge, 2010; Kane, 2010; White & Wang, 1997). In their comprehensive review of the information seeking literature, Alwis, Majid and Choudhry (2006) have categorised the findings of previous empirical studies into four dimensions; the contextual, situational, personal/socio-cultural and informational as illustrated in Table 2.3.

Table 2.3 Dimensions and factors influencing information source preferences

Contextual (nature of problem)	Situational (structural characteristics)	Personal/Socio-cultural (relational/source characteristics)	Informational (value, relevance & quality)
Work roles Power Complexity of problem Pressure to find solution Potential audience Access to technology Motivation	Organisational structure Organisational culture Motivation/incentives Nature of industry Competitive situation	Cognitive style Educational/professional qualification Age/Gender Work experience Longevity with company Information seeking style and preference Membership of professional organisations Social influences Personal motivation	Acceptable quality Accessibility of source (proximity, time, social and economic cost) Availability Choice of sources Awareness and prior success with source Information richness and clarity Quality of source (credibility, authoritativeness, currency) Speed of response Trust

Adapted from (Alwis, Majid, & Choudhry, 2006)

The first dimension is related to the problem context, the second and third dimensions to the structural and relational dimensions of social capital and the final dimension is associated with valuing knowledge; a recognised stage in the absorptive capacity model. The antecedents and influences on the choice of source and knowledge transfer listed in Table 2.3 provide the basis for the ‘a-priori’ template and thematic coding of the interviewee’s narrative; as discussed in the methodology chapter.

In conclusion this research brings together a number of parallel streams of theory that are related to external knowledge transfer. These include the use of social networks and templates to access and transfer knowledge, information seeking routines, the micro-foundations of absorptive capacity and in particular, the mechanism of valuing new information. This theory underpins the three research questions which act as the focus for the study.

Research Question 1: How do scientists use their social networks to obtain knowledge?

Research Question 2: How do scientists use templates in knowledge transfer?

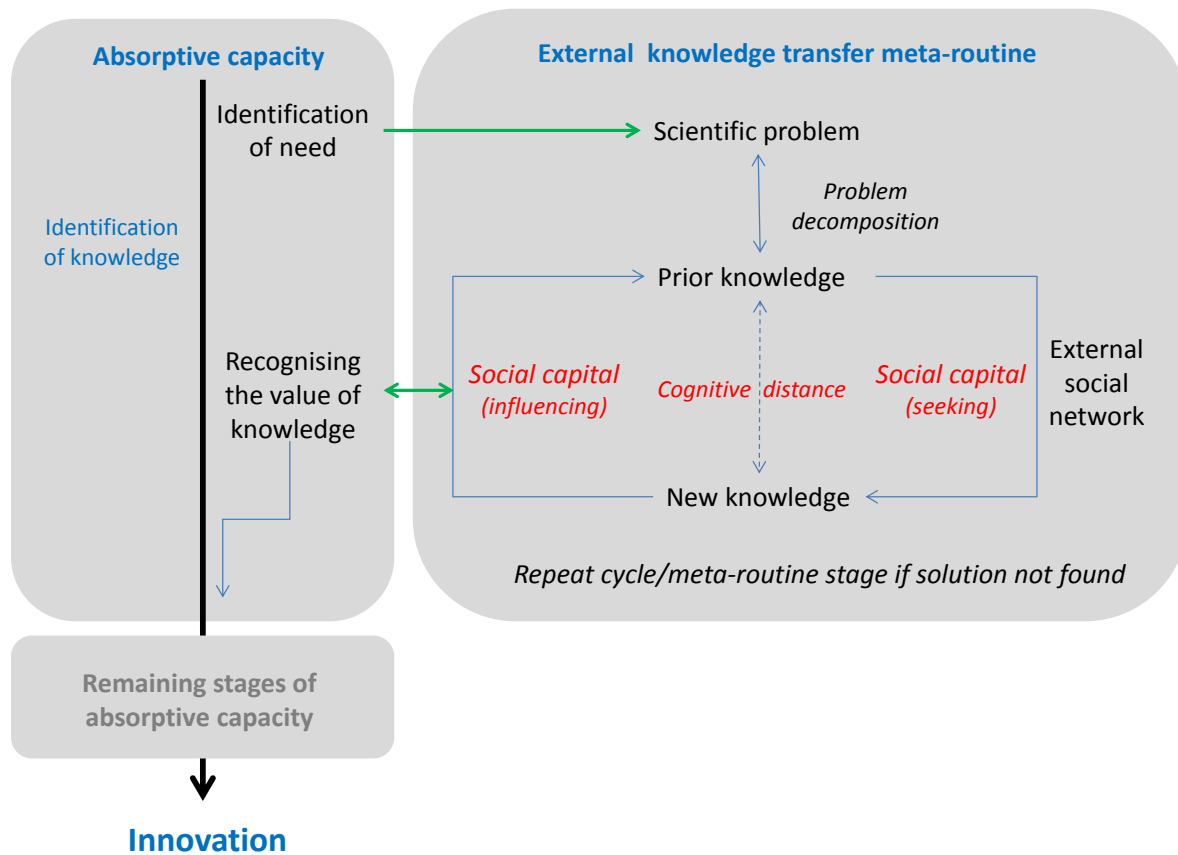
Research Question 3: What criteria are used to determine the value of new knowledge?

The overarching premise of this research is that there is a link between problem solving (knowledge transfer) and absorptive capacity through the recognition of the value of external knowledge. It is also proposed that social capital acts as a mediator in this process by enabling knowledge transfer from external networks and by adding creditability to knowledge when received from the networked source. The three research questions will provide the basis to confirm if this proposition is correct and are schematically illustrated in Figure 2.7.

Figure 2.7 provides a tentative model that illustrates the interplay between absorptive capacity (box on the left) with the external knowledge transfer meta-routine (box on the right). The absorptive capacity box identifies the acquisition stage of absorptive capacity and provides a conduit for the transfer of knowledge and ultimately the innovation potential of the organisation. These two boxes have been interconnected by the ‘identification of need’ which triggers the problem solving process and returns via the absorptive capacity stage of ‘recognising the value of knowledge.’ The external knowledge transfer meta-routine involves a cyclical process which

links the research areas of information seeking and the requirement to value new information. This process is influenced by prior knowledge (cognitive distance) and the social capital of the actors.

Figure 2.7 A schematic of the interplay between external absorptive capacity and a problem solving routine



2.11 Literature review conclusion

The literature review has provided a critical review of the extant literature in relation to the three research questions. In support of the first research question, literature has been reviewed on the characteristics of knowledge and how these characteristics may influence the effectiveness of knowledge transfer. The concept of absorptive capacity has been introduced and its relevance to knowledge transfer within social networks has been demonstrated. Social network theory has been studied through the lens of social capital as a means of identifying structural, relational and cognitive aspects of knowledge transfer.

In support of the second research question extant literature on organisational routines has been critically reviewed with particular emphasis on the use of templates and their importance in knowledge transfer routines. Current theory with regard to the micro-foundations of problem solving and information seeking routines has been reviewed in order to provide a theoretical context for the final research question. This question has been addressed with a critical review of extant theory on decision making, advice taking and the influence of the source on the perception of value.

The chapter has concluded with a proposed model of how external problem solving routines might utilise the micro-foundations of external absorptive capacity routines and be mediated by social capital. The proposed model highlights the pivotal role that ‘recognising the value of information’ might play in this process.

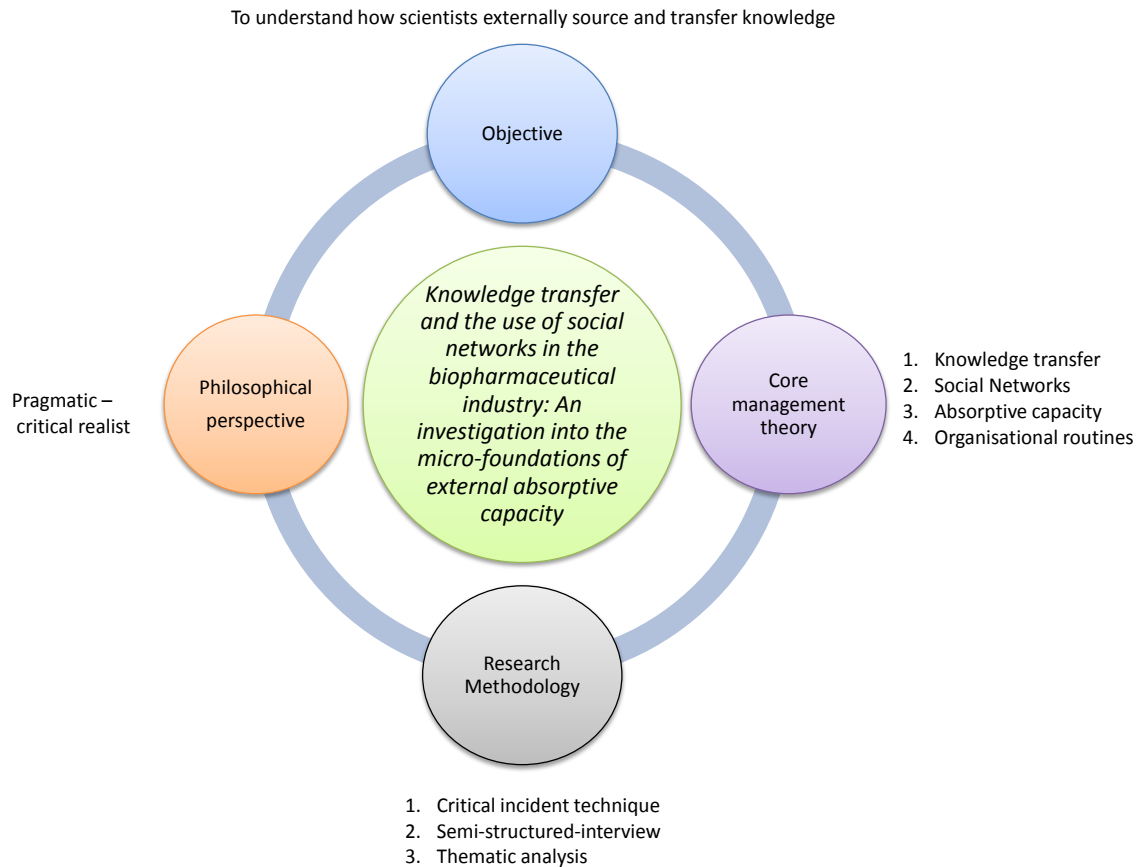
The literature review has provided a theoretical underpinning for each of the research questions and the overall research objective which seeks to determine how scientists use social networks to externally source and transfer knowledge

3 Research Methodology

The methodology chapter starts by detailing the philosophical approach that the researcher has taken with regard to the research methodology and then describes how the chosen research methodologies comply with this context. This is followed by a detailed description of each of the research methodologies that were used and how the sampling was performed and the data was collected. A review of the data analysis procedures is then undertaken with an emphasis on the reflexive practice, ethical considerations and limitations to the research

This study is in the main a deductive one, there already being significant research in the areas of knowledge transfer, social networks, information seeking behaviour and the concept of absorptive capacity. However, studies at the micro-foundational level have been limited (Kane, 2010) and the opportunity to develop the research area of how knowledge is valued prior to transfer is recognised (Yoo, Vonderembse, & Ragu-Nathan, 2011). The third research question is therefore more likely to have an inductive dimension and will aid the development of theory in this area. Figure 3.1 provides an overview of the research aims in conjunction to the research philosophy, the theoretical and methodological approaches.

Figure 3.1 Illustration of the methodological and research objectives



3.1 Research philosophy

The reality that is perceived by the researcher influences the understanding that the researcher has of the characteristics of knowledge, it is therefore crucial that these are made transparent when designing the research approach. Crotty (2009) proposes that research philosophies may be characterised by the following four hierarchical questions.

1. What *research philosophy* informs the theoretical perspective?
2. What is the *theoretical perspective* behind the methodology?
3. What *methodology* has influenced the choice of these methods?
4. What *methods* are proposed to be used?

The next section provides a discussion of the research philosophy, comprising of the ontological and epistemological perspectives which underpin the theoretical perspective and then considers how these influence the methodological choices in this research.

3.1.1 Philosophical and theoretical foundations of the research

When undertaking research it is important to consider the perceptions, assumptions and beliefs of the researcher in order to ensure that any researcher biases or perspectives are made transparent and considered in the light of the research methodology, objectives and output (James & Vinnicombe, 2002). These influences may be classified as the ontological and epistemological paradigms or more broadly the research philosophy. A consideration of ontology is important in order to understand how we position our version of reality and what constitutes knowledge within that reality. Management researchers contend that ontology and epistemology should be articulated in the research plan in order to provide the background for coherence and consistency (Hallebone & Priest, 2005).

Ontology is concerned with the *'science or study of being'* (Crotty, 2009, p. 10); or in other words the study of our view of the world and the nature of reality. The Realist ontological perspective is derived from the scientific tradition, whereas the Relativist perspective arises from an anti-scientific tradition of Humanism (Williams, 2003). The aim of the Realist researcher is to produce verifiable knowledge that will be of social use and takes the moral position that research should seek the truth regardless of their ideological stance (Hammersley, 2000). It also seeks to explain social life, typically through micro-level studies and aims to link to objective scientific account of the world to the subjective world of the individual (Hammersley, 1989). This perspective was typified by the Chicago school of sociology and authors such as Park, Burgess and Bulmer (Bulmer, 1984).

Epistemology describes the nature of knowledge, its scope and bias (Hamlyn, 1995). Maynard (1994, p. 10) succinctly defines epistemology in context of the social researcher *"Epistemology is concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate."* It is often considered that there is a close and inter-dependent relationship between epistemology and

ontology, where each informs and depends upon the other (Hatch & Cunliffe, 2006). It is for this reason that the two terms are often conceptually merged.

An epistemological and theoretical perspective may be used to evaluate or justify a research methodology (Miller & Tsang, 2010). The most common philosophical approaches in management research include those of Critical Realism (Bhaskar, 2008; Fleetwood, 2005); Positivism (Donaldson, 1996); Interpretivism (Lee, 1991); Constructivism (Mir & Watson, 2001) and Pragmatism (Powell, 2003). These are distinct from each other primarily due to the stance that they take on the relationship between ontology and epistemology.

The author's first degree is in biochemistry and he was educated with a broadly Positivist epistemology and within a Realist ontology and makes the assumption that there is an objective world that is separate from the human consciousness. However, the author has also been a practicing manager and recognises that social interactions are created and maintained through cognitive behaviour. The author takes the view that unlike the natural sciences, social behaviours are by their nature highly varied, complex and subject to multiple influences and interpretations, and are therefore less likely to be governed by testable theories; but rather built and maintained by social dialogue.

This view is widely recognised; for example Blaikie (1993) claims that the natural scientist studies nature from the outside and explains it through invented concepts and theories; whereas the social world is constructed and reproduced through social activities. Giddens (1976) proposes that the natural world has not been created by humans and so they must make sense of what is already there, whereas social phenomena stems from human interaction. Murphy (1994) takes this argument further and suggests that social factors act as a mediator between spatio-temporal reality and the natural sciences. More pertinent to this research however, is Delanty's view that social science is itself shaped by the discursive construction of problems and the seeking of a resolution to those problems (Delanty, 1997).

Empirical research in the field of small business and entrepreneurship however has identified that the majority of paradigms evident in research articles take an objective view of reality, which as the authors' state is leading to a lack of creativity and new theories and understandings (Grant & Perren, 2002).

3.1.2 Pragmatic Critical Realism

Philosophical perspectives can provide a procedural basis for research and this is particularly the case with Critical Realism (Williams, 2003). Pragmatic Critical Realism has gained increasing validity in the social sciences (Cruickshank, 2003), management (Fleetwood & Ackroyd, 2004) and marketing (Hunt, 1992). Pragmatic Critical Realism combines a Realist ontology, which accepts that the natural world exists independently to the researcher's knowledge of it and a Fallibilist epistemology which recognises that the researcher's view of the world is socially produced (Miller & Tsang, 2010; Sayer, 1992). In Bhaskar's words, in order "*to be fallibilist about knowledge, it is necessary to be realist about things*" (Bhaskar, 2008, p. 43).

Critical Realism is therefore a mediating epistemological stance between Interpretativism and Positivism (Maxwell, 2012; Mingers, 2004) and resides in the social world of human interaction rather than the hard science of the physical world (Bhaskar, 1998). In focussing on the social world, critical realism stratifies reality into the '*real*' unobservable structures and causal influences, the '*actual*' which consists of events and processes, and the '*empirical*' which are the experiences of human actors (Fairclough, 2005). A Pragmatic Critical Realist should challenge existing the structures (the '*actual*') and reimagine meanings that are attached to current practices (Kilduff, Mehra, & Dunn, 2011).

Critical Realist researchers in the field of organisation management recommend that research contributions should include more narrative research (qualitative) and more ethnographic approaches (Blackburn & Kovalainen, 2009; Blundell, 2006), as these provide insights into knowledge and learning (Sammorra & Biggiero, 2008). They may nevertheless, be highly pluralist and include both quantitative (extensive) and qualitative (intensive) designs, which aim to uncover the exploratory mechanisms relevant in particular cases (McLennan, 1995; Miller & Tsang, 2010). This pluralism is based on two presumptions; firstly that there is a combination of interpretive and explanatory understanding in the analysis of structural relations (Keat & Urry, 1982). This should be explored with methodology that explores structural relations, policies and actions in order to capture the actor's subjective meanings (Fielding, 1988; Kilduff, Mehra, & Dunn, 2011; Reed, 2008). Secondly, no methodology should be seen to be epistemically superior to another, as all are fallible, are prone to social construction and are influenced by differing ontological perspectives. However it is recognised that different methods may highlight different

aspects of the same phenomenon (Smith, 1975). Despite this pluralistic approach it is still important that the chosen research method should be considered in the light of being practical and adequate (Johnson & Duberley, 2006; Maxwell, 2012).

Additional implications of carrying out research from a Pragmatic Critical Realist perspective is to recognise that research methodologies will all be influenced in some way by the researcher's own observational language (Tinker, 1991). This possibility recognises the importance of critical reflection of the researcher's assumptions in their social construction of any discourse, in order to define the potential influences they have on their findings (Fay, 1975). Pragmatic Critical Realism demands a reflexive praxis, which does not claim to seek fundamental knowledge but instead seeks the knowledge which guides and shapes human activities (Johnson & Duberley, 2006). Critical Realism therefore takes a balanced perspective when confirming or rejecting theories that are based on empirical studies (Miller & Tsang, 2010).

In conclusion the author has taken a mediating stance between a realist and a relativist approach to this research. The findings have been accepted as a version that is close to the truth but that have been shaped by socio-cultural influences and are considered in light of this. The author has also taken a pragmatic stance and has not overly analysed the findings for hidden meaning and subjective influences beyond the obvious controls that were in place at the time of interview and during the subsequent data processing.

3.1.3 Pragmatic Critical Realist approach to the study of knowledge transfer

As a Pragmatic Critical Realist, the researcher is uncomfortable with the Positivist concept of knowledge as an identifiable commodity, which consists of facts that can be easily decoded (Gupta & Govindarajan, 2000). The author accepts that knowledge artefacts depend on an individual's interpretation (Reihlen & Ringberg, 2006) and recognises that knowledge transfer is heavily influenced by individual cognition (Duguid, 2005; Tuomi, 1999). A Pragmatic Critical Realist accepts that individual constructions are underpinned by structures of social reality and the intrinsic influence of certain technologies. These structures provide social order by either enabling or constraining the perception of the individual actor (D'Adderio, 2011; Johnson & Duberley, 2006). In consideration of these points, Pragmatic Critical Realism is well aligned

with the ‘socio-cognitive approach’ to knowledge transfer (Ringberg & Reihlen, 2008; Van de Ven, 2007).

It is for these reasons that the individual’s behavioural intentions and the identification of the causal structural conditions which affect social activities will be examined (Carter & New, 2004). These causal powers cannot be directly observed, but can be inferred through micro-foundational research and the examination of their relative effects on the actors (Reed, 2008; Johnson & Duberley, 2006). The study will reveal the practice of the micro-foundations of knowledge transfer routines and the cognitive behaviours of individuals in the recognition of value in knowledge.

3.1.4 Strategy-as-practice

A theoretical school of thought is often characterised from studies of the literature and epitomises the philosophy and methodological approach of the researchers in a particular field. A recent ‘school of thought’ in management and organisation behaviour is the ‘strategy-as-practice’ school.

Subscribers to the strategy-as-practice school of thought highlight the shortcomings of previous studies of organisational routines. They state that much of the extant research in this area has been extrapolated from aggregated organisational level constructs and outcomes, and that there is a lack of study in the micro-foundations of routines (Hansen & Vogel, 2010; Whittington *et al.*, 2003). Some authors claim that both routines and capabilities are a social reality (Felin & Foss, 2004) and that there is a lack of clarity about what practices really are in relation to individual actors’ actions or interactions (Chia & MacKay, 2007; Felin & Hesterley, 2007). Individuals after all possess ‘a-priori’ knowledge as well as experiences, skills and personal characteristics which cannot be ignored. (Felin & Foss, 2004). As a consequence the foundations and workings of routines at the individual level have not been fully developed in connection to innovation, competitive advantage and sustainability (Hansen & Vogel, 2010).

The main focus of organisational strategy research practice is on the management and the routines that are used to enact strategies (Chia & MacKay, 2007; Jarzabkowski & Wilson, 2002); and is akin to the ‘activity based view’ where practice may be observed in situ (Jarzabkowski, 2005; Johnson, Melin, & Whittington, 2003). The strategy-as-practice school of thought

considers not just the concept of the routine itself but the regular decision making and strategizing of the individual actors, thus emphasising the role of human agency during their everyday activities. Organisational strategy is therefore not just considered to be an organisational phenomenon by the proponents of the school-of-practice, but is something that members *do* as an ‘on-going’ social activity (Jarzabkowski, Balogun, & Seidl, 2007; Johnson, Melin, & Whittington, 2003).

Taking these contextual and cognitive activities into account, the strategy-as-practice approach aims to capture the origins of the routine and capability accumulation (Regner, 2008) and calls for a consideration to be made not just of the habits and preferences of the actors (Chia & MacKay, 2007), but also the innovative and creative nature of the individuals in a socially constructed world (Regner, 2008). This research has as its unit of analysis the individual problem and explores the micro-foundations of the routines that individual participants follow. This is in accordance to the strategy-as-practice school of thought and is in alignment of the ethos of a professional doctorate (Trafford & Leshem, 2009).

3.1.5 The use of multiple theoretical perspectives

Taking the view that several management theories can coexist, some researchers propose that organisations should be examined through multiple theoretical lenses (Nambisan, 2002; Rajagopalan & Spreitzer, 1996), in order to provide a holistic perspective (Douma, George, & Kabir, 2006). This approach is considered by the author to be compelling, given the lack of a general theory that deals with the broad complexity of organisations. However, the use of multiple management theories has been criticized by some management researchers on the basis that it can provide the excuse for not specifying the assumptions and implications of different theories or the compatibility between theories. It has however been recognised that these debates tend to be on a philosophical level rather than the methodological level (Miller & Tsang, 2010).

The author is approaching this research from a number of theoretical perspectives. The concepts of absorptive capacity, knowledge transfer, social networks and the micro-foundations of organisational routines are linked with associated theories. Whilst the author recognises that this adds additional breadth and complexity to the research, he believes that not to do so will leave significant unanswered influences, which may be crucial in explaining the interrelated nature of

these theories and their influence on the micro-foundations of external knowledge transfer routines.

3.2 The research challenges

3.2.1 The challenges of measuring organisational social phenomena

The investigation of social phenomena within organisations is a particularly challenging one as organisations are typically diverse, complex and changeable (Astley & Van de Ven, 1983). There exists a number of different levels and ill-defined boundaries within social processes (Fabian, 2000) and social actors still have the freedom to determine their own actions, despite being constrained by processes, rules and organisational routines (Archer, 2000; Downward, Finch, & Ramsay, 2002; Searle, 2001). The behaviour of actors may also be influenced by new knowledge which is created by researchers, leading to the charge that they may be causal in influencing organisational practice (Bradbury & Litchenstein, 2000; Knights, 1992).

In order to manage the complexity of the social phenomena, the Critical Realism Paradigm encourages the use of mixed methodological designs of both the ‘extensive’ and ‘intensive’ forms (Mingers, 2006). Extensive designs tend to be concerned with empirical correlation and statistical significance (Mingers, 2004). However quantitative statistical techniques will not reveal the underlying generative causal mechanisms that are an important epistemological foundation for the Pragmatic Critical Realist perspective (Sayer, 1992). Indeed many empirical studies in strategic management that use correlational methods, fail to directly test the mechanisms suggested by management theories (Bromily & Johnson, 2005; Tsang, 2006). This may be the reason that many of the quantitative studies which use suggested indicators, for example research expenditure as a ‘proxy’ for absorptive capacity, reach very different conclusions (Murovec & Prodan, 2009).

It has therefore been suggested that when evaluating social relations, that the researcher should be aiming to measure the qualitative relationships between variables in order to make inferences between dynamic social processes; rather than looking for the existence or the extent of a phenomenon (Williams, 2003). Also that qualitative research should be rigorous and rich in its approach and provide a meaningful contribution to organisational research (Tracy, 2010). The intensive design of this study enables the researcher to explore causal generative mechanisms

which can provide evidence of how causal mechanisms operate for different actors in different contexts. A comparison of these studies can identify the similarities and differences and how they affect the outcomes (Harrison & Easton, 2004); and identity extreme or critical cases can reveal conditions where mechanisms are subverted or blocked (Danermark *et al.*, 2002). On the basis that it may be more important to determine why a mechanism goes wrong, than it is to observe it working properly (Collier, 1994).

The author recognises the complexity of organisational social phenomena and has developed a qualitative methodological approach that aims to capture the detailed granularity of individual decisions, whilst at the same time providing a bounded, context sensitive scenario in order to illustrate the causal mechanisms within successful and unsuccessful problem solving routines. This research is therefore answering the call for complementary methods that provide more breadth and flexibility (Balogun, Huff, & Johnson, 2003).

3.2.2 The challenges of evaluating micro routines

Routines comprise of both abstract understandings and observable performances which interact in complex ways. When unpacked, routines can demonstrate an individual's ability to give meaning to and respond to problems through sequences of actions based on experience, context and emotional state (Corbin & Strauss, 2008). The deconstruction of routines can help the researcher to recognise and apply ideas and theories from all branches of social, behavioural and organisational sciences in order to explain the interactions and influences (Pentland & Feldman, 2005). Salvato and Rerup (2011) suggest that this might be achieved by breaking routines down into sequences of individual actions to understand their evolution and effectiveness.

Extant research into routines has identified that too little emphasis has been placed on the individual's role in using and modifying routines and their interactions with their social networks (Lane, Koka, & Pathak, 2006; Lewin, Massini, & Peeters, 2011; Zahra & George, 2002).

However distinguishing routines solely at the level of the individual actor is not an easy option (Pentland & Feldman, 2008). Partly because the distinction between the macro (distant from the individual) and the micro (close to the individual), is an artificial one (Corbin & Strauss, 2008).

Hence the researcher intends to trace the relationships between the macro and the micro contexts

to problems, situations and events in order to investigate the interplay between the two (Corbin & Strauss, 2008; Hodgson, 2007)

The identification of a routine is often difficult as many routines, such as problem solving and information seeking involve actions that could be constituent parts of other routines. Often, there is a significant divergence from patterns and documented procedures and it is not always possible to even determine the start or end point of a routine (Pentland & Feldman, 2005). Indeed it has been shown that organisations learn to decompose a problem into a series of sub-problems, which are governed by other implicitly coordinated systems (Egidi, 1996). Nonetheless actors recognise the specific routines that are taking place either by identifying the intended outcome, or by focussing on a particular event or action within the routine (Edmondson, Bohmer, & Pisano, 2001).

An additional complication is that in some studies the labels that are applied by the researcher (etic perspective) may not correspond to the understanding of the actors (emic perspective); but are nevertheless important to the researcher as the imposition of an etic perspective can reduce ambiguity and allow the researcher to see patterns which may not be visible to the actor (Pentland & Reuter, 1994; White, 1992). The comparison of patterns in a routine may be cross sectional (synchronic) where comparisons are made at one point at a time, or longitudinal (diachronic) which typically compares routines before and after a change event (Barley, 1990). Emically generated critical incidents, and synchronic comparisons are appropriate to this research and will provide opportunity to compare both the performative and ostensive aspects of the routines (Pentland & Feldman, 2005).

From a researcher's perspective the performative aspect of the routine may be recorded, transcribed and indexed according to a coding scheme (Pentland & Feldman, 2008). However from a participant's perspective as a routine becomes practiced and more familiar it also becomes harder to explain (Pentland & Feldman, 2005). The ostensive parts of the routine, which are likely to be abstract and comprise of significant tacit assumptions, are more difficult to observe or for the actor to verbalise, and may lead to participants merely describing the general idea of the routine which only reflects the ostensive part (Pentland & Feldman, 2005). This may lead to variability in responses depending upon whether the questions are asked with relation to

the ostensive or performative parts of the routine. One way around this issue is for the interviewer to find a single narrative thread which binds the performative and ostensive activities together as a coherent sequence (Cohen & Bacdayan, 1994). This has been achieved in this study with the participants using the critical incident technique as a means to focus on the performative part of the routine.

Narratives are typically used to divulge rich context related information (Pentland & Feldman, 2007) and can represent the social world in the form of a 'narrative network' or a network of stories (Orlikowski & Iacono, 2001). To qualify as a narrative however, the fragments of the narrative need coherence (Abel, 2004), and in the case of organisational routines this is a focus on the purpose (Czarniawska, 1998). The next section discusses how the methodology seeks to use narrative methodologies to uncover the tacit behaviour of the actors when performing knowledge transfer routines.

3.2.3 The challenges of uncovering tacit skills during the interview process

Micro-routines are tacit in nature and may therefore be difficult to uncover through the use of 'extensive design' or highly structured interviews (Ambrosini & Bowman, 2001). The degree of tacitness will however, have a bearing on the accessibility of tacit skills. Deeply ingrained tacit skills are considered the most problematic to uncover (Ambrosini & Bowman, 2001), but other forms of tacitness are more accessible and include those that can be 'imperfectly articulated' and which can be 'readily articulated' (Ambrosini & Bowman, 2001). The imperfectly articulated tacit skills are by definition more difficult to verbalise but may be represented through the use of metaphors and storytelling (Wilkins & Thompson, 1991). Storytelling is also a means of implicit communication which is commonly used in organisational contexts (Martin, 1982). The author intends to use the critical incident technique (CIT) to encourage a storytelling narrative that is unimpeded by the interviewer. This technique has been chosen as the most likely to be able to uncover the imperfectly articulated tacit skills.

The readily articulated tacit skills may be expressed by asking questions that will uncover those actions that were not consciously considered in the interview. Probing questions which focus on the situations and actions of the participant (Kvale, 1983), can provide the opportunity to elucidate the readily articulated tacit skills that the interviewees may be aware of, but may be

unseen by the interviewer (Schwartz, Groves, & Schuman, 1998). This follows work which demonstrates that if the right probing question is asked then what is tacit may be made explicit (Berry, 1987). Hence with a combination of CIT followed by probing with semi-structured interview questions, the author intends to uncover a range of tacit skills that are related to the ostensive component of the routine, and might otherwise have been filtered from the participant's consciousness (Hansen & Kahnweiler, 1993).

3.3 Methodological approaches

3.3.1 The critical incident technique

The critical incident technique was first used as a Positivist tool in social science investigations (Flanagan, 1954) where it gained acceptance for its reliability and validity. The CIT is a procedure for collecting observations and psychological principles of human behaviour, in such a way to optimise their usefulness in solving practical problems (Flanagan, 1954).

Since the 1990s CIT has assumed more of an Interpretivist approach, by taking the participant's account in the context of the cognitive and behavioural factors (Chell, 2004). Its broad appeal has provided new methodological insights into decision making, problem solving, information seeking research and emotional investigation. Flanagan defines a critical incident as “*any specifiable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act*” (Flanagan, 1954, p. 327). A critical incident provides sufficient scope for the interview participant to narrate a ‘story’ that they deem relevant to the investigation, placing emphasis where they believe it is important. Hence it differs from the semi-structured interview in that the output is interviewee centric and unfocused in its direction. Focus will however be provided by the researcher asking supplementary probing or confirmatory questions and probing during or after the narrative story telling (Giroux, 2009).

The use of CIT in conjunction with semi-structured interviews is well established. Previous research that is particularly pertinent to this study include the evaluation of problem solving capabilities of small business managers (Giroux, 2009); information seeking behaviour (Sonnenwald, Wildemuth, & Harmon, 2001); exploring social learning through problem solving in small firm entrepreneurial networks (Taylor & Thorpe, 2004) and determining the source preferences when problem solving (Savolainen, 2008). It was found to aid recall of the origin of

the problem, the context, the major information sources, the order that these were used and the development of their approach to the problem (Savolainen, 2008).

In the context of this study, critical incidents are defined as ‘memorable and specific problems that the participants had solved through the use of their external social networks’. The technique allows participants to describe the problem in their own words and talk about the problem solving stages in a way that was meaningful to them. The use of CIT in the context of the exploration of micro-routines is particularly pertinent in that it allows the author to relate patterns to causality and explore thought processes, frames of reference and feelings. The output from the CIT provides rich examples of the relationship between context, process and outcome (Chell, 2004). It has also been suggested that critical incidents which illustrate success and failure in organisational settings can also be useful in elucidating factors that would otherwise not come to light (Flanagan, 1954). The participants in this research were asked to consider both successful and unsuccessful problem solving incidents prior to the interview.

3.3.2 Semi structured interview

Interviewing involves asking questions to those that have information about a phenomenon and that the interviewer has not been able to observe. Interviewers are likely to ask interviewees to speak about themselves, provide information on others and to recall events and speculate about future situations (Snow & Thomas, 1994). Kvale defines a qualitative interview as “*an interview, whose purpose is to gather descriptions of the life world of the interviewee with respect to the interpretation of the meaning of the described phenomena*” (Kvale, 1983, p. 174). This definition is pertinent to this research as it emphasizes the importance of determining the topic from the perspective of the interviewee. Apart from the innate flexibility of the approach, interviews are particularly useful for exploring topics where meanings need to be established and is particularly beneficial in complex organisational investigation (King, 2004). This study is able to make use of the author’s technical background which will enable a full immersion into the micro-level interactions, people and technologies.

Interviews may be achieved through a structured, semi-structured or unstructured approach. Unlike the structured approach, semi-structured and unstructured interviews are not standardized, but the interview may be conducted with a series of themes or questions to be covered and still

leave the opportunity open to add further probing questions to the discussion (Saunders, Lewis, & Thornhill, 2003). This provides the opportunity for the interviewer to direct the interview to topics that had not been previously considered but which may be significant to gain a better understanding (Torrington, 1991). Without this approach the interview is unlikely to lead to a focused discussion on the relevant issues (Easterby-Smith, Thorpe, & Lowe, 2002; Robson, 2002). The interviews for this research are conducted in two parts, the first stage with the CIT and the second stage with the use of semi-structured probing questions.

3.3.2.1 Reflexive practice at interview

Reflexivity has been defined as *“the concept used in social sciences to explore and deal with the relationship between the researcher and the object of research”* (Brannick & Coghlan, 2006, p. 60). The collection and interpretation of the data requires self-awareness and an understanding of the relationship and influence between the researcher and the researched. The degree and emphasis that a researcher places on reflexivity depends on their philosophical orientation (Corbin & Strauss, 2008; Lynch, 2000). The orientation will provide an expectation of how much importance is placed on the viewpoint of the participants and that of the researcher; or what the impact is of the interviewer on the findings. There are however limitations to the feasibility of reflexivity as it is broadly recognised that much of what we do and perceive occurs in deeper levels of consciousness (Cutcliffe, 2003).

It is often assumed that better ‘validity’ can be achieved if the researcher becomes a participant in the researched group, as it is widely recognised that having a shared understanding of not just an explanation for an act but also the reason for it will provide valuable research findings (Weber, 1978). An ‘insider’ perspective can however lead to issues of association and some ‘objectivity’ may be lost in the process (Williams, 2003). Some authors subscribe to the view that reflexivity is unremarkable and that there is no particular advantage in demonstrating reflexivity in research, as it merely serves to add ‘methodological virtue’ (Lynch, 2000, p. 47). Indeed, extreme forms of reflexivity have also led to claims of academic ‘navel gazing’ and ‘watered down’ findings (Findlay, 2002, p. 220). However a more neutral and pragmatic perspective is that it may provide a useful account of the author’s ‘voice’ in the findings, which on occasions might be useful.

The author's experience in the pharmaceutical industry and a degree in Biochemistry provided useful insights into understanding the science, technologies and terminologies that were described. However, it was equally important that this 'insider knowledge' did not take precedence in interviews by proposing scenarios, steering conversation in particular directions, putting 'words in the participants mouths' and making assumptions. As an experienced interviewer undertaking the interviews was not a challenge; the use of silence, gentle probing, permitting digression to put the participant at ease and re-directing conversations was almost second nature to the author. However during the interviews the author was sufficiently self-aware to notice that occasionally he was interrupting and leading the participant in directions that they may not have followed. When it was recognised that this was occurring, the author held back and later probed the same point from a different perspective.

After the interview the author listened to the recordings with a specific focus on the interviewer's approach. This technique was used to identify if interruptions and misunderstandings occurred; as these are more transparent when the focus of the interviewer is on their own influence rather than what is being said by the participant. The listening exercise demonstrated that there were occasions when interruptions occurred and the leading questions were asked, but after careful reflection it was considered that there was likely to be minimal impact on the narrative content, the direction or context of the problem solving incidents. Thus the narrative data produced by the CIT and subsequent semi-structured interview was close to an accurate reflection of the problem solving events, but the findings will still be subject to the vagaries of recall and possible intentional or unintentional embellishment by the participant.

3.3.3 Template and thematic analysis

The transcripts from the CIT and semi-structured interviews were subjected to both template and thematic analysis. Template analysis has been largely derived from techniques such grounded theory and phenomenological analysis (Crabtree & Miller, 1999; Waring & Wainwright, 2008). The use of themes and codes provide the technique with an element of Positivism, but the social construction of meaning is reproducibly packaged in such a way that social 'facts' or observations appear to emerge (Boyatzis, 1998), indeed Crabtree and Miller (1999, p. 27) has even called the technique "*qualitative Positivism*". Template and thematic analysis are considered by most qualitative management researchers as appropriate means of collating data

With the aim of ‘discovering’ the underlying cause of human action (King, 2004). Hence template analysis is applicable to a range of epistemological positions including that of a Critical Realist which accepts much of the Positivist position of quantitative social science (Kent, 2000).

Template and thematic analysis are systematic processes of identifying the context and relating the themes into categories (Berg, 1995) and are particularly useful if there is a large amount of data being generated by interviews. King proposed that coding, which is based on the theoretical position of the research, may be undertaken prior to the interview either in the form of full encoding or as partial coding, which is refined following an exploration of the interview transcript (King, 2004). Indeed it has been suggested that coding following a grounded procedure (Strauss & Corbin, 1998) also provides the opportunity to use prior theory and personal experiences to guide the data analysis (Bourdreau & Robey, 2005). However the code is generated, it should encapsulate the richness of a theme and provide reliability and validity (Boyatzis, 1998).

This study has used a combination of higher-order ‘a-priori’ coded domains for the template analysis and lower order ‘a-priori’ themes which were proposed in a comprehensive literature review on information seeking (Alwis, Majid, & Choudhry, 2006). New themes have been added to these as they emerged from the interview transcripts. Further details of this process are provided later in this chapter.

As a possible aid to the coding process I considered the use of *NVivo* software, as the potential benefits for categorising text-based data were attractive. However after trialling the software at the pilot study stage of the research, I decided that the software and tools were distracting me from the data coding rather than aiding the process. I reverted to a paper based system which provided both speed and flexibility when evaluating alternative thematic categories; without the ‘constraints’ of a software package.

3.3.3.1 Reflexive practice in data analysis

An important component of qualitative research is subjectivity in the relationship between the participants and the interviewer, and in the processing of the data. For example it has been suggested that ‘a-priori’ coding should not influence the exploration of new ideas by providing too few codes to successfully explore the granularity of the data, or too many to cloud the

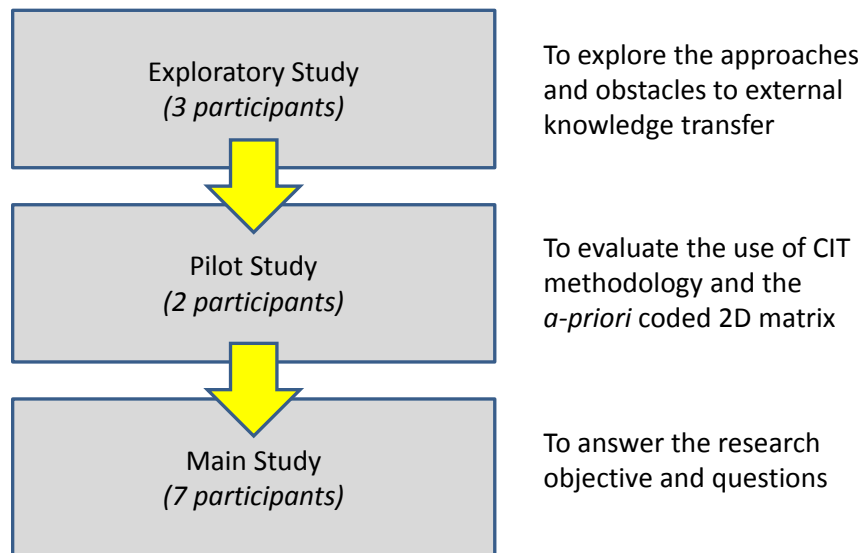
potential exploration of new areas (Boyatzis, 1998; Waring & Wainwright, 2008). The author was aware at all times to seek new codes that better fit new themes as they emerge. Template and thematic analysis was performed on the transcripts as they were produced, so that trends and themes emerged as the research progressed.

Reflexive practice was also demonstrated when codes were revisited in order to identify duplication and inconsistencies and if present they were re-coded by changing the classification of the theme, subdividing the category or through the formation of new themes. This process was repeatedly undertaken until all the themes were clearly defined and all the narrative findings were appropriately classified. This thematic process is fallible and subjective, but has attempted to identify new areas of interest that were related to previous theory and relevant to the research objectives. The ‘a-priori’ codes and thematic codes have been listed in the findings chapter in Tables 4.2 and 4.3.

3.4 Overview of the research approach

This research was subdivided into three semi-autonomous research studies, which were conducted in a sequential manner. These include an exploratory study, a pilot study and the main study. Figure 3.2 summarises the three staged approach to the study

Figure 3.2 An overview of the three research stages



3.4.1 Overview of the exploratory study

The research participants for the exploratory study were selected from three personal contacts in the biopharmaceutical industry. These included a chief executive of a German biopharmaceutical company, a business development professional involved in academic ‘spin-outs’, and a senior scientist that manages a research team in a major pharmaceutical company; together they provided a broad range of experience in different aspects of the industry. The chief executive had long experience at a senior level and was aware of the usefulness of networking, as he was involved in a number of formal and informal networked associations. The business development professional worked at the interface of academia and the biotechnology industry and could bring insights into cultural and behavioural differences. The senior scientist had experience working for different types of biopharmaceutical research groups, in a number of small biopharmaceutical companies and a major pharmaceutical research organisation.

The exploratory study involved three discrete semi-structured interviews, with the aim of clarifying the characteristics and broader industry issues; in particular in determining the use, benefits and obstacles to informal social networks in the biopharmaceutical industry. Two of the interviews were conducted face to face; the senior scientist at the pharmaceutical company was well known to the interviewer and was interviewed over the phone. Each interview was conducted with the use of open questions which were asked on the following broad topics (see appendix 1 for detailed examples).

- Organisational culture (e.g. differences between research organisations, creativity, openness, motivation to learn etc.)
- Management of formal networks (e.g. examples, size, frequency, control etc.)
- Characteristics of social networks (e.g. examples, history, changes over time, diversity, means of contact, seeking new contacts etc.)
- Use of personal contacts (e.g. examples, who, why, frequency of contact, ease of access, confidentiality etc.)
- External knowledge sharing (e.g. examples, formal, informal, transparency, understanding, ease of communication etc.)
- Serendipity (e.g. examples, how and why does it occur, benefits etc.)

With prior approval the interviews were recorded and transcribed and returned to the participant for checking. No changes to the transcripts were required and a broad analysis was conducted on the data, no ‘a-priori’ coding or thematic analysis was used in the exploratory study.

3.4.2 A pilot study to trial the methodological approach and data handling

Following the exploratory study, a pilot study was undertaken with two participants who were personal contacts in the industry and included a senior academic with a scientific role and a business development director in a biopharmaceutical company. The senior academic was interviewed face to face in a meeting room in Newcastle Business School (NBS) and the business development director was interviewed over the phone; subsequent to their approval both interviews were recorded. The interviews provided examples of scientific problems, one was seeking data, but internally within their organisation, the other was seeking a scientific recruit and extensively used a professional social network site. The complex problem solving examples

which although were not specific to the context of the study, were multi-staged and complex, and provided a useful evaluation of the interview format, data collection and analysis techniques.

From the findings and the subsequent analysis, the interviewer was able to evaluate the use of the CIT as a means to collect narrative stories of problem solving and to analyse the data with ‘a-priori’ coded template and thematic analysis. The interviews also provided insights to appropriate boundary conditions for the main study which included the background characteristics of the participants, guidance to the types of problems that might be used as examples, the selection of appropriate probing questions and to determine the time taken to complete the interviews. Whilst these two participants were outside the selection criteria for the main study (i.e. not working for the research institute, using internal contacts or using recruitment as a critical scientific problem); they did provide some useful insights to both the methodology and the research questions and will be referred to when discussing the findings for the main study.

3.4.3 Overview of the main study

Following the evaluation of the methodology in the pilot study; the main study aimed to fulfil the research objectives through a two staged interview. The first stage used the CIT and was followed by a second stage which permitted the researcher to probe aspects of the knowledge solving routine. The main study was conducted with seven senior scientists at the Northern Institute of Cancer Research (NICR) in Newcastle upon Tyne, UK. Seven senior scientists were interviewed and these provided thirteen critical incident examples of problem solving routines. These were analysed using the ‘a-priori’ coded template as evaluated in the pilot study. Table 3.1 details the interviews undertaken for all three components of the study and the number of interviews at each stage.

Table 3.1 Overview of the research sample

Participant #	Internal/external	Date	Role	Location
PP1	NA	12/04/2010	Chief Executive	Biopharm, Germany
PP2	NA	07/05/2010	Senior Scientist, ex Biopharm	Pharma, UK
PP3	NA	07/06/2010	Biopharm, Business Development	Newcastle Univ, UK
MT4	External	11/11/2010	Business Development Director	Biopharm, UK
MT5	Internal	10/11/2010	Senior Scientist	Newcastle Univ, UK
MS6	External	14/11/2011	Senior Scientist	NICR, Newcastle, UK
MS6	External	14/11/2011	Senior Scientist	NICR, Newcastle, UK
MS7	External	21/11/2011	Senior Manager	NICR, Newcastle, UK
MS7	External	21/11/2011	Senior Manager	NICR, Newcastle, UK
MS8	External	02/12/2011	Senior Scientist	NICR, Newcastle, UK
MS9	External	19/01/2012	Senior Scientist	NICR, Newcastle, UK
MS9	External	19/01/2012	Senior Scientist	NICR, Newcastle, UK
MS10	External	19/01/2012	Senior Manager	NICR, Newcastle, UK
MS10	External	19/01/2012	Senior Manager	NICR, Newcastle, UK
MS11	Internal/External	19/01/2012	Senior Manager	NICR, Newcastle, UK
MS11	External	19/01/2012	Senior Manager	NICR, Newcastle, UK
MS12	External/Internal	06/03/2012	Senior Scientist	NICR, Newcastle, UK
MS12	External	06/03/2012	Senior Scientist	NICR, Newcastle, UK

3.5 Main study data collection

A biopharmaceutical research organisation was considered suitable for the study of social networks as the exploratory study had found that pharmaceutical companies restricted the use of external social networks, a finding that is discussed more fully in the following chapter. A single institute rather than a range of organisations was selected as it provided easy access for the researcher and continuity to any findings and conclusions that are drawn. Whilst it is recognised that participants from different organisations might provide a broader perspective, the author decided that the relatively small sample size in this qualitative study, would not have provided sufficient scope for any organisational differences to become apparent. The decision was therefore made to simplify the data collection and to limit the scope to one biopharmaceutical research organisation. The NICR was considered by the researcher to be a suitable target organisation due to the leading edge biopharmaceutical research that they undertake, the extensive networks that the organisation maintains, the location on the university campus in Newcastle, the large number of PhD scientists that work at the institute and the support of the research director.

Following written approval from the research director the researcher used the institute's email database to select potential candidates. The pilot study suggested that those senior scientists who had more recently obtained their PhD were most likely to be involved in bench science and be more willing to participate in the study, than those in managerial positions. They were also more likely to use broad networks of social contacts within their university peer group and from previous places of employment, and were thus more likely to fulfil the criteria for participation.

From a list of 72 potential contacts 33 were selected at random with an approximately equal spread of gender and nationalities selected by British and 'non-British' names. The candidate selection technique was not looking to target a specific target demographic population, as the research objectives do not stipulate this; rather the aim was to ensure that the selection was as diverse as possible. Each of the 33 names selected was sent a personalised email referencing the approval from the institute's director, a brief overview of the research aims and requirements on their time.

Seven candidates volunteered to be interviewed for the main study. In the event five females and two males took part in the main study, three of the females originated from outside the UK; this was considered to be sufficiently diverse so as not to cause concerns over a lack of diversity in the sample. The relatively low response rate of 21% was perhaps a surprise, given the public support of the research by the research director of the organisation, however it was apparent that the candidates were very busy and were often conducting experiments which they could not leave for any length of time. Should further candidates have been required, they would have been sent a reminder email and if this did not have the desired response, further contacts would be made from the list; but in the event this was not necessary.

On receiving a positive response, the participants were sent a follow-up email thanking them for their interest and attaching a brief document (Appendix 2) which provided a diagrammatic overview of the research, detailed the preparation they would need to undertake before the interview and a copy of the ethical consent form (Appendix 3); which was to be signed at the interview. The preparation guidance was necessary to ensure that the participant could recall at least one critical incident when solving a scientific problem with the use of an external source.

3.5.1.1 Sample size

The unit of analysis in this study is the problem solving routine rather than the number of interviewees. At the start of the main study it was unclear how many interviews would need to be undertaken in order to obtain a sufficient number of diverse problems that provide a detailed insight into the nature of knowledge transfer routines. Researchers have suggested that this decision should be made within the context of the research focus but at the same time looking for variation, in order to maximise the potential for new properties or dimensions to be explored (Corbin & Strauss, 2008). Whilst it is difficult to determine the point of saturation (Guest, Bunce, & Johnson, 2006) the researcher determined that there were no new themes emerging after eleven problems were evaluated in the main study. Two further problems were however evaluated as the interview had already been arranged. Thus

in total 15 problems were evaluated; 13 for the main study plus the 2 problems in the pilot study that were collected under the same methodology.

3.5.1.2 Interview

Four of the main study interviews were conducted face to face in a meeting room at the NICR, thus reducing the inconvenience to the participant and providing a familiar and comfortable environment. The remaining three were conducted face to face in a meeting room in the Newcastle Business School at the suggestion of the participants. After pleasantries and a reminder of the purpose of the research, the participant was reminded that the interview was to be recorded on a digital voice recorder and the participant consent form was signed. The participant consent form had been previously approved by the Northumbria University Research Ethics Committee.

The first stage of the interview required the participant to recollect a problem in as much detail as possible and this typically took 15 minutes; but did vary depending on the complexity of the problem and the verbosity of the participant. The second stage of the interview typically took 40-60 minutes as the interviewer took the participant through each stage of the problem solving incident in a temporal fashion. During this stage open questions were asked and these resulted in additional recollection and more detail of the routine being revealed. The interviewer commonly had to redirect the participant to return to particular stages in the routine, and this was aided by the notes that were made during the interview. Digression was generally permitted if the content was thought to potentially revealing or helped to relax the participant. Examples of the probing questions are listed in Table 3.2.

Table 3.2 Showing examples of probing questions and their relation to the research questions and literature sources.

Example of main study probing questions	Theoretical connection & research question #
How did you recognise if they were approachable or not?	Characteristics of source (Alwis, Majid, & Choudhry, 2006) <i>Research question 1</i>
Were there other sources that you thought might be useful but didn't turn to... why?	Choice of source (Yaniv, 2004) <i>Research question 1</i>
Did you feel that you had to further clarify your needs before beginning the search?... How did you do this?	Problem framing (Hargadon, 1999) <i>Research question 1 & 3</i>
How did the protocol help you in the knowledge transfer process?	Use of artefacts (Nelson and Winter, 1982) <i>Research question 2</i>
In what ways did the protocol change during the knowledge transfer process?	Use of artefacts (Nelson & Winter, 1982) <i>Research question 2</i>
Did either of you have to explain things in different ways in order to reach an understanding?	Knowledge overlap (Nahapiet & Ghoshal, 1998) <i>Research questions 1, 2 & 3</i>
How important was 'gut-feel' when evaluating the accuracy of the new information?... explain how this works (metaphor?)	Importance of intuition (Mackenzie, 2002) <i>Research question 3</i>
How did you recognise that the information you had been given was relevant/appropriate or not?	Valuing of knowledge (Fang & Levinthal, 2009) <i>Research question 3</i>
How influential was the source of information when deciding on the perceived value of the information that was given?	Influence of source on valuing knowledge (Fang & Levinthal, 2009) <i>Research question 3</i>
Did you have cause to question or check the information with another source?... Why?	Stakeholder influence in valuing knowledge (Torodova and Durisin, 2007) <i>Research question 1 & 3</i>

3.5.2 Analysis of the transcript data

The interviews were transcribed by an external company and were checked for accuracy upon return. All participants were sent a copy of the transcript but none chose to correct it, this may be due to the high quality of the transcription, lack of interest or other pressing demands on their time.

All the main study and pilot study interview transcripts underwent two forms of analysis, a template analysis and a thematic analysis. The template analysis was structured on a temporal basis and used a two dimensional (2D) spreadsheet matrix in order to clarify the staged behaviour and context at each stage. The 2D matrix was proposed for the following three reasons.

1. To provide a high level 'a-priori' template which provided domains with which narrative extracts could be associated
2. To provide a tabular structure, enabling the deconstruction of the problem solving meta-routine into temporal stages.
3. To provide a tool which enabled the comparative analysis of the micro-foundations of characterising a problem, the role and development of templates in knowledge transfer; assessing the potential influence of an external source at each stage and valuing the quality of new information.

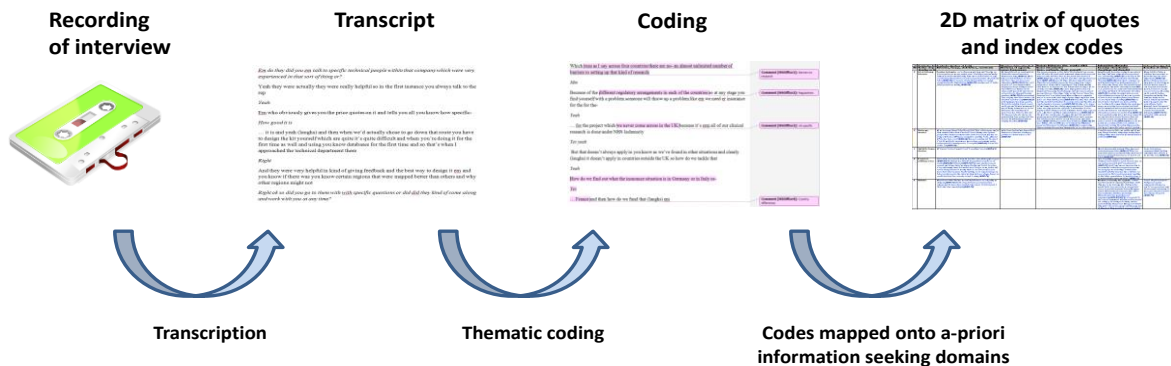
The second type of thematic analysis was less concerned with the stages of the routine but attempted to capture all the themes relating to problem solving with the use of social networks. Both forms of analysis are discussed below.

3.5.2.1 Template analysis of the transcripts using a 2D matrix

The first analysis of the transcripts was structured on a temporal basis and used a two dimensional matrix with the higher order 'a-priori' codes as recognised by Alwis, Majid and Chowdry (2006) and illustrated in the column headings in Table 2.3. These 'a-priori' domain topics had been re-confirmed through the findings of the pilot study and included a contextual, situational, personal/social-cultural and informational high level codes. These

were placed as headers in the 2D matrix columns; the rows representing the temporal stages in the problem solving routine. Figure 3.3 provides an overview of the process used.

Figure 3.3 Diagrammatic representation of the process from interview to final matrix



This following procedure was used for all of the main study interview transcripts and was used in the analysis of each of the three research questions.

- I. The transcript was compared for accuracy against the audio recording; errors were corrected.
- II. Each interview candidate was assigned a code according to the type of study that they were participating in (PP, Pre-Pilot; MT, Methodology Test; MS, Main Study); the order in which they were analysed and the critical incident problem that they identified.
- III. The transcript was then used to highlight participant narrative extracts and indexed comments were placed against each extract. Each highlighted and indexed section encapsulated the meaning of the statements and acted as signposts to particular types of thought process or action within the routine. A highlighted template with comments inserted is illustrated below

did you need their assistance at all?

No the they were really there there were certain steps which were more technically em you you needed to you know needed technical experience to do them and so it was at that point that I would approach them and em and ask them just to watch to make sure I'm doing that ok

Comment [MSOffice1]: Experience required

Comment [MSOffice2]: Confirm by practice and observation (teacher student)

- IV.** 'Free text' was then added to the relevant domains (spreadsheet cells) in a blank 2D matrix (see appendix 4), which gave contextual guidance to the researcher by ensuring that extracted narrative was going to be positioned in the appropriate domain. It also provided further high level domains which were related in similarly staged and semantic ways (Spradley, 1979).
- V.** The highlighted transcript was then used to map the narrative extracts into each domain according to the 'a-priori' high level codes (column) and the temporal stages (row) of the problem. Depending on the complexity and focus of the routine, some domains in the 2D matrix were more appropriate than others and some were redundant at particular stages. Each inserted narrative extract was indexed to the transcript through the comment number.
- VI.** The transcript was then re-read to confirm that potentially useful quotations or actions had not been missed.
- VII.** The 2D matrix was then further studied to ensure that quotes were placed in the appropriate domains, and if not they were adjusted accordingly.
- VIII.** The 2D matrix then underwent a second order analysis to move beyond the data domains and towards interpretation of the relationships between the domains and the staged themes (Van Maanen, 1979). The aggregated matrices were analysed on the basis of successful and unsuccessful stages (the intermediate stages where a complete solution had not been found). The matrix domains provided a tool for a comparison and identification of commonalities, differences and new perspectives.

3.5.2.2 Thematic analysis of the transcripts

The above process was applied to all the interview transcripts and provided a temporal summary of the actions and causal behaviours at each stage of the problem solving routine against high level 'a-priori' codes. In addition to the template analysis, a thematic analysis was undertaken to identify thematic codes that were associated with the transcript extracts. These codes were also 'a-priori' coded from those summarised by Alwis, Majid and Chowdry (2006) and detailed in the body of Table 2.3.

The thematic process was a repetitive and cyclical one of reduction, amalgamation and the renaming of the themes in order to categorise the content more appropriately (Bourdreau & Robey, 2005). The codes were substantiated by checking that there is a minimal overlap between them, and that the associated narrative extracts accurately reflect the theme that they are associated with (Boyatzis, 1998). During this re-coding process some of the terminology of the ‘a-priori’ codes that was initially used in the coding process was changed in order to better reflect the findings in this study. A comparative summary of ‘a-priori’ codes and the ‘new’ thematic codes are provided in the findings chapter.

A range of illustrative narrative extracts have been used in the findings chapter to highlight theoretical points and to demonstrate cognitive processes during the problem solving routines, thus illustrating the causal interaction between the actor and the micro-foundations of knowledge transfer routines (Lewin, Massini, & Peeters, 2011).

3.5.3 Follow up questions

Following the analysis of the main study it was determined that it would be useful to ask follow up questions to the three scientists that used the CIT to illustrate knowledge transfer problems. These questions were to provide a practitioner’s perspective on the possible use of organisation training in technology transfer in relation to the second research question. At the same time copies of protocols before and after the technology transfer process were requested, in order to provide evidence of the use of templates. The follow up questions are listed below

1. Was any formal or informal training provided by your organisation in technology transfer?
2. In hindsight, would there be any potential benefits of technology transfer training?
3. If so, how might this be achieved?

3.6 Ethical considerations

The research required primary data collection from research scientists and therefore invoked a number of ethical considerations. The primary data collection and other professional research practices were undertaken according to the research ethics code as stipulated by the Research Ethics and Governance Handbook (Northumbria University, 2009-2010). Minors or any persons at a disadvantage were not interviewed in this study and data was stored in accordance to the data protection act (1998). Prior approval of the ethical dimension of this research was given by the University Research Ethics Committee in October 2010.

Documented research approval was sought from both the participant and the organisation, the anonymity of the interviewees and was guaranteed (see Appendix 5 for NBS approved company agreement exemplar). The research director of NICR was not concerned with the organisation remaining anonymous, and indicated this on the ethical approval form. Prior permission was given for the interviews to be recorded and transcribed (Silverman, 2006) both by the director and by each participant. The transcript from each interview was sent to each interviewee in order to confirm the validity and accuracy of their statements. None were corrected.

Interview recordings, transcripts and narrative analysis were all coded upon evaluation, the names of the participants were held separately on a personal (password protected) laptop. Hence interview data could at no time be linked to individual participants.

3.7 Limitations of the research

The creditability (validity) of the methodology and the findings has been considered at the end of the discussion and conclusion chapter; this section concerns itself with the limitations of the methodological approach. In common with all forms of empirical research and in line with the Pragmatic Critical Realist philosophy this study is recognised to have limitations. The methodology has been considered in order to determine the scale and areas where these limitations might reside.

The participants were asked to use examples (critical incidents) of problem solving behaviour. Whilst problem solving has been shown to be associated with individual and organisational understanding and learning (Huber, 1991), there are other mechanisms of knowledge transfer which have not been studied in this research. This potential limitation is however a deliberate attempt to create a boundary to the research objectives and to focus the interview participants. This provides a focus on a particular form of knowledge transfer that is easy to recall and also provides a clearly defined organisational routine which is subsequently comparable.

Criticisms of qualitative techniques for data collection and analysis, such as CIT and template analysis, are that the findings lack generalizability and that the research is based on small sample sizes. Others highlight that qualitative interpretations are criticised as being superficial accounts rather than ‘proper research’ (Curran & Blackburn, 2001). The author however shares the opinion of the researchers who maintain that the benefit of focussing on small samples is that it provides a more in-depth understanding of the workings of the organisation (Chell, 1998). Qualitative methodologies are also the only means to achieve the aims and objectives of the research in determining the ‘actor-centric’ micro-foundations of external knowledge transfer routines.

In keeping with the Pragmatic Critical Realist paradigm, this study has undertaken to provide an explanatory understanding in the analysis of the causal influences, social phenomena, structural relations and an understanding of the behavioural intentions and motivations of scientists when transferring external knowledge (Carter & New, 2004; Keat & Urry, 1982; Reed, 2008). The researcher assumes that the accounts will bear a direct

relationship with their real experiences beyond the interview, although he recognises that they can still at times be subject to bias and exaggeration (King, 2004).

In adopting a narrative methodology with a focus on knowledge transfer, the researcher has made a series of epistemological choices which reflect the author's knowledge, skills and prejudices. This includes the recognition that critical incidents the participants may be engaged in a form of 'identity work' in which they were constructing versions of themselves, by following 'scripts', being involved in political action, or otherwise practicing impression management for the benefit of themselves and the researcher (Alvesson, 2003). The final results and the discussion of them are therefore likely to be the product of significant 'mediation' both on the part of the participant and that of the researcher (Brown, Stacey, & Nandhakumar, 2008).

The author was alert to this and endeavoured to limit its impact. In order to accurately reflect the interview participant's views, the author has attempted to be reflexive and self-aware during each interview and tried to avoid influence through leading questions or a selective analysis of the data. Transcripts were sent to each participant for accuracy checking and alterations would have been made if required, none were. Whilst these actions are unlikely to overcome all the forms of bias that inevitable creep into the research; the author's aim is to accurately reflect the nature of problem solving routines and the social interactions that occur in the biopharmaceutical industry, are representative of these activities in this specific context. Implicit to the Pragmatic Critical Realist tradition; the author recognises that outcomes of this study will not represent an objective truth, but merely provides additional insights into the research area.

A potential disadvantage of the CIT is that the incidents are always based on the recall of a story which relies on a good memory; however as this is a 'critical incident' the researcher assumes that recall is more likely. Transparency is often called into question with regards to qualitative methodologies. In this study the interview recordings, transcript and thematic codes are all available for scrutiny and will provide an audit trail such that the original quotation may be reviewed if the context or emphasis was of interest.

The research has focused on one biopharmaceutical research institute in the UK and the findings may not be applicable to other industries or elsewhere in the UK or overseas. However the resultant findings will be representative of the sample selected. Ideally, equal numbers of men and women would have been appropriate in the sample, as there have been some perceived gender differences in information seeking networks literature (Ibarra, 1995). However as the focus of this study is not specific to information seeking, this is not considered to be an important issue.

3.8 Methodology chapter summary

This chapter has provided an overview of the research philosophy and methodological approach that was undertaken in order to collect the data and analyse the results. It has been demonstrated that the research methodology is in keeping with the Pragmatic Critical Realist approach and has been optimized to achieve his research objectives. The combination of the critical incident technique with a semi-structured interview has been justified as useful and relevant to the research objectives. The challenges of measuring social phenomena, evaluating micro routines and uncovering tacit skills have been recognized. In line with the Pragmatic Critical Realist philosophy the importance of a degree of reflexivity has been noted both in the data collection and analysis.

The research methodology chapter has highlighted three stages of research investigation (exploratory, pilot and main study), and justifies the means and method of participant selection and data capture at each stage. The method of data analysis for each of the three stages has been described; the pilot and main studies use 2D matrices to capture the problem solving stages and a thematic analysis for capturing the scientist's behaviors and cognitive processes.

The author has recognised the ethical considerations and limitations of the methodology and has described how he intends to meet the ethical obligations and manage the research limitations so as to optimise the resulting output to be true and faithful to his participants as possible.

4 Findings

The findings chapter analyses the results that were obtained through both the exploratory and the main studies. In order to provide qualitative support for the arguments which are developed and critically discussed in the discussion and conclusion chapter, more than 18 hours of interviews have been transcribed, thematically coded and succinctly presented in this chapter.

The structure of the findings chapter will begin with a review of the outcomes of the exploratory study, with particular emphasis on the comparative use and the development of social networks in the pharmaceutical and biopharmaceutical industry, and the organisational barriers to knowledge transfer. The findings from this study are then summarised and conclusions are drawn which support investigation of the research questions in the main study.

The findings of the main study are then considered and structured around the three central theoretical streams of literature as presented in the literature review, namely social networks, knowledge transfer and absorptive capacity. The narrative extracts which are used in this chapter are chosen to represent the typical or interesting comments from a larger number of thematised narrative extracts on each subject. Additional illustrative narrative extracts have been tabulated against thematic codes in Appendices (6-12) and will be referred to throughout this chapter. All extracts are quoted verbatim in order to retain a degree of realism and context to the narrative and may be traced back to the original transcript source through the index code which is associated with the corresponding narrative extract(s), for example P1= Participant 1 of the exploratory study; MS9 = Main Study 9, followed by the transcript line number. The main study concludes with a summary of the findings which are discussed in relation to the extant literature in the following chapter.

4.1 Findings from the exploratory study

The exploratory study was undertaken in order to provide an understanding of the issues behind knowledge transfer in the pharmaceutical industry and to confirm the need for a better understanding of how external social networks are used. This was achieved by interviewing three industry professionals in order to gain three different perspectives. These included a German Chief Executive of a biopharmaceutical company; a senior research scientist that has worked in both small and large bio/pharmaceutical companies and a business development executive responsible for academic bio-medical spin-outs.

The exploratory findings are considered in two sections, the first compares the use and development of social networks in both pharmaceutical and biopharmaceutical organisations and the second section takes a closer look as to why the use of external social networks are restricted in the pharmaceutical industry. These findings provide some confirmation that knowledge transfer may be in part affected by the organisational support or otherwise in the use of external networks in each type of organisation. A thematic analysis was not undertaken on the exploratory study interview transcripts as the narrative extracts were a direct result of semi-structured questions.

4.1.1 A comparison of the use and development of biopharmaceutical and pharmaceutical social networks

The responses from the three participants demonstrate that biopharmaceutical organisations actively use their social networks to solve problems, seek appropriate information and recognise that the maintenance of a strong social network as being essential to long-term success (Appendix 6, Table 1). One surprising finding was that the German Chief Executive (biopharmaceutical) promoted the use of social networks as a strategic resource that was used when recruiting scientists; stating that *'people can make a huge difference'* [P1:634] if they bring their social networks to the organisation.

In contrast this study indicates that pharmaceutical scientists may have extensive social networks external to their organisation but they may rarely use them for solving problems; they are more inclined and encouraged to use internal sources. This does not appear to be an

issue to the pharmaceutical participant as he states that there are often suitable sources of knowledge available within multinational pharmaceutical companies. This point is illustrated in the following narrative extract.

“I think probably again large companies em you know, I would say, does anybody know anyone in chemistry that can to help me with this issue, or this question? And almost always somebody internally that knows could answer your question; that’s the benefit of a big company” [P3:526]

Biopharmaceutical organisations use their networks to solve problems, stimulate creativity and actively use their networks to seek relevant information. The business development professional discussed the importance of gaining a ‘*critical mass*’ of scientists as a means to stimulate creativity. The German biopharmaceutical executive used terms such as ‘*alert filter*’ and ‘*osmotic barrier*’ to describe a process where scientists are actively encouraged to seek information with certain characteristics. This new knowledge needs to be pre-filtered so it can be seen to be relevant and useful. In the words of the biopharmaceutical Chief Executive:

“You try to guide people and when you even say to them, ok if you communicate with the outside world, just just keep in mind what we are interested in, yeah so there is some type of alert filter for this osmotic barrier” [P1: 867]

It is also apparent that a biopharmaceutical scientist’s social network develops over time in order to adapt to the different scientific needs of the organisation and changes in business focus. This was explained by the German Chief Executive as requiring a different social network for early stage biopharmaceutical development, through different drug targets and to later stage clinical trials. The German Chief Executive was also stated that it is important to regularly refresh their network in order that it remains critical and dynamic. It is assumed by the author that this is a reference to the generation of new and challenging ideas and in order to avoid the network from going stale. However it was also stated that reliable and useful network contacts were always maintained.

4.1.2 Organisational restrictions in the use of social networks in the pharmaceutical industry

The culture of exchange of information appears to be very different in large pharmaceutical companies than in smaller, more informal, biopharmaceutical organisations. The pharmaceutical scientist stated that larger pharmaceutical companies place more emphasis on confidentiality in a social situation than smaller biopharmaceutical organisations do and through their policies and procedures try to restrict the deliberate or accidental transfer of intellectual property. Apparently this is achieved by pre-approval of the content of external presentations, reinforcing the importance of confidentiality, reducing the risk of damage to the reputation of the company through the loss of IP, and encouraging scientists to think twice before discussing anything remotely confidential. The following extracts from a pharmaceutical scientist illustrate the broader narrative.

“So anything that’s written or say presentations or papers and that sort of stuff, all have to go through a vetting procedure which is far more, em, require far more levels of sign off than you’d ever have needed at at prev- sort of small companies, em, in terms of other and we’d have to sort of comply with various policies regarding what we we what we can say and what we can, also what we can listen to, what we can hear bizarrely [P3:434] ... I’m very aware that they’re very very cautious about, em, any disclosures on that sort of line, I feel like sort of makes you would feel ‘mealy mouthed;’ that’s my problem; is you know we go to conferences and we can’t actually we’re presenting data from sort of three and four years ago for various reasons.” [P3: 308]

The pharmaceutical participant seems to be suggesting that pharmaceutical companies enforce confidentiality in two directions; both to filter what is shared with external scientists but also to discourage the ‘accidental’ overhearing of what might otherwise be useful information. This restriction on the exchange of knowledge was considered by the pharmaceutical scientist as being directly linked to the competitive nature and the funding regime of the industry. In comparison the pharmaceutical scientist suggests that the biopharmaceutical organisations are less constrained from a knowledge sharing perspective and regularly exchange ‘confidential’ information with external sources. This may be in part

due to the fact that that corporate image is of less importance to the small biopharmaceutical company. However there was a warning from the business development professional that the scientists often share more than they should, but this is countered by the German Chief Executive with comments to the effect that sharing some knowledge establishes trust and better working relationships.

It is suggested by the German biopharmaceutical Chief Executive that the relaxed means of exchanging confidential information may actually benefit the organisation by helping to develop long term relationships between biopharmaceutical scientists. Sharing information in an informal manner was seen to be a means to explore the possibilities of a more formal exchange of information. This was not generally considered to be a problem as long-term relationships between the actors were often built on trust and the broader social network was considered by the German Chief Executive to be a '*type of closed-shop.*'

To summarise, these exploratory findings support the notion that knowledge transfer through external social networks may be inhibited in a larger pharmaceutical company by their internalised culture and external dissemination procedures. This is most likely to be as a result of commercial pressures and the competitive nature of the industry. This small exploratory study has also indicated that research scientists in universities and biopharmaceutical organisations actively share information and proactively use their social networks to stimulate ideas and to solve problems. The impact of potential knowledge loss or damage to the organisation's reputation would appear to be less of an issue in these organisations. These two very different approaches to knowledge sharing and the use of social networks are likely to influence the degree of knowledge transfer.

In conclusion the exploratory study supports the concerns of other industry analysts (Haas & Park, 2010; Murray & Stern, 2007; Newell *et al.*, 2008; Pisano, 2006) in that knowledge transfer in the pharmaceutical industry is restricted and might account, at least in part, for the relative lack of innovation in the industry. Biopharmaceutical organisations appear to be less restrictive in their use of external social networks and are therefore worthy of exploration into how knowledge transfer occurs, and from an absorptive capacity perspective, how new knowledge is valued.

Additional narrative extracts for this section of findings may be found in Appendix 6, Table 2.

4.2 The main study

The exploratory study has shown that the use of social networks is important to biopharmaceutical organisations in the transfer of new knowledge. The main study required access to research scientists in a biopharmaceutical organisation which had links to other organisations.

The main study was conducted at NICR which is a biomedical research institute based on the city campus of Newcastle University in Tyne and Wear, UK. The institute aims to improve the management of cancer and leukaemia by developing medicines for adult and paediatric, solid and blood based malignancies. Founded in 2001, the NICR has gained a global reputation with 90% of its research classed as internationally excellent or world leading (Northern Institute for Cancer Research, 2012). The institute functions within the Faculty of Medical Sciences at the University of Newcastle. It houses more than 200 clinicians and scientists in a purpose built open-planned multidisciplinary facility; additional clinical input and imaging facilities are provided by local hospitals.

The NICR maintains formal collaborative relations with a number of cancer charities, the National Health Service, pharmaceutical companies and other research organisations from around the world. The NICR has had for example major pre-clinical drug discovery collaborations with Astex Therapeutics, Astra Zeneca, Cancer Research Technology, Pfizer and Sienna Biotech. The NICR scientists are also highly networked with many being members of European Organisation for research and treatment of cancer, contribute to soft tissue and bone Sarcoma research groups and pharmacology and research into molecular mechanisms special interest groups (Northern Institute for Cancer Research, 2012).

In order to investigate the use of informal external social networks in the transfer of knowledge, nine participants were identified. With the aid of the critical incident technique (Flanagan, 1954) these candidates identified fifteen problems which had utilised social networks. Two of these participants were not employees of NICR, as they were the subject

of the pilot study which trialled the critical incident technique. A small number of pilot study narrative extracts have however been used in this chapter as they provide interesting comparisons with the other participants; where used these have been identified.

Although the research questions are process orientated, the characteristics of the participants and the problems that they solved are still of contextual interest. All the participants wish to remain anonymous and because of the relatively small size and specialist nature of their work, detailed biographies are not disclosed in this thesis. The participants have however been categorised into two types, 'senior managers' and 'PhD scientists.' The 'senior managers' have control of subordinates and have large scale project management responsibility. One female and two male managers are represented in the sample; they are over 40 years old and had at least 25 years' experience in NICR and other biopharmaceutical laboratories. The larger sample comprises of what has been termed 'PhD scientists,' this group contains four females, all in their late 20s and have in the last four years obtained their PhDs. All the candidates have been working at some level in the biopharmaceutical industry for at least 6 years.

The main distinguishing feature between the two participant groups is the level of experience and likely size of their social networks. It was difficult to determine if their approach to problem solving was different as the problems the senior managers faced were different to those of the PhD scientists. In general the senior managers were more concerned with strategic problems, whereas the PhD scientists were concerned with shorter term, smaller scale projects, the largest of which was methodology transfer.

The study has identified four different types of problems that the participants solve, seeking resources (data or biological materials), legal hurdles (National and International), methodology transfer (complex and lengthy procedures) and methodological issues (analytical or procedural). The attributes that distinguish between the methodology transfer and methodological problems is one of scale and intent. Methodology transfer involved a physical presence at another organisation to observe the detailed and often intangible techniques in order to learn from them. The techniques are then transferred directly to the home institution for use, thus reducing time, cost and extended 'learning curve' problems.

The methodological problems were characterised by issues that occurred in an otherwise successful method in the problem solver's laboratory and required assistance to solve the problem.

These classifications demonstrate the broad range of needs and common problems that are solved by scientists. Putting to one side the legal and recruitment examples, the majority of the problems are associated with gaining resources or achieving success in a scientific method, rather than solving theoretical concepts; as might have been expected. The problems that were identified through the use of the critical incident technique and their characteristics are summarised in Table 4.1

Table 4.1 A summary of the participants and their scientific problems

#	Participant type	Problem Code	Problem (critical incident) description (<i>MT4 & MT5 are pilot study participants</i>)	Problem feature	Problem Category
1	<i>Bus. Dev. Director (Pilot Study)</i>	<i>MT4</i>	<i>Seeking scientific employee</i>	<i>Recruitment</i>	<i>Resource</i>
2	<i>Senior Scientist (Pilot Study)</i>	<i>MT5</i>	<i>Seeking scientific data internally</i>	<i>Data requirement</i>	<i>Resource</i>
3	<i>PhD Scientist</i>	<i>MS6a</i>	Seeking a source of biological material	Biological material required	Resource
4	<i>PhD Scientist</i>	<i>MS6b</i>	Seeking theoretical material for lecture	Presentation material required	Resource
5	<i>Senior Manager</i>	<i>MS7a</i>	Legal requirements -patient samples	Complex distributed problem	Legal
6	<i>Senior Manager</i>	<i>MS7b</i>	Legal cover for international project	Distributed problem solving	Legal
7	<i>PhD Scientist</i>	<i>MS8</i>	Transfer of methodological protocol	Methodology transfer	Meth. transfer
8	<i>PhD Scientist</i>	<i>MS9a</i>	Development of new method with aid	Methodology transfer	Meth. transfer
9	<i>PhD Scientist</i>	<i>MS9b</i>	Development of new method with aid	Methodology transfer	Meth. transfer
10	<i>Senior Manager</i>	<i>MS10a</i>	Cell growth problem	Problem with widespread impact	Methodological
11	<i>Senior Manager</i>	<i>MS10b</i>	Specialist surgical needle use	Technique problem	Methodological
12	<i>Senior Manager</i>	<i>MS11a</i>	Cell growth problem	Contacts rule out user error	Methodological
13	<i>Senior Manager</i>	<i>MS11b</i>	Analytical methodology problem	Analytical problem	Methodological
14	<i>PhD Scientist</i>	<i>MS12a</i>	Transfer of methodological protocol	Methodology transfer	Meth. transfer
15	<i>PhD Scientist</i>	<i>MS12b</i>	Transfer of methodological protocol	Methodology transfer	Meth. transfer

In order to further illustrate the types of problems and the mechanism by which they were solved, all the problems underwent an analysis using the 2D matrix as described in the methodology chapter. By way of example, two completed 2D matrices are available in Appendix 7 (MS6 and MS9). This process enabled a temporal analysis of each problem solving routine with each step being illustrated by narrative extracts. An analysis of each step was important in order to relate contextual factors to each decision stage. A more detailed description of each of the problems which were previously identified in Table 4.1 follows.

- **Searching for a scientific recruit [pilot study] [MT4].** A new account manager was required by the biopharmaceutical business development director for a sales region in the USA. Through an unplanned meeting at a conference, a recruitment consultant proposed some candidates. Whilst quite good, they did not meet all the criteria. A request was then placed on the social network site LinkedIn and a previously unknown contact recommended another candidate. The candidate was interviewed and was instantly liked. The senior management and scientists of the company then met with him and confirmed his appointment. It appears to have been a good decision.
- **Internally seeking data for a new project [pilot study] [MT5].** This senior scientist requested data for a department but received highly complex data, containing irrelevant information and lacking important facts. They took the data to a meeting of ‘experienced heads’ in order to work through and to achieve a consensus; however their collective knowledge was not adequate. Unsolicited help was provided from outside the group which moved things forward but not to completion. The seeker then directly approached the head of research and arranged a meeting which resulted in a mechanism to extract the relevant data in a simple way. This solution was particularly beneficial as it was easy to disseminate to other interested parties.
- **Search for scientific presentation materials [main study] [MS6a].** Presentation materials were required by this PhD scientist at short notice to do a presentation in a scientific area that was new to them. They contacted a university friend through Facebook. The friend recommended a web-site containing material that was appropriate, was easy to understand and was reliably sourced. The website has since been recommended and used for other purposes.
- **Requirement for a biological model [MS6b].** The PhD scientist required a biological model and approached a senior colleague who recommended a contact in the USA. They approached the source directly, mentioning their mutual contact and arranged to

meet at a scientific conference. They established a shared interest and the ‘mouse model’ was provided. They have since closely collaborated on other projects.

- **Clinical study with legal problems with regard to holding and reusing DNA samples** [MS7a]. The participant is in senior management and at the time managing an International clinical trial. They had several hundred potentially useful biological samples from a previous study which had been already been approved and they required the use of these samples for a new study. This new study however, required new ethical approval and agreement from the patient donors (many of which had since died). They contacted more than twenty sources, through emails and meetings to find a way forward. Eventually they found that they could re-assign their biological samples to a generic collection called the ‘research tissue bank’ as this already had an established legal basis. This overcame the legal problem.
- **International clinical trial, liability problem** [MS7b]. The senior manager identified the issue of liability for clinical patients at an early stage in the clinical trial, but it was found that UK indemnity was not sufficient for the other European partners in the study. The participant met with the project partners to decide the best way forward. Each country investigated the problem from their country’s legal perspective with the help of administrative and legal stakeholders. A solution for each region was found, but the solutions created additional cost which had to be covered out of existing budgets.
- **Methodology [technology] transfer to own laboratory** [MS8]. This PhD scientist needed to transfer a scientific protocol from a German laboratory to a UK laboratory. Two trips were undertaken to observe the German scientists in their own laboratory and to ask questions with regard to the technical detail. During these visits a new protocol was developed which was more robust in its use. The method was then tested in the UK laboratory with a different technician following the new protocol; the protocol was further modified before it was considered to be fully ‘fool-proof’.
- **Requirement for a new method** [MS9a]. A new scientific method was required by this PhD scientist. The participant initiated the search for a suitable method by searching a scientific database and through the internet. After they had gained some ideas they contacted two scientific suppliers and a company in Munich, both of which provided technical assistance. Due to a lack of scientific resources at the Institute they then sought and obtained permission to work at the Sanger Institute. The methodology

was tested and worked well and is now used back in their own laboratory. In recognition of the assistance, a joint publication is likely with the Sanger Institute.

- **Methodology transfer & practise** [MS9b]. This PhD scientist required a new scientific method to solve a problem and used a supplier and a German company to provide expertise and resources in transferring protocols from one laboratory to another. This involved three months at the laboratory practising, learning and testing the method, prior to a successful transfer to the UK laboratory. Joint publication is likely in recognition of the help that was provided.
- **Cell growth problem** [MS10a]. This senior manager had a problem that their cell cultures were not growing. They tried different batches of growth media and contacted the supplier who claimed that there were no known issues. Others within the institute that were using the same media either experienced no problems or were trying different suppliers and adding other nutrients in order to solve similar problems. As each group of scientists were experiencing different, although related problems, there appeared to be no common solution. Scientists did not coordinate their problem solving efforts but worked independently from each other. The problem remains unresolved
- **Improved needle technique required** [MS10b]. This senior manager was experiencing problems in using sampling needles. The current sampling technique was problematical as it required practice and skill to successfully collect an adequate biopsy volume. The participant searched widely in the scientific literature for tips in technique and needle types but found no solution. Subsequently at a conference they were able to discuss the problem more widely with their peers. One conference delegate suggested an alternative type of needle, which was costly but the participant was subsequently planning to try it.
- **Cell growth problem** [MS11a]. This senior manager tried to use a previously published method with their own cell cultures. A three month trial with this methodology was not successful. They then contacted three independent and experienced ex-colleagues for advice. None had used this type of cell and so the participant concluded that the experiment was unlikely to work. They changed their focus to an alternative cell line, which was likely to work but was unlikely to be optimal. The problem is still unresolved.

- **Methodological problem** [MS11b]. This senior manager had an analytical technique which only partially worked and needed further optimisation. They contacted an analytical supplier which had previously been knowledgeable and helpful and they provided assistance which solved the problem. No obligation was explicitly stated although the participant did later purchase supporting materials from the supplier.
- **Method transfer from scientific paper** [MS12a]. This PhD scientist was attempting to use a published method for their own purposes. However the publication lacked sufficient information and the publishing scientist could not provide this. The participant searched internet and contacted other scientists in order to fill in the ‘gaps’ of their knowledge and to solve the problem and, although suggestions were made, the problem was not solved. Finally they found supporting information on a supplier’s data sheet which provided a workable solution.
- **Method transfer from USA** [MS12b]. A partnership between two laboratories was being managed by this PhD scientist. The UK laboratory was attempting to ‘mimic’ the USA laboratory’s methodology; however the method was not producing the correct results. Numerous phone calls and emails to the American scientists have not solved the problem, and despite ‘working’ materials being sent to the UK the method is still not working. The participant would like to observe practice in the USA and feels sure that this would help to identify the issue, but a lack of funding will not allow for this.

4.2.1 Thematic codes derived from the interview transcripts

As previously discussed in the methodology chapter, both template and thematic analysis were performed on the interview transcripts. The template analysis used ‘a-priori’ codes as column headers in the 2D matrix. These high level codes included ‘contextual’, ‘situational’, ‘personal/social-cultural’ and ‘informational’ themes. The thematic analysis also used some ‘a-priori’ coding as a starting point and further developed these codes in conjunction with new thematic codes. In the end a total of 19 higher order themes and 51 second order codes were identified or re-confirmed from the ‘a-priori’ list. Table 4.2 has been reproduced from the literature review (Table 2.3) in order to highlight the ‘a-priori’ codes that were anticipated in the study. All the factors that have been re-confirmed and found relevant to this study, have been highlighted in bold.

Table 4.2 Dimensions and factors influencing information source preferences

Adapted from (Alwis, Majid, & Choudhry, 2006)

Contextual (work related)	Situational (organisational)	Personal/Socio-cultural	Informational (credibility and quality)
Work roles Power Complexity of the problem Pressure to find solution Potential audience Access to technology Motivation	Organisational structure Organisational culture Motivation/incentives Nature of industry Competitive situation	Cognitive style Educational/professional qualification Age/Gender Work experience Longevity with company Information seeking style and preference Membership of professional organisations Social influences Personal motivation	Acceptable quality Accessibility of source (proximity, time, social and economic cost) Availability Choice of sources Awareness and prior success with source Information richness and clarity Quality of source (credibility, authoritativeness, currency) Speed of response Trust

The ‘a-priori’ codes that have not been found in this study include *age/gender*, which was not a research focus of the study, but neither was it highlighted by the participants as a factor in information seeking or the choice of source. There was no evidence of *information seeking style* being a factor in either information seeking behaviour or related to the preference of source, but again this may not be surprising as it was not a factor that was being specifically investigated. Finally the *speed of response* was not identified by any of the participants as being important when seeking solutions, but serendipity of timing was identified as being significant on one occasion. The lack of acknowledgement for this theme may be due to the relative longevity of the problem solving process. This does not mean of course that these previous findings are not relevant to the biopharmaceutical industry or appropriate in other contexts.

All the thematic codes that were found in this study have been listed in Table 4.3 and aligned to the three predominant streams of theory and the three research questions. Those that are in bold font are the ‘a-priori’ codes which have previously been identified in the literature. These themes will be discussed in the next sections detailing social networks, knowledge transfer with the aid of templates and the absorptive capacity construct, valuing new knowledge.

Table 4.3 Thematic codes resulting from the main study and aligned to the three theoretical streams

Research themes (aligned to research questions)	Primary code (‘a-priori’ code in-bold)	Secondary code (‘a-priori’ in bold)
Social Networks Research question 1: How do scientists use their social networks to obtain knowledge?	Access	<i>Who?</i> <i>Why?</i> <i>How?</i> <i>Referrals</i> <i>Reciprocity</i> <i>Personal relations/History</i>
	Power	<i>Influence</i>
	Luck	<i>Serendipity</i> <i>Timing</i> <i>Intuition</i>
	Benefits of assistance	<i>Personal development</i>
Knowledge transfer Research question 2: How do scientists use templates in knowledge transfer?	Benefits of methodology transfer	<i>Access to knowledge</i> <i>Access to resources</i>
	Use of existing protocols	<i>Use of existing protocols</i>
	Problems with tacitly	<i>Problems with tacitly</i>
	Mechanisms for understanding	<i>Communication</i> <i>Observation</i> <i>Note-taking</i> <i>Questioning</i>
	Re-writing the protocol	<i>Understanding</i> <i>Lack of understanding</i> <i>Learning problems</i>

		<i>Encoding tacit behaviour</i>
	Knowledge overlap [teacher/student]	<i>Teacher/student</i> <i>Different knowledge base</i>
	Benefits of previous experience in methodology transfer	<i>Benefits of previous experience</i> in methodology transfer
	Use of new protocol by others	<i>In student's laboratory</i> <i>Final modification of new protocol</i>
	Personal motivations	<i>Personal motivations</i>
Absorptive capacity Research Question 3: What criteria are used to determine the value of new knowledge?	Problem task characteristics	<i>Clarity of solution- objective</i> <i>Clarity of solution-subjective</i> <i>Simplicity</i>
	Knowledge quality/measures of value	<i>Quality</i> <i>Relevance</i> <i>Specificity/Repeatability</i> <i>Accuracy</i> <i>Reliability</i> <i>Currency</i>
	Relational/behavioural characteristics	<i>Weight to source credibility</i> <i>Perceived experience</i> <i>Knowledge demonstrability</i> <i>Authority</i> <i>Reputation</i> <i>Trust and the source</i> <i>Trust and the technology</i>
	Knowledge overlap	<i>Understanding</i> <i>Familiarity</i>
	Decision making	<i>Judgement and decision making</i>
	Stakeholders	<i>Stakeholders</i>

4.3 Social networking

The previous exploratory study indicated that social networking has been found to be extensively used by scientists in biopharmaceutical organisations. The findings relating to the use of social networks as a means to solve problems and enable knowledge transfer are the subject of this section. The thematic codes that are associated with this topic include findings regarding the access to sources of information, influences such as power and reciprocity on the use of social networks and motivations behind the selection of a source. These findings will be reviewed and illustrated with participant narrative extracts. Appendix 8 provides additional illustrative narrative passages that exemplify these findings.

All the critical incident examples have shown that prior to the choice of source there is an initial stage of recognising a need and problem framing. The internet and other published sources are primarily used so that when help is sought the seeker more fully understands the nature, scale and scope of the problem. It was stated by one PhD participant that this is particularly important when new and possibly senior contacts are to be contacted, as the problem has to be clearly presented. In addition and usually subsequent to the initial ‘data’ scoping stage, social contacts are used as a secondary means of scoping the problem.

4.3.1 Findings with regard to access to external sources

Following the scoping process local sources within the company may be the first to be approached, but on other occasions, for example the PhD scientist that was seeking presentation materials, a known external source in the scientist’s personal network is used. Approaches to initial contacts are often made with the use of email. Email was described by a PhD scientist undertaking methodology transfer as being useful because the email content can ‘*set-the-scene*’ by explaining the problem and if the email is carefully constructed it may also provide a framework that might help to structure a solution. This is illustrated by the following quotation.

“Email is good, because you do collect all the things together, and er, not just like picking phone for a second, oh how do you do that and you’re just like also write down notes more carefully; and then you just also get mail back so you have like a protocol, rather than you do like you can lose some information on the phone sometimes, so if you like small bits of information.” [MS12:29]

Subsequent contacts throughout the life of the problem were typically made by telephone, email and video or face to face meetings. Senior managers most commonly used Webcasts but this may have been specifically related to the geographically distributed legal problem, where many stakeholders were involved in finding a solution.

The participants and in particular the PhD scientists, often turn to social contacts which were made at university and had since transferred to different organisations. If suitable contacts were not available in the problem solver's network, referrals and recommendations were sought with the aid of other scientists. These referees were most commonly senior scientists which were considered to have appropriate networks and when consulted they suggested contacts from within their own network. One example included the PhD scientist that used their manager as a referee as they had a contact in the USA which was known to have a 'mouse model.' On these occasions it was commonplace for the seeker to refer to the referee in the initial communication, thus providing an introduction. No examples were found where the referee contacted their source on behalf of the seeker, but it is assumed by the author that this may also occur.

The three senior managers in the study stated that useful social contacts are maintained over the scientist's career, even when the scientist moves to a similar role in a new organisation. However, the social network is also expanded with the addition of work colleagues and other contacts made through referrals, conferences and other meetings. The importance of longevity in a personal relationship was regularly stressed by both the senior managers. The business development director in the pilot study indicated that long relationships develop trust; a point that is made in the following narrative extract.

"Obviously it makes it [social networking] far more enjoyable, but also you know, I know that because of that strength of relationship that it does give me a solid, you know foundation." [MT4:138]

This study also provided examples of how an embedded or 'socially networked' scientist may be used in two ways, both as a source of information and as a seeker of information. It would appear that scientists not only provide help in solving problems but to a lesser extent use their own social networks to solve their own problems. This was the case with one senior manager who was regularly asked to help with methodological problems and also required help with their own cell culture problem.

It would appear that social network contacts may also be made through scientific social networking sites. One senior manager has used a drug development internet based forum but found it less than helpful in answering problems, but there was one occasion when they learned from another scientist's problem.

4.3.2 Influences on the use of social networks

Other than the previous themes that were associated with the use of social networks, other themes which influence the use of social networks have emerged from the transcripts and have been coded as power and reciprocity. Power was represented in the problem solving examples by position and through the control of financial and scientific resources, such as project budgets and specialist laboratory instrumentation. Powerful contacts were often respected by the relatively junior PhD participants and they treated these relationships with care; paying particular attention to a thorough framing of the problem and the respectful approach that they made to the source. However it was stated by one senior manager that if the problem was an interesting one, the more 'powerful' source would often be happy to help.

Power was also used in problem solving as a means of enforcing behaviour, for example by 'calling in favours' or when referring a subordinate to a networked contact. One senior manager cited an example of a friendly relationship which had developed between them and a more junior scientist, until a professional disagreement between them threatened to undermine the authority of the senior manager. As the manager stated, it created a '*conflict of interests*.' In this instance the manager's decision was enforced and once this was accepted by the subordinate scientist, normal social relations were resumed.

Whenever help was provided by a networked contact there was often an unspoken or tacit expectation that the source may on some future occasion 'call in the favour.' This reciprocity was not made explicit in any of the participant problems, but it would appear that the greater the help provided, the higher the unspoken expectation. For instance reciprocation was not necessarily expected if it involved simple data transfer, such as in the search for presentation materials; but joint publication was considered to be a reasonable exchange for weeks of 'in-house' methodological assistance; or an order might be expected if a supplier had helped to solve a problem. This unspoken 'expectation' was highlighted by a number of the scientists and is typified by the following extract

“Yeah I mean you’d want something back [laughs] yourself wouldn’t you? If you were to invest that much time and effort and money into... training someone, it’s always nice to get something back, ...definitely if they came to me for advice, definitely I would you know I would offer it, I wouldn’t want anything back you know it’s... ’cause it’s repaying the favour” [MS9:77/78]

4.3.3 Motivations behind the selection of the source

Sources were selected by the participants for reasons including their knowledge, reputation, experience and access to alternative resources. Contacts that had more experience often held senior positions which also implied that they had a broader range of networked contacts and a *‘bigger picture’* with regards to the problem. One senior manager claimed that the reason he is often used to solve problems was because of his longevity in the laboratory.

In this study, reputation was judged by one of several means, by referral through a respected contact, the seniority of their position, their publication record or the size of their research group. For instance a PhD scientist stated that *“looking though their research publications and so on I think they are pretty good”* [MS8:19/20]. On occasions the specialist nature of the industry dictated the use of unique resources, such as a ‘mouse model;’ of which there were only two in the world. This seemed to both enhance the reputation of the sources and limit the alternative options. In other problem solving examples the availability of expensive and specialised instrumentation also influenced the choice of source.

When solving a problem the scientists also regularly seek the help of suppliers, this was the case when two senior managers each needed to solve problems with their cell growth media or their analytical methods. It transpires that suppliers often had highly specialised knowledge through their experience of solving problems in other organisations as is illustrated by the following extract

“They obviously they have sales reps as well, in general they em are people who’ve come from an analytical background and have moved into sales; so they usually have a good er knowledge” [MS11:33]

The reasons why the scientists in this study were motivated to solve problems and to provide help, included having a genuine interest in the problem and the solution; the satisfaction and personal pride/reputation of having solved the problem and the opportunity to develop new

knowledge and new social contacts. One PhD participant claimed that helping others and not knowing how the new contact might be used in the future was an interesting dimension of the job.

Luck and serendipity were often mentioned by the participants in relation to the critical incident problems. This typically took the form of unexpectedly finding out useful information during a conversation or by beneficial timing, often by having the right person in the right place at the right time. All the participants that commented on serendipity or luck stated that you could help to 'create your own luck,' through the engagement with and the expansion of social networks. Intuition only seemed to play a role when interacting with others for instance when finding that they 'are on the same wavelength;' but also when the solution is another person, as was demonstrated in the pilot study when selecting a recruit. Intuition was not however a theme that was associated with other aspects of scientific problem solving.

The themes that have been thus far documented are associated with social networking and are related broadly to the first research question. These will be revisited in the discussion and conclusion chapter in conjunction with the extant theory in the use of social networks for information seeking and problem solving.

4.4 Knowledge transfer - the use of templates (protocols)

The use of social networks as a mechanism to gain access to new information has been established in the exploratory study and has been demonstrated in the solving of problems with the aid of social networks. How knowledge is transferred is not always apparent, but the use of artefacts, templates or protocols is a recognised method of codifying knowledge in order that it may be transferred. All the problems encountered in this study utilise the supporting use of artefacts in the problem solving and knowledge transfer process. These artefacts included legal documents, manufacture's data sheets, websites, presentation materials, reports, SOPs and most importantly for methodology transfer, templates or in scientific parlance 'protocols.'

In the main study five of the problems directly relate to methodology transfer issues and will be used as exemplars to illustrate the use of templates. These problems have in common three female PhD scientists that undertook the methodology transfer. The inadequacy of existing protocols resulted in the recoding of the method in the form of a new protocol, before transfer could occur. All the thematic codes were created solely from these interview transcripts. Additional exemplars of narrative extracts and their associated descriptors may be found in Appendix 9.

4.4.1 The development of protocols

The problems associated with scientific protocols in this study stem from the trait that the existing protocols did not contain sufficient detail to allow them to be successfully used by other less experienced scientists. In order to overcome this issue, a scientist who wishes to use the methodology elsewhere needs to observe the original protocol in practice, a process that also requires forms of rich communication and repeat questioning. Once an understanding of existing practice is achieved, this knowledge is used to adapt and enhance the protocol predominantly by adding more detail and codifying tacit practice.

The importance of understanding practice was highlighted in all the methodology transfer problems and was particularly pertinent to the creation and subsequent practise of the new protocol. This learning took place between the existing user and the 'novice,' in a form of 'teacher' / 'student' relationship. It was clear that without assistance from the 'teacher' the process would either not happen, or would be long and resource intensive as was illustrated in the following extract.

“It was actually it was a very technically demanding protocol you know. It took forty five days to do the whole thing, ... from you know step one to step you know twenty, em, and so it could have gone wrong at any certain point and it was really I think like I say, we would have generated results because we would have got something back; but I don’t think it would have been as specific or as good” [MS9:60]

Learning from existing practice was highlighted as being important but it was also apparent that access to resources such as equipment, disposables, control materials etc. is an also central to methodology transfer. The participants all stated that the use of these resources was critical in ensuring that the protocol would work. Apparently the use of different laboratory equipment and consumables provided potential sources of protocol variability, in a technique in which the ‘student’ scientist was unfamiliar. When the participants questioned the ‘teacher’ about the finer points of the protocol it was sometimes evident that the original rationale behind some of the parameters and techniques had been forgotten. Under these circumstances a pragmatic approach was taken and the protocols were accepted as they were, whilst ensuring that these parameters were not changed.

As previously mentioned it is evident that the level of practical detail is not sufficient in most protocols or published papers, and this was summed up by one PhD participant as a protocol typically contains only *“half the information”* [MS8:35]. Commonly it was not the scientific parameters that were absent; presumably as these were most likely to be forgotten they were documented for future reference. Rather the protocols were written by those that were very familiar with the technique and who tended to ignore the important skills and experiential detail that others might not be familiar with.

In order to learn the necessary tacit skills and ensure that the protocol worked in less skilled hands, a form of rich communication was required. Verbal communication was considered by the participants as essential, with other forms of communication being considered to be a poor substitute. The following quotation is typical of the PhD scientists.

“I always thought to transfer a technique you need to communicate, otherwise you can’t if you usually just get sent the devices with a description it’s never good enough, you need to have someone to speak to” [MS8:79]

Several participants commented on the importance of both the quality of the communication that was required but also the benefits of being friendly with the ‘teacher.’ It was indicated

that a personal friendship both aided the ease of communication and also allowed the ‘student’ to ask ‘dumb’ questions without the fear of ridicule. This friendship often developed from a common background of the ‘student’ and the ‘teacher,’ it was suggested by one PHD scientist that it was their age, education and relatively recent completion of PhD which helped to establish a common bond.

In addition to rich conversation, observing the protocol working in an ‘experts’ laboratory was claimed to be the best means to achieve a rapid and accurate methodology transfer. The following narrative extract is typical.

“You know you can write it down, but I think it’s actually seeing someone physically do it is different” [MS9:64]

Observation was typically accompanied by repeated questioning and note taking. Notes taken at this stage were subsequently converted into an enhanced draft protocol, which was always more detailed and therefore longer than the original. One PhD participant claimed that they needed to “*ask again and again and again,*” [MS12:41] and that she recognised this was probably going to make her unpopular with the ‘teacher.’ According to one PhD scientist the writing process was slow and painstaking; with one participant using the evenings to reflect on what she had seen and to write up the details. The process is illustrated by the following narrative extract.

“I remembered and could write it down and once you have the full text you can shrink it again to the details which you actually really need to know.” [MS8:41]

When writing the enhanced protocol, care was taken to ensure a sufficient level of detail but it was also important to avoid ambiguity and the possibility of ‘*misinterpretation.*’ Once the new protocol was created it was checked with the ‘teacher’ in order to ensure accuracy and applicability. This collaborative process between the ‘teacher’ and ‘student’ often required several iterations before the protocol was considered to be robust.

Once the enhanced protocol was considered to be complete, two of the three PhD participants practised the methodology in the ‘teacher’s’ laboratory using their new protocol but were unaided by the ‘teacher.’ Once it was determined that the technique worked it was then transferred to the ‘students’ own laboratory and practised often with a different combination of instrumentation, reagents, consumables etc. The final test was to pass the protocol to a new

user to determine if it can be successfully performed without further intervention; one PhD scientist likened her research associate to a ‘chimp’ as they would be the ultimate test of method viability.

4.4.2 The influence of knowledge overlap and previous experience

For understanding to occur between the ‘teacher’ and ‘student’ it was clear that some overlap of knowledge was required; previous experience in methodology transfer and protocol writing was also seen to be beneficial. Somewhat surprising to the author, was that previous experience in the use of the methodology and instrumentation was claimed to be more important than the knowledge of the underlying science. This was illustrated by a number of comments; the following narrative extract is an example

“I think it’s more the understanding of and it was kind of my project, so it’s like how it all fits together.” [MS9:69]

On this theme one participant emphasised the benefit of coming from a different scientific field as it provided a reason for asking ‘dumb’ questions, provided a guide as to what sort of questions needed to be asked and indicated the level of detail that was required. In one of the methodology transfer examples (MS8), the ‘student’ came from a cancer background whereas the ‘teacher’ was from an antibody background; it was stated that having different scientific backgrounds created a mutual respect for each other’s complementary experience. It would appear from this study that existing experience and tacit skills in the technique were a potential disadvantage when attempting to identify and explicitly document all the protocol steps.

Finally it was also shown that protocol enhancement became a personal objective and motivation for the ‘student,’ with success being measured when the new protocol was successfully used by a scientist that was not familiar with the process. The sense of satisfaction of a ‘job well done’ was commented upon by all the participants involved in methodology transfer and it was considered to be a recognisable personal achievement.

4.4.3 A comparison of protocols before and after modification

In order to understand the practical intricacies of methodology transfer and the writing of a new protocol, an example of a protocol before and after modification was obtained. Appendix 10 contains this protocol, in the both the original format and the enhanced format. The

original protocol is comprised of two pages; the first is a list of ingredients (reagents and buffers) with their respective concentrations; the second page consists of a list of seventeen steps or actions which contain the scientific parameters, such as temperatures, concentrations, speeds and timings.

During the recoding process the original protocol evolved into a significantly more detailed protocol but the number of steps remained constant. In order to illustrate the additional detail that was added in the revised protocol, one stage has been taken from the original protocol (before) and compared to the same stage in the final protocol (after). The following extract illustrates the additional tacit detail that has been added and includes hints and tips which should be followed in order to optimise the methodology.

Before: *'Elute bound proteins with IMAC column wash buffer (50mM Ma-phosphate buffer pH7.5, 250mM NaCl. 35mM imidazole.'*

After: *'Elute bound proteins with 50ml 1xPBS (for anti-CD33)*

Use not more than 500ul each fraction, otherwise protein too diluted!!!

Pipette elution buffer carefully on top of bed, no splash-destroys packaging of the bed and hinders maximum elution!!!!

TIPP for decision which fractions to collect: BRADFORD on 96 well plate, (900ul 1x Bradford solution from Biorad + 100ul flow through), collect drops in Eppis and combine fractions with most blue in BF-test

Analysis of this protocol before and after enhancement, shows that the new additions fall into four categories

- Instrumentation and methodology technical conditions
- Tips for better performance or warnings of pitfalls
- Notes on why steps or procedures are important
- Tacit skills to enhance the methodology

These details provide for an improved ability to transfer the method to different environments with different users, consumables, sources of reagent and instrumentation. It also provides a

deeper understanding of why each stage or condition is important so that emphasis is placed at these points and shortcuts are less likely to be made.

4.4.4 Training in methodology transfer

Subsequent to all the participant interviews, the author contacted three of the methodology transfer participants and asked three questions relating to the management of methodology transfer; the questions and responses are available in Appendix 11. In brief, there was no formal training provided methodology transfer techniques. It is also apparent that training might be beneficial if it was based on general concepts rather than specific methods, as there is no one correct way to undertake methodology transfer. Finally, experience was seen to be critical when developing these skills as a thorough practical understanding of analytical techniques is required, an understanding of the underlying science is believed by the participants to be of less importance. For instance, one PhD participant came from a validation background and claimed that this helped her to quickly identify the important features of the method.

The responses to the questions relating to the benefits of experience and training in methodology transfer and protocol enhancement, will be considered in the discussion and conclusion chapter

4.5 Absorptive capacity - valuing new knowledge

The previous sections have uncovered the micro-foundations of the use of external social networks and templates in the knowledge transfer process. Extant literature in this field has shown that the availability of knowledge is only useful if it can be recognised as potentially valuable. This study uses problem solving as a proxy for knowledge transfer; the evaluation of a solution to a problem provides a foil for the determination of the characteristics and influences when determining value. This critical step is recognised by many authors as the first stage in the absorptive capacity construct.

The narrative extracts that relate to these influences are linked to the characteristics of the sources through the final two columns in the 'a-priori' coded matrix, which are knowledge quality and knowledge creditability. It is important to link the source characteristics with the cognitive evaluation of the value of the solution at each step as the extant theory suggests that both may be considered when valuing new knowledge. The 2D matrix was therefore used in conjunction with thematic codes which were identified from the interview transcripts; examples of two completed 2D matrices may be found in Appendix 7.

The thematic codes that are related to absorptive capacity have been associated with additional narrative extracts and may be found in Appendix 12, Tables 1-3. The first table relates to themes that are associated with the characteristics of the problem which may affect the clarity and subjectivity of the solution. The remaining sections include the determination of knowledge quality and creditability and the importance of knowledge overlap.

4.5.1 The clarity of the problem

The clarity of the problem is likely to have a bearing on the ease of identification of the solution. In all the critical incidents the problem was clearly defined and was the case even if the path to the final solution was initially unclear. For instance resource problems fulfilled a material need, whether it was data, theoretical material, biological material or in the case of the pilot study when a new recruit was required. Legal and ethical problems required specific solutions that met legislative requirements, methodological and methodology transfer problems required the adjustment of a method or the complete transfer of a process. All of these problem types provided conditional and explicit boundaries to a successful solution. Most of the decision making in the problems that were encountered was therefore objective in nature and could be clearly defined by the initial problem framing exercise.

The benefit of a clearly definable objective was that it provided a clear stop signal that indicated when an appropriate solution had been found. This was described by a pilot study participant as being “*black and white*” [MT5:81] or distinguishable from “*stuff that I didn’t want*” [MT5:30]. Although in some cases, such as determining an acceptable level of purity, or the relative benefit of a new biopsy needle; the stop decision appeared to be based on relative criteria in comparison to other purifications or other biopsy techniques. These measures would appear to be more subjective as one of the PhD participants anecdotally (not recorded) suggested that other influences like time pressures may influence the acceptance of the solution.

In a number of problems the solution that was chosen was said to have the benefit of being ‘*simple*.’ The senior scientist that participated in the pilot study and was seeking data, claimed the benefit of a simple solution was that it was easier to disseminate and ‘*defend*.’ The PhD scientist that was seeking presentation materials saw the recommended website as a simple starting point which could be developed.

4.5.2 The determination of knowledge quality

Additional narrative extracts related to the themes of knowledge creditability may be found in Appendix 12; Table 2. Participants commented on the ability to recognise an appropriate solution as being a learned process, born out of experience. It would appear from several of the interviews that this might work on a negative basis with the problem solver being sceptical and critical of potential solutions, until they were confirmed by some other means as being acceptable.

“I would take her ideas on board, but I would also have my own ideas as well you know; so I’d kind of merge the two together.” [M6b: 94]

Terms that were ‘a-priori’ coded as indicators of quality included relevance, specificity, accuracy, reliability and currency. Relevance was implied on a number of occasions as ‘*appropriateness*’ to a problem and this was particularly evident in the pilot study data seeking problem (MT5). Perhaps not surprisingly, specificity and repeatability were also important criteria of solutions to scientific problems, as repetition is an important criterion of scientific validity. This was illustrated in the following narrative extract.

“It was more you could repeat the data, it was more you know you could replicate itEm better, and em, like I say it was more specific so it was better for our our needs.” [MS9:19]

Related to reliability, the robustness of a solution was also considered to be important by the participants. To the extent that even if the solution is provided by an otherwise reliable and reputable source it will often be independently assessed as the ‘problem solvers’ own reputation may be effected by a wrong outcome. For example the PhD scientist who required a ‘mouse model’ insisted that she checked the viability of what she had been sent by the otherwise reputable source, stating that *“you’ve got to feel comfortable with it yourself.”* [M6b:36]

The final dimension that is considered to be related to quality is the currency of the solution. In the problem solving examples, currency was demonstrated either by the latest research methods or the use of the latest equipment. The following narrative extract illustrates the influence of currency as indicated through the latest equipment and also the influence of reputation on the acceptance of a solution.

“It’s all really organised to be as high throughput as possible you know, I walked into one room and so I think one of the sequences at the time was like half a million pounds, and they must have had forty or sixty of them lined up[MS9:41] ... I think they’re em, they lived up to their reputation.” [MS9:45]

4.5.3 The determination of knowledge creditability

Additional narrative extracts related to the themes of knowledge creditability may be found in Appendix 12; Table 2.

As previously noted the selection of a source for a scientific specific problem largely relied on the ability of the source to provide a solution. It is also apparent that in some instances such as sourcing a ‘mouse model’ and the methodology transfer problems, that the field of study is so small that they could only be solved by a few members of the scientific community. This had the benefit that sources were more likely to have the relevant experience and could be more directly targeted, but it also limited the number of suitable sources that could be approached.

This study also indicates that the creditability of knowledge obtained from the sources is influenced by the reputation of these sources. The creditability of the source for the scientific

problems was provided by the source's publication record or the reputation that the source has in their field. Personal experience of the source was also perceived or demonstrated through their subsequent actions which served to confirm that their experience is aligned to the problem solvers' expectations. One PhD scientist (MS8) that was involved in a methodology transfer problem claimed that in hindsight that the source was the best person to contact. Authority and reputation also seemed to provide clues with regards to creditability of the source and this adds weight to the information that is received. This is most succinctly summarised by a senior scientist in the following pilot study extract.

"Relevant, appropriate and trustworthy information, I suppose mainly because of who he is."
[MT5:68]

One senior manager however, also warned about the dangers of accepting the reputation of a source at face value. They gave an example of a highly respected journal (The Scripts Group) which is considered to be a high impact journal; but in which an article was shown to be poorly researched.

Reputation and authority have also been linked in this study to trust as an indicator of reliability. The word 'trust' was frequently used by all the participants to describe source quality and reliability. In all cases this was based on reputation and personal experience. The following narrative extract from a PhD scientist indicates that trust is based on experience.

"You trust them [laughs] a little bit more than somebody novel you know you doing it."
[MS9:26]

In the case of a physical article or method, the phrase '*proof of use*' was also used as an indicator of trustworthiness.

4.5.4 The importance of knowledge overlap

The source characteristics would therefore appear to influence the recognition of value, but it is also apparent that cognitive influences such as knowledge overlap is also important when making decisions on the value of information. Knowledge overlap between the source and the recipient is assumed when solving any of the problems. Indeed sources were sought who were thought to possess relevant and highly specialised knowledge. Where this was not so easy, for example when discussing scientific principles with other professionals such as

accountants or lawyers, the participants referred to knowledge overlap as ‘*reaching an understanding*’ or by sharing the ‘*important issues*,’

A representative selection of participant narrative extracts may be found in Appendix 12, Table 3. The findings suggest that knowledge overlap provides the basis for discussion, understanding and improves the ability of both parties to contribute to the solution. The following narrative extract from a senior scientist illustrates why knowledge overlap is important.

“You’ve got to put it into context and you’ve got to tell them why you’re doing it, in the way that you’re doing it; otherwise er, I think it’s quite hard to do those things in a complete vacuum” [MS7:98]

However it was also highlighted that things change, for example even those that were once familiar with a subject can lose the ability to understand information, especially if over time it has evolved into a different form. In the problems this applied to both the sources of data as well as science and analytical technology which had subsequently ‘evolved.’ This can lead, as in the pilot study data seeking problem, to an inability to interpret the data, as the terminology and format was very different to what the participant had been used to.

As previously indicated; intuition and judgement did not appear to be important when making scientific decisions. However one clear example where intuition was required was in the pilot study example of finding a recruit, as this decision was partially based on personal ‘chemistry.’ Phrases such as being “*on the same wavelength*” [MT4:41] indicated an intuitive contribution, whereas “*he had the right kind of qualities that I was looking for*” [MT4:44] indicated more of an objective contribution to the same decision. In this recruitment example personal chemistry appeared to be an important influence, although the perspectives of other stakeholders also influenced the final decision.

The demonstrability of knowledge or the recognition of appropriate knowledge has also been found in this study to influence the recognition of value. The findings indicate that knowledge in a subject can manifest itself in a wide variety of ways, for example by presenting in a subject, their publication record, as well as by the source’s reputation or authority which have previously been discussed. In the following extract it would appear that both the reputation of the source and the degree of knowledge overlap has influenced the

degree of knowledge demonstrability as they claimed that the source had superior knowledge and was therefore better able to interpret the data.

“He had more knowledge about these sorts of posts, he could interpret it in a better way than I could.” [MT5:54]

In approximately half of the critical incidents other stakeholders were involved in the final decision and these often had a vested interest in the solution that was being considered. In the case of the clinical trial legal problem, stakeholders each carried equal responsibility for solving the problem in a distributed manner. One PhD scientist admitted the involvement of stakeholders in the decision making process by stating:

“You get sort of confirmation from people who are, you know, have a vested interest in it.” [MS7:18]

In summary this study has found some evidence that when valuing new information there are a number of factors which influence perceived value of information. These include the degree of objectivity in a potential solution; the evaluation of quality, the creditability of the source, knowledge demonstrability and the influence of stakeholders on the final acceptance of the solution.

4.6 Findings chapter summary

This chapter has illustrated the key findings of the study by providing extracts from the participant narratives. The interview transcripts have been also been deconstructed and incorporated into 2D matrices in order to provide a temporal sequence of events relating to participant behaviours and cognitive decisions.

The exploratory findings have compared the use of social networks between the participant pharmaceutical and biopharmaceutical companies. The findings have identified important organisational and cultural differences in the use of social networks and attitudes to sharing knowledge.

The characteristics of the participants and their critical incidents (problems) have been described and the thematic codes that were derived from the aggregated transcripts have been presented. Thematic codes have been placed into categories that relate to the main literature streams and to the three research questions, social networks, the use of templates in

knowledge transfer and the use of the absorptive capacity construct when valuing new information. The themes have been associated with illustrative narrative extracts and will be further developed in relation to the extant literature in the following discussion and conclusion chapter.

5 Discussion and Conclusion

This chapter builds upon the previous findings chapter and will discuss the findings in light of previous empirical research and theories. It is structured in broadly the same order as the findings section, and is based upon the following three research questions.

Research Question 1: How do scientists use their social networks to obtain knowledge?

Research Question 2: How do scientists use templates in knowledge transfer?

Research Question 3: What criteria are used to determine the value of new knowledge?

By structuring the discussion chapter around the research questions, the discussions will more closely follow the organisational practice of knowledge transfer and will bring the relevant theory, such as social capital or absorptive capacity, to the discussion where appropriate. The concluding part of the chapter will highlight the most important findings in relation to the extant literature, discuss the implications for management practice and provide suggestions to overcome the dilemmas that pharmaceutical managers have when balancing the freedom to social network with the potential loss of IP.

5.1 A comparison of the use of biopharmaceutical and pharmaceutical social networks; findings from the exploratory study

The main aim of the exploratory study was to clarify the characteristics and broader industry issues, in particular comparing the use of informal social networks in the biopharmaceutical and pharmaceutical industry. The exploratory study clearly illustrates that the SME sized biopharmaceutical organisations recognise the importance of, and extensively use informal social networks as a means to solve problems (Widen-Wulff *et al.*, 2008; Zheng, 2008); to obtain critical tangible and knowledge-based resources (Christensen, 2000; Powell, Kogut, & Smith-Doerr, 1996) and to stimulate creativity (Sundgren *et al.*, 2005). This research has also identified a barrier to the exchange of knowledge that may be related to the competitive nature and the funding regime of the industry (Murray & Stern, 2007). This factor is more likely to affect grant and venture capital funded business models than the larger pharmaceutical industry.

The next two sections compare the relative use of social networks and the disclosure of knowledge in biopharmaceutical and pharmaceutical industries.

5.1.1 The comparative use of a social networks

The smaller biopharmaceutical organisations maintain a strong external academic network (Fetterhoff & Voelkel, 2006), and actively employ scientists that have good scientific and academic contacts. The relative importance of a scientists' personal network has only tangentially been reported in the extant literature. Previous research has suggested that the extent and quality of a candidates' social network is an important means to identify suitable recruits (Harris & Rae, 2011; McCann, 2011). However, the recognition that scientists are recruited, at least in part for the extent of their personal networks, has not been widely reported and may be an important component in the development of an organisation's relational capability (Dyer, Kale, & Singh, 2001; Swan *et al.*, 2007). This finding demonstrates the recognition in an organisational setting, that individuals with a large number of quality ties may accrue positive benefits for themselves and their organization (Burt, 2000).

The exploratory study has found that a biopharmaceutical scientist's social network tends to develop in line with the organisational strategy and the developmental stages of the pharmaceutical product. This parallel development ensures that as products come closer to market, the social networks shift more towards market and product licensing expertise, and the network relations which were once important for early stage drug development become less important. These findings support those of Chesborough (2003) who found that the number of direct ties and the cooperation experience were positively correlated with growth in young biotechnology firms. The narrative extracts also illustrate the practical benefit of modifying organisational links to optimise knowledge transfer throughout the product development process (Diestra & Rajagopalan, 2012; Swan & Scarborough, 2005). Through this process it would appear that the biopharmaceutical organisation endeavours to maintain a degree of embeddedness (Granovetter, 1973), whilst demonstrating organisational ambidexterity by being able to aid both the exploration and the exploitation of new innovations (Jansen *et al.*, 2009).

Previous studies have identified gatekeepers as a means of providing a level of defence from information overload, whilst at the same time recognising the importance of the role as information filters and uncertainty absorbers (Aldrich, 1979; Lewin, Massini, & Peeters, 2011). However, the Chief Executive of a biopharmaceutical company's encouragement to his employees to find specific information, and his use of terms such as '*alert filter*' and

'*osmotic barrier*,' illustrate the proactive focus of the search process. It would appear that some biopharmaceutical scientists are actively encouraged to use their open networks to seek specific knowledge that is relevant to their organisation's interests.

Whilst opportunistic knowledge transfer through open innovation networks has been widely reported (Chesbrough, 2006; Newell *et al.*, 2008). The active and strategic search for knowledge, through a scientist's networked contacts has not been previously linked to an organisation's capability for knowledge transfer; and may provide benefits to the firm by increasing the likelihood of 'knowledge spill-over' (Murray, 2002; Owen-Smith & Powell, 2004). This finding, also serves to demonstrate the level of importance that may be assigned to the relational capability of a small leading edge, high technology organisation, a finding recognised in previous work in the area (Christensen, 2003; Dyer, Kale, & Singh, 2001).

The results also provide evidence that smaller biopharmaceutical organisations use their external social networks to a greater extent than employees of large pharmaceutical companies. A senior scientist that had worked for both types of organisation claimed that there was almost always some internal source in a company that could be contacted. Sufficient expertise and resources can usually be found within a large organisation; however this may not just be the result of the benefits of operational scale (Smith, Collins, & Clark, 2005). There may be other reasons related to age (Gray & Meister, 2004), culture (Weick & Westley, 1996) or internal rules and indeed it may be peculiar to these companies or the industry. It does however seem likely that the situation is more multifaceted and possibly more industry specific than has been previously stated.

5.1.2 The comparative disclosure of knowledge

Previous quantitative research that has attempted to correlate the size of the organisation to the degree of knowledge transfer has found mixed results, with some researchers finding a positive correlation (Dhanaraj *et al.*, 2004; Laursen & Salter, 2006), whilst others have found a non-significant (Tsang, 2002) or negative correlation (Gupta & Govindarajan, 2000). This qualitative study, which is based on the comments from a small number of scientists, does not presume to refute the results of previous large scale quantitative studies. However it has found some evidence that at the extreme ends of the size spectrum at least, there is less external networking in a larger pharmaceutical company than in the smaller biopharmaceutical organisations.

It is clear from this study that a scientist from a pharmaceutical company is more cautious and very aware of the potential loss of intellectual property and subsequent damage to their company's reputation than those in a smaller biopharmaceutical company. The pharmaceutical company maintains a culture of caution by requiring approval of the content of external presentations, which reinforces the importance of confidentiality and highlights the risk of damage to the reputation of the company through the loss of IP. This study has found that a pharmaceutical company encourages its scientists to think twice before discussing anything that is remotely confidential. These characteristics have been recognised in the literature as organisational measures which restrict informal boundary spanning activities, due to the possible loss of confidential information (Hamel, Doz, & Prahalad, 1989).

Withholding this sort of information in social situations, and in particular in scientific conferences, did make the senior scientist feel '*mealy mouthed*', and uncomfortable in presenting data that was known to already be three or four years old. This relatively bureaucratic and risk adverse culture has been previously recognised by authors such as Mintzberg (1979) and Powell(1996), with Bouty and others claiming that trying to stop 'out-going' information will inevitably inhibit the reciprocal nature of information exchange and thereby reduce the volume of incoming information (Bouty, 2000; Starbuck, 1992). It is therefore possible that this factor might account for some of the lack of innovation that has been recognised in the pharmaceutical industry. The impact of the enforced secrecy on the individual scientists working for the pharmaceutical industry is also worth further exploration, as the nature of a scientist is to openly share and challenge each other's findings in order to advance science (Nelkin, 1984; Polyani, 1962).

It was also apparent that, unlike the large pharmaceutical companies, the smaller biopharmaceutical organisations did not overly concern themselves with corporate or legal matters. An example of this was over-hearing 'confidential conversations' at conferences. With one participant stating that as an employee of a large pharmaceutical company he would have to leave the room, but with a biopharmaceutical company they would attempt to overhear conversations. This indicates that scientists in biopharmaceutical organisations are more likely to share confidential matters, and that this trust may be the result of the '*closed shop*' mentality of the biopharmaceutical network (Dakhli & De Clercq, 2004; Simons & Peterson, 2000; West & Anderson, 1996). This study also provides some support to Cross

and Sproull's (2004) observation that trust does allow for deeper relationships to develop, which in turn broadens the conversation and allows for a greater likelihood for the actors to exchange information.

Researchers have recognised that the open disclosure of information and the building of loyalty in an atmosphere of cooperation as being important precedents to successful knowledge intensive firms (Ayers, Gordon, & Schoenbachler, 2001; Starbuck, 1992). The appropriateness of this action will of course be reliant on the judgement of the scientist. An important point that was made in this respect was that some scientists do not always understand the importance or value of their knowledge, a situation which might lead to a significant unintentional knowledge spill-over, before a legal basis for the relationship is established. Something that this study has indicated may be more of a concern to the pharmaceutical industry than the biopharmaceutical industry.

5.1.3 A summary of the exploratory study findings

The lack of innovation and growth in the pharmaceutical industry has been attributed to the lack of information sharing between organisations (Haas & Park, 2010; Pisano, 2006). This has been attributed to unequal power alliances (Alvarez & Barney, 2001), but may be compounded by the growing level of secrecy in the industry (Louis *et al.*, 1989).

It is also evident from the exploratory study, that biopharmaceutical scientists appear to be recruited for and then actively use, maintain and develop their open innovation networks to their organisations' advantage. This is in contrast to pharmaceutical companies that have been shown to actively discourage the use of external social networks and share anything other than outdated research. The reasons that small company biopharmaceutical scientists are more open to knowledge exchange without the legal 'over-head' can only be speculated on. It may be due to their close connections and often recent employment in an academic environment (Gompers & Lerner, 2001) or their scientific and philosophical approach to enlightenment and the reciprocity of knowledge (Ladyman, 2006).

Alternatively an openness to knowledge exchange might be due to an ignorance of IP protection (Murray & Stern, 2007), or working in a more risk accepting entrepreneurial culture (Bernstein & Singh, 2006; Haas & Park, 2010). The different approach to the use of external social networks may also be due to an acceptance that a carefully managed communication of explicit knowledge might be worthless without the accompanying tacit

knowledge (McEvily & Chakravarthy, 2002); an eagerness to be 'belong' to a group (Kane, Argote, & Levine, 2005); necessity to get access to resources (Christensen, 2003) or simply a natural enthusiasm for their subject. Whatever the combination and importance of these factors; this exploratory study has implied a difference in approach to social networks and knowledge transfer which might account for the difference in innovation and growth potential.

5.2 Research Question 1: How do scientists use their social networks to obtain knowledge?

Building on the findings of the exploratory study, the first research question aims to uncover the micro-foundations of the use informal social networks in a biopharmaceutical organisation, as a means to transfer knowledge. In this study the transfer of knowledge was demonstrated by the solving of a problem with the use of informal sources that were external to the organisation. In order to more clearly relate the main study findings to the extant literature, the discussion has been divided into five parts.

- The benefits of social networks
- The uses of social networks
- Access and choice of sources
- Creating social networks
- Developing and maintaining social networks

These sections represent all the themes that were identified in the findings section that were related to this question and have been subdivided in order to provide focus to specific aspects of the broader question.

5.2.1 The benefits of social networks

The following narrative extract from a PhD scientist typifies the comments received from all the biopharmaceutical participants and clearly illustrates not just the importance of social networks but the constant evolution of the network in order to match new technological and scientific demands.

“As you build up your [external] networks, ... you realise who’s doing what and things like that, it becomes very useful you know” [MS6:13].

The two main benefits of the connective nature of routines in a social context are the opportunity for information transfer (Monge & Contractor, 1999; Wellman & Frank, 2001) and the opportunity to create shared understandings (Orr, 1996). The ability to share information and create understanding was a common theme that occurred with all successful problem-solving routines, and was particularly highlighted where relationships subsequently developed into long-term collaborations. Hargadon and Bechly (2006) suggested that this

social process consists of help seeking, help giving, reflective reframing and reinforcing. This empirical study has identified these factors as common to all the problem solving cases, as each actor considers and builds upon the information from their sources and the final solution creates joint understanding and a closer relationship.

The extant literature highlights the importance of learning from previous enactments of routines and the selective application of the relevant aspects of a previous routine to a new routine (Felin & Foss, 2009; Rerup & Feldman, 2011; Salvato, 2009). It is evident from the study that previous experience in using social networks provides a platform for learning, which on subsequent occasions speeds up the problem solving routine (Das, 2003). Learning that was achieved during this process included the relative usefulness of the contact for current and future problems, knowledge regarding scientific theory, knowledge regarding technique, and legal and ethical considerations. There was also a significant requirement for intangible knowledge in all the skills-based problems as has been exemplified in knowledge transfer and the use of templates.

Personal motivations for using social networks included gaining new and useful knowledge as well as improving the participant's reputation. Personal motivations have been widely recognised in the field of information seeking as it is influenced by goals and beliefs which provide a cause, a reason and a motivational basis to find a resolution (Kallenhauge, 2010).

5.2.2 The uses of social networks

According to Cross and Sproull (2004) there are five reasons for seeking information and of these looking for a solution was common to all the problem scenarios. In this study sources were sought for their experience and knowledge, for further referral, and problems were frequently 'brainstormed' with sources which resulted in problem re-formulation. The recruitment and legal problems used validation and legitimation in order to add weight to their arguments and to provide stakeholder support for the solutions. Hence all five reasons for information seeking have demonstrated a multidimensional approach to the use of advice networks in the fifteen problem solving examples. However in addition to these five reasons, this study has found that sources were also sought to invalidate or disqualify potential solutions, thus allowing the problem solver to move on to other approaches. This is a motive that has not been widely reported in previous studies. It is also possible that information was

sought from some sources solely in order to develop or maintain relationships; although due to the nature of this study no evidence has been found to support this.

All the scientists participating in this study were able to find appropriate sources to help with a solution. Research in the field of attention based theory has shown that with a high task uncertainty there is a tendency to undertake a depth-first approach to information seeking (Bin, 2011; Occasio, 1997). This would appear to be confirmed with this study, with each participant undertaking some form of initial research before further help in sought. However potential sources of information were often limited, as scientific specialisms are created in small enclaves that may be geographically dispersed.

Savolainen (2008) had previously found that three or four information sources were used when looking for problem-specific information and that seekers tended to start with human sources. In this study some of the more complex problems, where multiple referrals were required, three or four sources were used in the information pathway (Johnson *et al.*, 2006) but more typically two or three sources were supplemented with the use of other data sources, such as scientific papers and the internet. This minor difference to Salolainen's (2008) findings may be attributed to differences in methodology, industry and scale of the study.

5.2.3 Access and choice of sources

All the scientists were asked to recollect critical incidents in order to demonstrate the use of their external social networks. On encountering a complex problem, established networks of core contacts (e.g. ex-colleagues) were the first to be contacted (Warner, Murray, & Palmour, 1973), but if these were unable to help then others were sought, typically through the use of referrals. The widespread use of referrals supports the proposal that the most useful form of knowledge transfer is via the use of 'weak ties' (Granovetter, 1973), in this case the use of secondary contacts. These findings also support Chen and Hernon's (1982) work who found that sources were initially chosen as they were familiar to them. There was a high degree of consideration and mindfulness in the selection of sources in this study (Schreyogg & Kliesch-Eberl, 2007) and this was based on the criteria that they were already known, they would know who to recommend, but most commonly that they had the necessary experience, knowledge or resource. Illustrating that it is not just the degree of experience that is important, but also the focus of that experience.

These findings are in accordance to previous research in which the perceived usefulness, the ease of use of the source and trustworthiness were identified as important criteria in information seeking behaviour (Bin, 2011; Fisher & Naumer, 2006). Sources that are considered to be expert and with a greater perceived knowledge in relation to the seeker were also sought (Goldsmith & Fitch, 1997; Jungermann & Fischer, 2005). Previous studies have also indicated that sources which are greater in age, authority, education and life experience than themselves were actively sought (Choo, 2007; Feng & MacGeorge, 2006; Zerubavel, 1997), but this was not found to be the case in this study. Rather the source's experience in the subject area or technique was the most important aspect, even if that meant that someone of a similar age and education was approached.

Access was not a serious consideration with any of the problems, indeed there was one example where a source and resource was chosen in the USA rather than in Germany. One could argue that on this occasion that neither the 'cost-benefit framework' (Anderson *et al.*, 2001; Fidel & Green, 2004) or the 'law of least effort' (Gerstberger & Allen, 1968; Hardy, 1982) applied. Indeed, the scientist admitted that the German 'mouse model' was not perfect, hence quality was the most important criteria when selecting the source (Auster & Choo, 1993). In the problem solving examples this quality measure was represented either in terms of the institutional reputation or the publication record of the source (Miller, 1994), in the case of the 'mouse model' it was the reputation of the source.

In this study there was an additional issue that the authors of scientific papers were often seen as unapproachable and if approached were generally less than useful. This was possibly due to several authors on each publication and the research was conducted between them. Additionally authors tend to get bombarded with questions and requests, this reducing the willingness to help those in genuine need. When sources of help were provided, it typically led to an element of formal, personal or professional obligation (Fairclough, 1994). In these cases there was an often unspoken expectation by both parties that the help would be reciprocated if required and this may be recognised with the source's name on a research paper as a means of '*repaying the favour*' (Lewicki & Bunker, 1996).

With the exceptions of selecting a recruitment consultant, where the financial consideration was minor; or the evaluation of a new biopsy needle, where cost was a consideration if the needle performed no better than their current needle; no other problem solving examples could be categorically applied to either the law of least effort or to the cost-benefit

frameworks. This may be because each of the other problems had a precise and defined knowledge or resource requirement which resulted in a direct approach to the targeted source. Also where there was scope for choice, the source was selected on the basis of previous experience (Mackenzie, 2002), rather than convenience (Hirsh & Dinkelacker, 2004), effort, obligation (Fiske, 1991) or accessibility (Allen, 1977, pg. 185; Monge *et al.*, 1985). Hence these research findings agree with other information seeking studies that have downplayed the importance of the financial or personal cost in relation to information seeking (Borgatti & Cross, 2003; Cross, Rice, & Parker, 2001), and supports the finding that the source preference depends not just on the availability of the source (the principle of least effort) but perhaps more importantly the specific requirements of the problem to be solved (Savolainen, 2008).

5.2.4 Creating social networks

The creation and maintenance of social networks require skills that are related to the relational features of social capital. This study has shown that social networks are created through relationships with ex-colleagues, business associates, 'student' friends, referrals and conferences, which have been identified in previous studies (Hill & Rothaermel, 2003). The use of, or a preference for a diverse network was not specifically commented upon by any of the participants in the main study, yet it was widely recognised that having a range of sources to call upon was beneficial to the scientist when problems needed to be solved. It was also clear that efforts were made by the biopharmaceutical scientists to actively develop networks, although this was typically within their own research area.

In this study scientific meetings and conferences were especially used to find and develop new contacts, via organised 'speed dating' but also for the socialisation that sometimes led to business opportunities. Scientists also go prepared to these meetings with lists of questions to be answered and with the intent to develop new relationships. This finding fits well with the common group identity model (Gaertner & Dovidio, 2000) that highlights the benefits of belonging to a superordinate group, through which tasks are completed (Dovidio *et al.*, 1997) and knowledge is shared (Kane, Argote, & Levine, 2005).

The use of internet based social networks is also used, at least amongst the younger and perhaps more IT literate PhD scientists, both as a means of keeping in touch or tracking down

past contacts, but also as a means of 'broadcasting for help', as is illustrated in the recruitment problem and the use of 'Linked-In.'

Another interesting finding that came out of this study was the extensive use of technical sales contacts to solve problems. Five of the fifteen problems were advanced or solved with the help of suppliers. The suppliers were in turn motivated to help in order to develop business opportunities, although this was never made an explicit requirement before assistance was given. The use of suppliers has been widely confirmed in the social capital literature (Uzzi, 1997), but less so in the information seeking and problem solving literatures. One might argue that there is a power dynamic between the scientist and supplier. However, the influence of power in these relationships did not appear to affect the dynamic of help giving and receiving, but was perhaps associated with an unspoken obligation for future business (Easterby-Smith, Lyles, & Tsang, 2008)

This study showed that if the problem solver was in need of a new contact for a particular problem, they typically asked around within their own organisation for recommendations. The sources of help in these circumstances are in effect acting as gatekeepers (Tushman, 1977; Lewin, Massini, & Peeters, 2011) and were always established figures in the organisation (Burt, 1992; Obstfeld, 2005). Being referred by a gatekeeper enabled the problem solver to contact the source directly; in these problems this was always by the means of email which quoted the referee's name as a means of introduction. Email was commonly used as it allowed for careful construction of the introduction and summary of the problem, was flexible across time zones and enabled a record to be kept of the two way communication. Subsequent communications was by telephone and where possible, face to face. Those problems that had an international dimension commonly used 'Web-Ex' video conferencing.

Referrals are of particular use in social networks, perhaps as a means of 'calling in favours' between referees, but also as a means of introduction of new researchers to more senior members of the scientific community. These concepts have been widely reported in the extant literature on communities of practice and social networks (Widen-Wulff *et al.*, 2008).

5.2.5 Developing and maintaining social networks

This study found some support that strong ties were formed between scientists who had similar backgrounds and education, had access to similar resources (related research) and were from the same social strata (Ibarra, 1995; McPherson, Smith-Lovin, & Cook, 2001). Relationships commonly developed into strong ties (Granovetter, 1973), and over time many became good friends with regular meetings and family gatherings outside the work environment. The extant literature does warn of the consequences of becoming embedded in relationships as they may restrict the search for novelty (Hansen, 1999; Maurer & Ebers, 2006). However, so long as scientists continue to solve new problems with new combinations of network relations (possibly with the aid of gatekeepers) as well as maintaining existing relationships, the network should still function in an ambidextrous manner (Capaldo, 2007).

Previous research has suggested that informal social ties are considered to be superior conduits for knowledge transfer between different organisations, especially those in geographically dispersed locations (Adler & Kwon, 2002; Bell & Zaheer, 2007; He & Wei, 2009). This appears to be important for two reasons, as it is seen as a means of making work more enjoyable but also as a means of calling in special favours when timelines are short. In this study it was evident that good relations or strong ties also provided the opportunity and foundation for rich communication which was particularly important in method transfer problems.

Research has shown that formal authority in a social situation can act as a barrier to communication by creating a dominant and powerful party (Easterby-Smith, Lyles, & Tsang, 2008). This study has shown that this may be because the problem solver does not want to be seen as a 'timewaster', or appear to look 'stupid'. It was suggested by a participant that a key determinant of whether the senior person would be amenable to helping or not, is if the question is interesting or challenging to them. The approach to people in a position of seniority is however different or '*more professional*' to those of a similar hierarchical level, which are contacted in a more '*jokey*' way.

Problems can occur if there is a power imbalance between the two parties. For example with one of the problems a friendship was struck up between the project leader and a more junior member of the team, and the project leader subsequently had to overrule the junior member's decision. They reverted to their professional roles in order to resolve the issue, and then

‘returned’ to their previous relations without significant impact on their friendship. This has been recognised in the extant literature in so far that difficult relations such as those of power asymmetry may be offset by trust, the recognition of norms, shared visions or goals, obligation and identification with the other party (Inkpen & Tsang, 2005; Garcia-Morales, Moreno, & Llorens-Montes, 2006). One of the participants also recognised that trust reduced the chances of conflict.

5.2.6 Summary of findings for research question 1

The first research question was to determine how scientists used their social networks to obtain knowledge. The thematic analysis has re-affirmed many of the factors that have been previously identified in the extant information seeking and problem solving literature, as also being relevant to the biopharmaceutical industry. Scientists have been shown to undertake a ‘depth first’ approach, with the use of data sources and gatekeepers to help to frame and scope the problem, before targeting a source that is directly able to provide specialist help. This is often undertaken with the expectation of some form of reciprocity.

The nature of the scientific field, however, limits the number of potential sources that are available and creates differing priorities on search criteria to other industries, with subject relevance being the upmost importance. Sources are therefore selected on the basis of their experience, with potential restraining factors such as seniority, perceived power and accessibility as less important than knowledge relevance. The other significant difference is in the development of social networks. In the biopharmaceutical industry scientific conferences and technical sales people are routinely used to solve problems and to build and maintain social relations; a factor that has been previously identified, but is perhaps less prevalent in other industries.

5.3 Research Question 2: How do scientists use templates in knowledge transfer?

The use of templates has been demonstrated in many studies of organisational knowledge transfer, and is widely considered to aid the transfer of explicit knowledge (Barley & Tolbert, 1997). All the scientific problems in this study demonstrated the supporting use of artefacts in the problem solving process. These artefacts included legal documents, curriculum vitae, manufacture's data sheets, websites, presentation materials, reports and most importantly for knowledge transfer, methodological protocols (Nelson & Winter, 1982).

One particular finding of this research was that whilst many of the artefacts were used as referent documents to document and disseminate knowledge, processes and routines; it was the use of templates (protocols) in knowledge transfer that were the most utilised to achieve knowledge transfer and learning (Armenakis & Harris, 2002). The mechanism of how knowledge may be transferred between laboratories was exemplified by the five problems that were associated with methodology transfer. These methodological transfer problems all required the transfer of complex protocols from an external laboratory (usually geographically distant) to the participant's own laboratory; and are indexed in in Table 4.1. The terms 'template' (theoretical term) and 'protocol' (scientific term) will be used interchangeably in this chapter.

In order to provide a focus on the question the discussion has been divided into four parts

- The use of templates in the knowledge transfer process
- Changes to templates
- The process of re-coding and enhancing templates
- Pre-requisites for knowledge transfer

5.3.1 The use of templates in the knowledge transfer process

Templates (protocols) were found to provide appropriate information to others, and included information on such things as instrumentation, timings and environmental conditions to perform the experiments. This study has found that once the protocol was sufficiently practised, a high degree of automaticity was used to enact the protocol, requiring just the barest referral to remind the user of important and easily forgotten scientific factors. This move from a highly mindful behaviour to one of automaticity born out of practise has been

found in other organisational environments (Aarts & Dijksterhuis, 2000; Narduzzo & Warglien, 2008); but is perhaps surprising in this instance given the relative complexity of the scientific routine.

All the participants stated that without additional help from the source, the transfer of the knowledge would have been difficult, if not impossible, even with the protocol. The importance of the source in aiding knowledge transfer is in line with the findings of Lane and Lubatkin (1998) who propose that the dyadic relationship may be one of ‘teacher’ and ‘student’ and is particularly applicable if the scientists have similar training, backgrounds and basic scientific knowledge.

The original protocols in the methodology transfer problems, were more akin to codified notes, or ‘principles based templates,’ documented by and written for the scientist and their immediate colleagues. These protocols were not only lacking in sufficient detail but also the necessary tacit information. This suggests that ‘copy EXACTLY!’ templates (McDonald, 1998) rather than a ‘principles’ based templates may be most suited to complex situations such as biopharmaceutical protocols. This consideration has been previously recognised both in the case of organisational compliance but also where direct replication and reproducibility is required (Winter & Szulanski, 2001).

The extant literature has identified that direct replication cannot always be accomplished just by the use of a template (Collins, 1991), as most tacit knowledge has to be recreated by the receiver (Kogut & Zander, 1992; Nelson & Winter, 1982). Relevant tacit knowledge needs to be codified and added to the template in a clear manner, in order to make it more accessible to other users (Herschel, Nemati, & Steiger, 2001). The omitted, but highly relevant tacit information, is available and can be made to be ‘*idiot-proof*’ if someone is willing to observe and codify the practice.

The scientist that re-codes the protocol (the ‘student’) was in each case highly motivated to ensure success, they often had financial support for the project and it was their sole responsibility to make the method work. The importance of ‘personal responsibility’ in the re-coding of templates is often ignored in the extant literature, but would appear to be an important motivator to ensure that the re-codification process is fully and broadly functional. In these circumstances a partially working protocol is not an acceptable solution.

5.3.2 Changes to templates

Changes of protocols were undertaken on a selective and incremental basis by the user of the template, most commonly in response to changes in equipment, chemicals and materials. This finding is in accordance with previous suggestions that modifications to templates may occur in response to changes in the environment (Occasio, 1997) and may only affect part of the routine (Rerup & Feldman, 2011). The fact that protocols tend to ensure the stability of the routine and were modified in an incremental manner by the user, and without the involvement of management, also supports previous research in this area (Rerup & Feldman, 2011; Witt, 2011). It was less common to find major changes to scientific protocols, but when they occurred it was usually as a result of the protocol no longer providing an appropriate output; for example an extract was not sufficiently purified; and in this respect they may be considered to be acting in the form of *immutable mobiles* (Latour, 1987). This study however also supports extant research which suggests that performance improvements may occur through the modification of the micro-foundations of routines through the adjustment or replacement of templates (Abel, Felin, & Foss, 2008; Salvato, 2009).

However, an important distinction needs to be made between modifying protocols and merely enhancing them. In their original form the protocols were often unusable by other scientists as they lacked the appropriate codified or tacit information (D'Adderio, 2008). Holistic re-writing of protocols therefore required an 'outsider' to observe the performative and tacit side of the protocol and update the ostensive side according to their understanding. Whilst the new protocol was more detailed and accessible to a broader range of scientists, the fundamentals of the protocol rarely changed. Indeed the new protocol did not necessarily replace the original as the 'teacher' had sufficient experience and tacit knowledge of the protocol and still used it as an 'aid-memoir.'

This use of multiple forms of what is essentially the same template provides an interesting insight to the evolution of templates and the use of different versions of the protocol in different laboratories. The author suggests that in this study this feature may be accounted for by the relative need for detail. Less experienced scientists that needed more tacit advice used forms of the protocol that were more 'prescriptive.' Others that were more familiar with the practice used simpler forms of the protocol, which consisted mainly of numerical reminders (timings, speeds, temperatures etc.) and representing templates that are closer to the 'principles' end of the spectrum.

Additions and enhancements to templates were generally related to instrumental and methodological conditions, and notes which provided hints, tips and advice. These additions may provide a deeper understanding to the user of why each stage or condition is important so that emphasis is placed at these points and shortcuts are less likely to be made. A less experienced scientist is less likely to make mistakes due to an ignorance of the tacit subtleties of the technique.

5.3.3 The process of re-coding and enhancing templates

Baden-Fuller and Winter (2008) have previously considered templates as being predominantly used as a means of direct copying, and are often implemented without a detailed understanding (why) of the underlying concept. This research suggests however, that whilst this may be the case in the performative stage of the replication process, the re-codifying of the template or the ostensive stage requires a deeper understanding (Pentland & Feldman, 2008). This is achieved primarily through observation and other rich forms of communication that benefits from the scientists having common backgrounds such as having recently completed PhDs (Ahuja & Katila, 2001; Lane & Lubatkin, 1998).

Template enhancement through recoding is analogous to D'Adderio's model of framing (prescribing), overflowing (interpreting) and reframing (modification) that is undertaken when observing the differences between the template and the performance of the routine (D'Adderio, 2008). This research has shown that during observation of the process, copious notes were taken and the details checked with repeated questioning, a feature that could be attributed to the overflowing stage of D'Adderio's (2008) model. All the knowledge transfer practices demonstrated a shifting awareness between the tools and the task, whilst reflecting on their experiences and 'thematizing' the circumstances and then discussing them with others (Tsoukas, 2003).

Observational learning has been recognised as a particularly effective form of learning (Nadler, Thompson, & Van Boven, 2003; Shebilske *et al.*, 1998) and is the most likely form of learning to facilitate the transfer of tacit knowledge (Nadler, Thompson, & Van Boven, 2003). In this study it was clear that observation of practice was seen as a superior form of knowledge transfer. Observation also benefitted the 'student' learning by providing a practical context and an immediate opportunity to ask questions and to clarify ambiguities. It is also likely that the protocols provide a structure and format which enables the tacit

knowledge sharing process, a factor that has been demonstrated in previous studies (D'Adderio, 2001; Herschel, Nemati, & Steiger, 2001).

Practising the technique at the 'teacher's' laboratory was also a powerful way to learn and understand the subtleties of the techniques. All new protocols that had undergone the detailed observation in the 'teacher's laboratory' tended to work after this stage. Those protocols that were not successfully transferred were typically those that were being used for a different scientific use or those that did not undergo any observation procedure. This was despite frequent telephone and email questioning.

The extant literature provides empirical evidence that observational learning can provide greater access to tacit knowledge which other forms of learning cannot achieve (Nadler, Thompson, & Van Boven, 2003). This study has found that by observing the 'teacher's' subconscious skills it prompts questions and often leads to a change of practice. The use of analogy was also considered to be important as the 'student' was found to relate the new tasks to previous experience of similar situations (Dunbar, 1997; Pirolli & Anderson, 1985; Ross & Kilbane, 1997).

This research has found that care was always taken over the wording of the protocol in order to avoid ambiguities. In most cases the protocol was developed after reflection upon each day's observations, and planning for the next day's questions. Overall the newly coded protocol enhanced the original protocol by adding more scientific conditions, such as detailed specific resources and additional hints and tips to the procedure. This not only made it more tangible, but also added warnings so that potential pitfalls can be avoided. The ultimate test of any new protocol was the trial of the complete protocol by another relatively inexperienced scientist in the home laboratory, which was the final test of transferability.

This complex dyadic interaction between 'teacher' and 'student' and tacit and explicit knowledge in re-coding a template has been illustrated in Figure 5.1

Figure 5.1 The encoding of tacit practice during methodology transfer

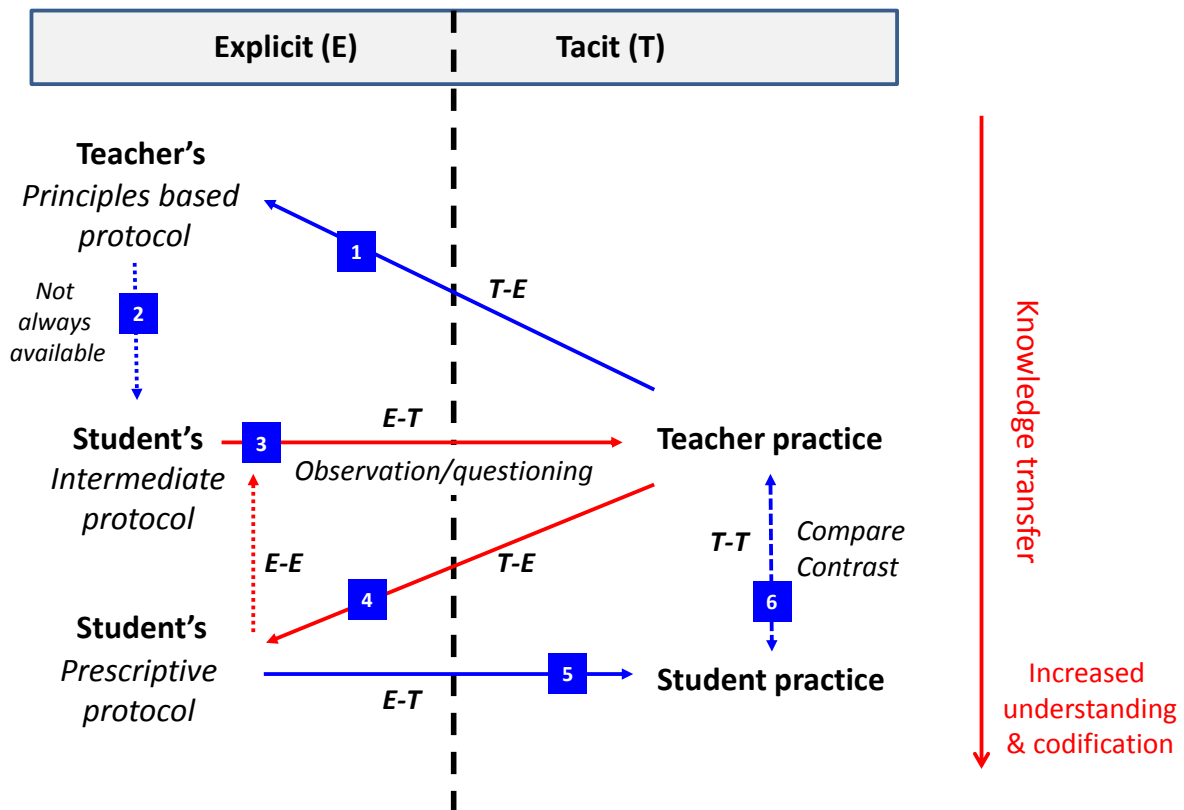


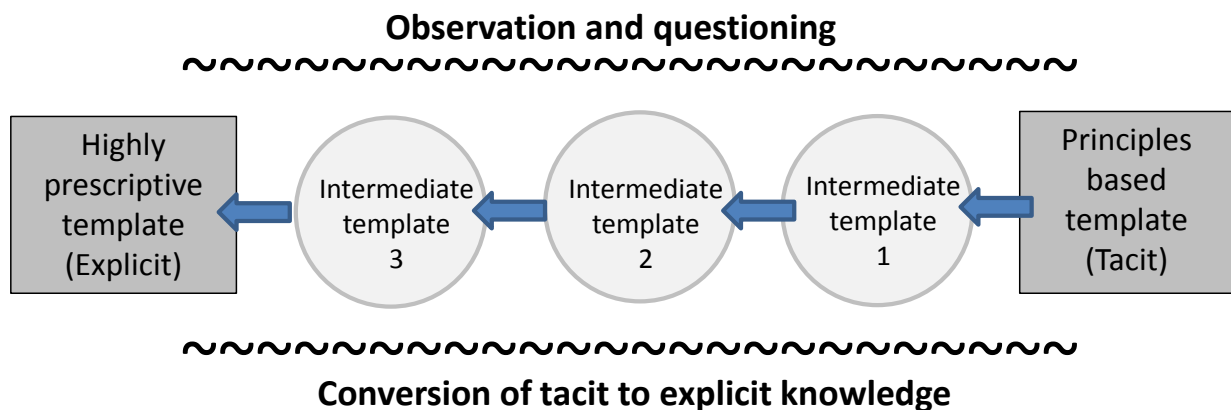
Figure 5.1 illustrates the use of the SECI model (Nonaka, 1994) as applied to the practice of enhancing and coding of a complex scientific protocol so that it contained both explicit and tacit information. It includes all four conversions of different forms of knowledge by socialization (tacit to tacit), externalization (tacit to explicit), combination (explicit to explicit) and internalization (explicit to tacit). The externalization conversion is achieved through observation and questioning (socialisation).

The stages are numbered from 1-6 and start with the 'student' receiving the principles based protocol from the 'teacher' (1 and 2). The student then aims to understand methodological practice by using the principles based protocol as a basic template and repeatedly questions the 'teacher' in order to increase their understanding (steps 3 and 4). This cyclical process is directly analogous to Nonaka's internalization and externalization forms of knowledge conversion (Nonaka, 1994). The activity illustrated by steps 3 and 4 is most likely to require multiple iterations until the protocol is deemed to be sufficiently robust and accurate by the student.

Once a ‘fully encoded’ protocol is thought to have been achieved it is put into practice by the student as represented by stage 5. Commonly the resulting practice is jointly assessed by the ‘teacher’ and ‘student’ as represented by stage 6. At this point the ‘student’ has achieved a sufficient understanding to encode the protocol in appropriate detail so that it can be used by other less experienced scientists in their own laboratories. A successful method transfer demonstrates Nonaka’s assertion that externalization through socialization has been achieved; and helps to answer concerns over the static nature of the SECI model (Adler, 1995).

During the encoding process (steps 3 and 4) a series of intermediate templates (Jensen & Szulanski, 2007) are formed. These intermediate templates may be represented as a continuum between broad ‘principles’ and ‘prescription’ or ‘copy-EXACTLY!’ templates (Baden-Fuller & Winter, 2008). The proposed relationship between these extremes has been modelled in Figure 5.2 further illustrating the dynamic nature of intermediate templates.

Figure 5.2 The conversion of tacit knowledge through the use of intermediate templates, ‘The caterpillar tractor’ principle.



The ‘caterpillar tractor’ model schematically illustrates the development of a highly ‘prescriptive’ template from a ‘principles-based’ template through the generation of a series of intermediate templates. The intermediate template that is most completely developed (codified) is to the left of the diagram. This model reflects the study findings which showed the incremental development of a series of principles based templates over the period of each successful methodology transfer project. This was achieved through the repeated questioning and observation of the ‘teacher’s’ tacit practice. This schematic illustration is supported by the findings of this study in that questioning and observation were identified as being crucial to test a ‘student’s’ understanding of the process before the templates were modified.

The proposed model brings together several theories relating to template evolution (D'Adderio, 2008), observation and questioning as a means of making tacit knowledge more explicit (Nadler, Thompson, & Van Boven, 2003; Nonaka, 1994) and the role of intermediate templates in the co-creation of knowledge (Latour, 2005; Jensen & Szulanski, 2007). The model clearly illustrates D'Adderio's assertion that moving from template to performance and visa-versa, does not just require codification and de-codification but also requires a socio-technical transformation that involves both actors and artefacts (D'Adderio, 2011). Whilst these concepts are not unique, the author believes that modelling this process makes a useful contribution to the understanding of the relationship between prescriptive and principles based templates in the development or modification of routines and the transfer of knowledge.

5.3.4 Pre-requisites for knowledge transfer

During the knowledge transfer process it became clear that there was a requirement, or at least a preference, to also use the source's scientific resources. This was the case even if similar resources existed in their own laboratories. By all accounts this was because it reduced the chance of variability with unknown factors such as different plastics, reagents and differently calibrated instruments. This issue has been recognised in the extant literature where problems of reproducibility were identified under different environmental conditions (Winter & Szulanski, 2001), but not however in a scientific context.

The protocol recoding process requires an understanding of the underlying science and technology. This study suggests that the ideal person to undertake this enhancement appears to be one that is experienced in similar forms of transfer and the writing of highly explicit protocols, rather than being an expert in the science behind the methodology. When scientists had previous experience in methodology transfer, they tended to remind themselves not to hurry the codification process and to ask obvious questions as this was most likely to save time later. This concurs with Weick's work on sense-making or coming to an understanding that is reasonable and based on past experiences and expectations (Weick, 1993). In one of the methodology transfer examples, the 'student' was trained as an engineer but still had sufficient knowledge of the technical aspects of the methodology to understand the importance of detail.

Upon reflection this does seem reasonable, as an outsider has the ‘excuse’ to ask ‘dumb’ questions when re-coding protocols (Cross & Sproull, 2004), and will tend to want to know the detail that other more experienced scientists may just take for granted. In other words they will be more of a ‘student’ and less of an ‘equal.’ It is clear from these examples that the less you know about a situation the more likely you are to make useful connections (Lowry, 2011). If the ‘student’ also happens to have relevant experience in similar analytical techniques and can demonstrate an overlap of mental models, this is of course a bonus. The presence of a common language or ‘combination capability’ (Nonaka & Takeuchi, 1995) for exchange to occur is re-confirmed by this study; however the extent of knowledge overlap and the need for a common knowledge has been brought into question.

Previous research emphasises the importance of a deep understanding for knowledge transfer to occur (Lane & Lubatkin, 1998; Lane, Salk, & Lyles, 2001; Powell, Kogut, & Smith-Doerr, 1996; Reagans & McEvily, 2003), and has shown that knowledge diversity negatively impacts on shared mental models. This study has, however, found in favour of the proposal that diversity of mental models may be moderated by an overlap through the establishment of explicit roles which serve to establish communication norms and common aims and reduce negative relationships (Banks & Millward, 2000; Hautala, 2011; Paletz & Schunn, 2010). A deep understanding of the science in this case is less important than a good understanding the mechanics of the methodology and previous experience in writing protocols.

This finding has not been widely reported in the knowledge transfer literature or recognised in the development of templates for routinized behaviour, and adds weight to those that call for more research at the level of the individual in how prior knowledge is used to learn from external sources (Volberda, Foss, & Lyles, 2010). The role of the organisation in providing training for scientists involved in tacit knowledge transfer will be discussed later in this chapter.

5.3.5 Summary of findings for research question 2

The use of templates in the form of protocols has been established in this study as a structural tool for enabling knowledge transfer. This research has identified three forms of template development and evolution, the initial development of a template, incremental modification of parts of the template and the enhancement of templates for a wider use. The enhancement of templates in order to make them more accessible to a wider audience was achieved

through extensive observation, questioning and testing. This process has been illustrated with the applied use of the SECI model. The incorporation of tacit knowledge into the protocol followed the understanding of the performative part of the routine by the 'student' and was developed with the aid of intermediate templates. The holistic process has been illustrated by a newly proposed 'caterpillar tractor model.'

Multiple forms of the protocol were in use in different laboratories, depending on the skills and familiarity of the scientist to the technique. The research relating to this question also found that a full understanding of the science underlying the protocol was not necessary and might even be a disadvantage when enhancing protocols. These factors have not been widely reported in the template development literature.

5.4 Research Question 3: What criteria are used to determine the value of new knowledge?

It is generally understood that knowledge will only be transferred if the value of that knowledge is first recognised; as represented in Cohen and Levinthal's (1990) proposed model of absorptive capacity. However, it is recognised that the concept of valuing new knowledge as a function of absorptive capacity has been under-researched to date (Torodova & Durisin, 2007, p. 777) and the final question attempts to address this need. The discussion of this research question requires the consideration of the content into four discrete areas relating to the factors used for determining value. These include:

- The subjectivity of information
- Quality characteristics and valuing knowledge
- The cognitive influences on valuing knowledge
- The influence of source characteristics when valuing knowledge

Despite the complexity of the problems, which often took months or years to solve; at the outset each problem had clearly defined and explicit goals. This 'tightly structured' (Shapiro & Spence, 1997) nature of the problems was a surprise to the author, as the expectation was that the scientific problems would be difficult to define and require a pragmatic approach to solving them (Carlile, 2002; Cross & Sproull, 2004). All the problems that were encountered in this study required solutions which were workable, achieved the desired ends and were acceptable to the stakeholders (Cross & Sproull, 2004).

5.4.1 The subjectivity of information

As the problems in this study were simple to define, the identification of a 'stop-rule' was generally clear from the initial problem framing (Agosto, 2001; Morehead & Rouse, 1982), and the determination of an acceptable 'solution' was rarely on the basis of a largely subjective judgement. As indicated with Laughlin's (1980) task continuum and Hogarth's (1980) predictive and evaluative judgements, between these extremes there are a range of possible combinations (Bonabeau, 2003; Hayashi, 2001; Landry, 2003). In an attempt to categorise the problems and define the evaluation of the solutions they have been categorised in Table 5.1

The table has been ordered such that the most objective (predictive) solution is at the head of the table; the most subjective (evaluative) is at the foot. For example, seeking data has been identified as either relevant and acceptable or not relevant and not acceptable, as indicated by the YES/NO code, there is little room for subjective judgements. The middle of the table, starting with seeking presentation materials relies on benchmarks (B), if there is no benchmark available then anything of relevance is useful, the other examples in this category benchmark against previous results and performance. The problem of finding a recruit is at the foot of the table and exemplifies the only example (although not in the main study) where the solution, in this case the selection of a candidate, was based largely on experience and instinct (Y?)

Table 5.1 A categorisation of degree of subjectivity in the problem solving examples

Problem type	Evaluation of the solution	Code
Seeking specific data	Explicit and clear with stakeholder approval	Y/N
Seeking animal model	Explicit and clear with stakeholder approval	Y/N
Legal hurdle	Explicit and clear with stakeholder approval	Y/N
Seeking presentation materials	Anything of relevance is an improvement on nothing	Y > B
Cell growth problem	Improvement on existing benchmark	Y > B
Analytical method improvement	Improvement on existing benchmark	Y > B
Technique (needle) improvement	Improvement on existing benchmark	Y > B
Finding a recruit	Subjective, based on experience and stakeholder influence	Y?

Hence, the problem solving categories in this study have different stop-rules and may be placed on a linear scale, with one end representing the objective (predictive) and clear means to determine a solution, as exemplified by a participant when they described the solution as ‘*black and white,*’ and when another participant was clearly able to distinguish between appropriate and inappropriate data. With the other parts of the scale being subjective (evaluative) and represented by suggestions that it was an ‘*inexact science.*’ These extremes of decision making are analogous to that which has been previously proposed with a rational

decision making at one extreme versus a subjective decision making at the other end of a single spectrum (Eisenhardt & Zbaracki, 1992; Tello, Latham, & Kijewski, 2010).

In the middle of these extremes stop-rule decisions have been found to be influenced by benchmarks that are based on past experience. This middle ranking and semi-subjective portion of the scale provides a minimum standard of acceptability, above which is an improvement that might be acceptable to the problem solver and other stakeholders. As exemplified by a very low benchmark i.e. '*anything that is relevant is better than what I have at present*'; or '*it's an improvement on what we had before,*' as exemplified by higher growth or improved performance. It is presumed in all these cases that if time pressures, stakeholder demands or frustration influence the problem solver then satisficing may occur (Prabha *et al.*, 2007; Simon, 1997; Zach, 2005). This study extends Laughlin's (1980) model by demonstrating that valuing intermediate solutions may be aided by benchmarking against previous experience, thus providing the lower of the two dimensions of acceptability and making the judgement of stop-points significantly easier. The use of benchmarks to simplify subjective stop-rules represents an interesting new avenue of research.

5.4.2 Quality characteristics and valuing knowledge

Zmud (1978) has demonstrated a direct relationship between the use of the highest 'quality' information sources and relevance, accuracy, reliability, timeliness and specificity to the problem being addressed. In this study it was found that when seeking data or presentation materials, quality is most commonly determined by relevance or specificity (Barry, 1994; White & Wang, 1997). Accuracy is related to relevance but denoted precision and correctness (Kallenhauge, 2010), and was particularly significant in the methodology transfer problems. Reliability and reproducibility are especially important in science as they demonstrate stability over time, characteristics that are vital in the practice of scientific methods and techniques.

Researchers have proposed that the motivation to process information increases with the perceptions of its relevance (Petty & Wenger, 1998), but it has not been possible to confirm this in the study. The importance of currency has however been demonstrated and has been exemplified by the demand for the newest techniques, such as the latest generation of sequencers. Timeliness and the relative importance of the problem have also been shown in extant research to be an important criterion for determining quality (Bin, 2011). Whilst

timeliness has been identified as serendipitous and beneficial to problem solving, none of the participants directly related this factor to quality. This suggests that timeliness may only be linked to quality when ‘time is of the essence’.

The difficulty of interpretation and insufficient detail were found to be a barrier to knowledge transfer in a number of the problems. Most notably this was recollected when data was found to be in a ‘new’ format and with the difficulty of interpreting ‘principles-based’ protocols. These findings support previous research on indicators of information and knowledge quality and have now been confirmed as relevant to the biopharmaceutical industry (Cappiello, Francalanci, & Pernici, 2003; Nelson, Todd, & Wixom, 2005).

The benefit of ‘simplicity’ of the solution was described on a number of occasions in the study and aided the problem solver in one of two ways. Firstly, the clarity of the solution provided the seeker with an opportunity to conclude the search process, and secondly it provided a means to aid cross-functional or cross-disciplinary communication and in particular when explaining and legitimatising new knowledge to stakeholders. The value of simplicity has been identified as a benefit when selecting a source, when assessing the richness and clarity of information (Cross & Sproull, 2004; Daft & Lengel, 1988) and in the use of perceptual filters which amplify relevant information and attenuate irrelevant information (Walsh, 1995). The usefulness of ‘knowledge for sharing’ has been recognised in previous studies (Rao & Osei-Bryson, 2007; Soo, Devinney, & Midgley, 2004). Simplicity has also been recognised as an important antecedent when applying new knowledge (Yoo, Vonderembse, & Ragu-Nathan, 2011). However, the simplicity of knowledge has not been previously identified as a beneficial quality when disseminating the problem solution to stakeholders.

5.4.3 The cognitive influences on valuing knowledge

Knowledge overlap or a small cognitive distance provides the basis for an understanding between both parties, and has been identified as essential for successful knowledge transfer and learning (Nahapiet & Ghoshal, 1998; Smith, Collins, & Clark, 2005) in the pharmaceutical industry (Sundgren *et al.*, 2005). Understanding has to occur before quality can be assessed, but difficulty in understanding may occur between scientists and other scientists from different research areas, and also between scientists and other professionals. In this study there was a general recognition that both parties benefitted if ‘*you can have an*

informed discussion about it;’ and that sharing ‘just enough’ information enabled this to happen.

Several examples were provided where a poor mutual understanding led to a ‘dead end’ as no ‘frame of reference’ or ‘shared knowledge structures’ were available to enable sense-making (Weick, 1995), or to assist in comprehension (Schall, 1983; Starbuck & Milliken, 1988). A large cognitive distance (Oliver & Montgomery, 2008) was identified in this study as a source that was unable to help as expectations between the seeker and source were different. In order to overcome this, an explanation was required and often this was in the form of some basic science teaching. The extant literature recognises this phenomenon as reducing the cognitive distance to enable the transfer of knowledge and the achievement of goals (Gilsing & Nooteboom, 2005)

In a knowledge transfer problem, despite the fact that both ‘teacher’ and ‘student’ were scientists and their knowledge overlapped in most areas, their different scientific focusses resulted in some teaching and learning. When this situation was identified, an effort to ‘teach’ the other party was undertaken. Teaching or modifying the language or manner in which data is displayed provides the opportunity for a degree of shared language or ‘combination capability’ (Nonaka & Takeuchi, 1995). Cumulative experience in shared technology can also aid knowledge transfer (Zander & Kogut, 1995).

This study has identified and confirmed two important characteristics of overlap, an overlap or understanding of language and an understanding of knowledge, although clearly knowledge may also have its own form of associated language. An understanding is a prerequisite for valuing knowledge and transferring new knowledge but is unlikely to occur unless both a language and understanding overlap occurs (Boisot, 1995; Boland & Tenkasi, 1995). Knowledge of a subject is born out of education and practice, but it also includes the ability to decipher and simplify the language (Pondy & Mitroff, 1979). Interpretation was mentioned in this study as an issue that occurs when an actor has been away from a project for some while and upon returning to find that the language, formatting and style had evolved such that it was no longer assessable.

5.4.4 The influence of source characteristics when valuing knowledge

Of the determinants of quality, the source's expertise can serve as a shortcut through which actors rely on to process information (Foreman, Ghose, & Wiesenfeld, 2008; Petty & Wenger, 1998). The qualities of the contacts which influence the choice of the source (the source *preference*) include trust and reputation, which were discussed earlier in the chapter. However the source *relevance* focuses on the criteria of how people judge the value of their knowledge and therefore tends to be used in the final stages of problem solving (Savolainen, 2008). In this study each participant went to great lengths, through referrals and other forms of research to obtain help from a source that was considered to be an expert in their particular field, with the understanding that an expert would not only be most likely to be able to provide advice or a solution, but could also be trusted to provide a solution of appropriate quality.

The value that is assigned to the source's experience and reputation when evaluating information, appears to be more significant in this study than the relative power between that of the source and the seeker. In most cases the seeker was referred to, or found the solution through a source which did not hold a more senior position in their organisation than the seeker; i.e. expertise and reputation was considered to be more valuable than their position of seniority. This finding is somewhat at odds to that of Torodover and Durisin, who claim that the valuing and the exploitation of knowledge will be influenced by power relationships (Torodova & Durisin, 2007). However the researcher recognises that power is more likely to be significant when stakeholder influence is considered; the more powerful the stakeholder is, the more likely they will influence the acceptance of a solution. It is also possible that the scientific arena is more of a meritocracy than others which are characterised by power and influence.

Trust develops as a relationship matures, but initially trust is based upon reputation, recommendation and seniority (Brelade & Harman, 2000; Dakhli & De Clercq, 2004; Simons & Peterson, 2000; West & Anderson, 1996). The word 'trust' was frequently used when describing the strength of the relationships, but other phrases such as '*give me a solid foundation*', and '*a higher likelihood of reliability*' also indicated that trust is the basis for the acceptance of the solution and therefore an influence on the assessment of quality. In accordance with previous work, this study has found trust to be a valuable commodity in external social networks as it pre-validates the knowledge that is exchanged (Simons &

Peterson, 2000); however it is important to note that it is not always accepted at face value and was often independently checked. Trust based on a personal relationship was always considered in this study to be advantageous when assessing the quality of a solution in comparison to un-validated information such as that obtained through the internet.

Despite quality indicators being present, rarely was information, knowledge or resources taken at face value. This was predominantly because the scientist's own reputation was also at stake. Under these circumstances ideas would be considered in conjunction with the problem solver's ideas. The problem solver would often test the materials or the data to reassure themselves that there was not going to be a problem. These statements do not reflect in a negative way on the sources, but rather serve to ensure that mistakes were not accidentally made, or that the new information was in agreement with existing knowledge.

The judgement of quality was in this study also aided by the experience of receiving similar information from the same source in the past. This is in accordance to the extant literature which claims that decision makers will in time learn how to identify which source has which type of knowledge, which advisor is most accurate and under which circumstances, and whether the sources confidence ratings are valid indicators of accuracy (Hollenback *et al.*, 1995). Data from such a source was held in high regard if it had been previously observed; i.e. the sources presented knowledge demonstrability (Kane, 2010) and was accepted more or less at face value; on other occasions the quality was known to be poor. In the case of poor knowledge demonstrability, if the source was human then they were avoided, but on occasions a journal, which may have an otherwise good reputation might be the only source. In this circumstance the participant distinguished between the '*thoroughness*' of the research rather than the '*quality*' and took these factors into consideration when evaluating the solution.

This study has not been able to confirm or refute the proposition that when sharing a social identity with a source that knowledge will be more thoroughly considered than from outside the group (Van Knippenberg, 1999). It has, however, shown that knowledge transfer tends to be more pleasurable and in a richer form when there is a common social bond, but it could not be established if this influenced the perceived value of the information that was provided. However stakeholder influence (Heath & Gonzalez, 1995) has been identified as an influence in all the problems in this study; i.e. the problem solver has acceptance criteria based around stakeholders needs. Stakeholders often have a casting vote, even if they have not at the outset

influenced the form the solution should take. They may therefore be considered at all stages of the problem from initial framing, through choice of source to contributing to the valuing of the solution.

In conclusion it has been demonstrated that the social capital factors of experience, authority, reputation and trust are important influences on the perceived quality of the information received (Alwis, Majid, & Choudhry, 2006; Hovland & Weiss, 1951; Julien & Michels, 2004). These factors appear to work by influencing the confidence in decision making. Characteristics of the source have been shown to influence the perceived 'quality' of the source and would also appear to indirectly influence the perceived value of the solution.

5.4.5 Summary of findings for research question 3

A review of how scientists' value information from their networked sources has confirmed much of that previously established in the decision making, advice taking and the information seeking literature. Solutions have been determined with the aid of a range of predictive and evaluative characteristics.

This study has identified the importance of comparing previous experience to the current problem, which provides a benchmark and makes the subjective judgement of a solution easier to achieve. The influence of stakeholders has been found to be important in determining the stop-point in all forms of solution, a factor that has not perhaps been given sufficient prominence in the extant literature. This study also suggests that as a criterion for evaluating solutions, the value of simplicity has been largely overlooked and should be more fully explored.

The influence of social capital factors, such as experience, reputation and trust have been reaffirmed as important influences on the judgement of quality of the solution, as has the source's ability to exhibit knowledge demonstrability. However this study has also identified that scientists have a tendency to check all forms of new knowledge, regardless of the 'perceived quality' of the source. There appears to be a high degree of critical reflection and mindfulness in this process, partly in order to preserve and protect their own reputations, but also presumably to reduce the wasting of time and resource. This is worth further investigation as it is an area that is under-researched at present.

In summary there are a wide range of factors which influence the valuing of information, and these have been diagrammatically represented in Figure 5.3

FIGURE 5.3 Model illustrating the influences on valuing new knowledge

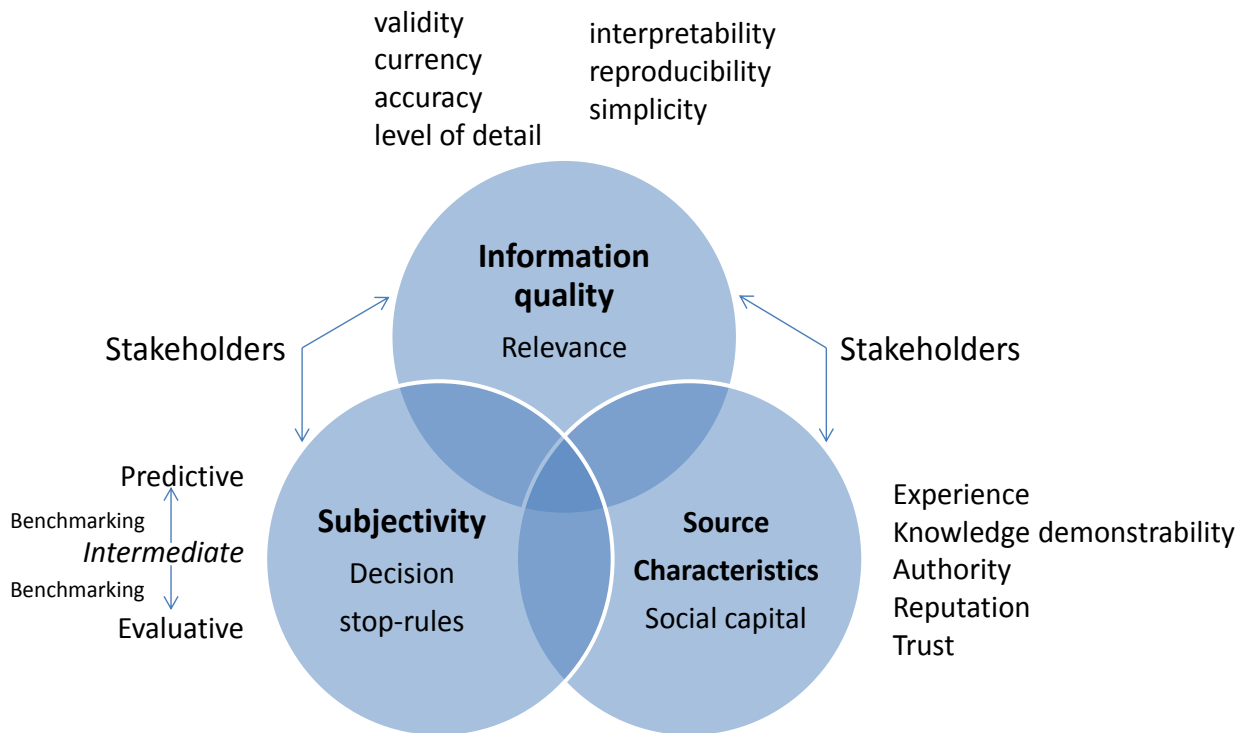


Figure 5.3 demonstrates the interplay of the three main influences on how problem solvers value information. It assumes that the problem solver has undertaken an initial problem framing exercise in order to know what to look for. The information characteristics or solution that is under consideration will be determined by the factors that have been grouped together as quality or relevance. The source characteristics such as experience, authority and trust have also been shown to influence the validity of the solution. Finally the decision to stop looking and accept the information is influenced by a range of factors on a scale between highly predictive or highly evaluative (subjective). This study has also found that a stop-decision may also be influenced by benchmarks. External stakeholder pressure, i.e. those not directly involved in the process of knowledge transfer, has been represented as influencing each of the three forms of consideration, although this influence may only be applied in one or two areas, or not at all, depending on the circumstance.

Together these factors constitute an attempt at providing a holistic model which demonstrates the most important factors that are consciously or subconsciously considered whenever solutions are sought and information is provided. There has been no attempt to rank these factors in order of importance, due to the qualitative nature and the specificity of the study, but it is presumed that each factor will have more or less influence depending on the context. Whilst this study has been conducted on scientific problem solving within informal social networks, there is reason to presume that these factors are also likely to have some influence in other scenarios, such as seeking data or information seeking through social networks.

5.5 Contribution of the study to academic theory

5.5.1 A review of the proposition

As a means of pulling together all the strands of the study and providing a macro overview of the research area in relation to the theory, the model that was proposed at the end of the literature review (Figure 2.7) has been re-assessed for validity following the empirical study and may be found in Figure 5.4

FIGURE 5.4 A model demonstrating the importance of the valuing information micro-routine as a conduit between problem solving routines with absorptive capacity.

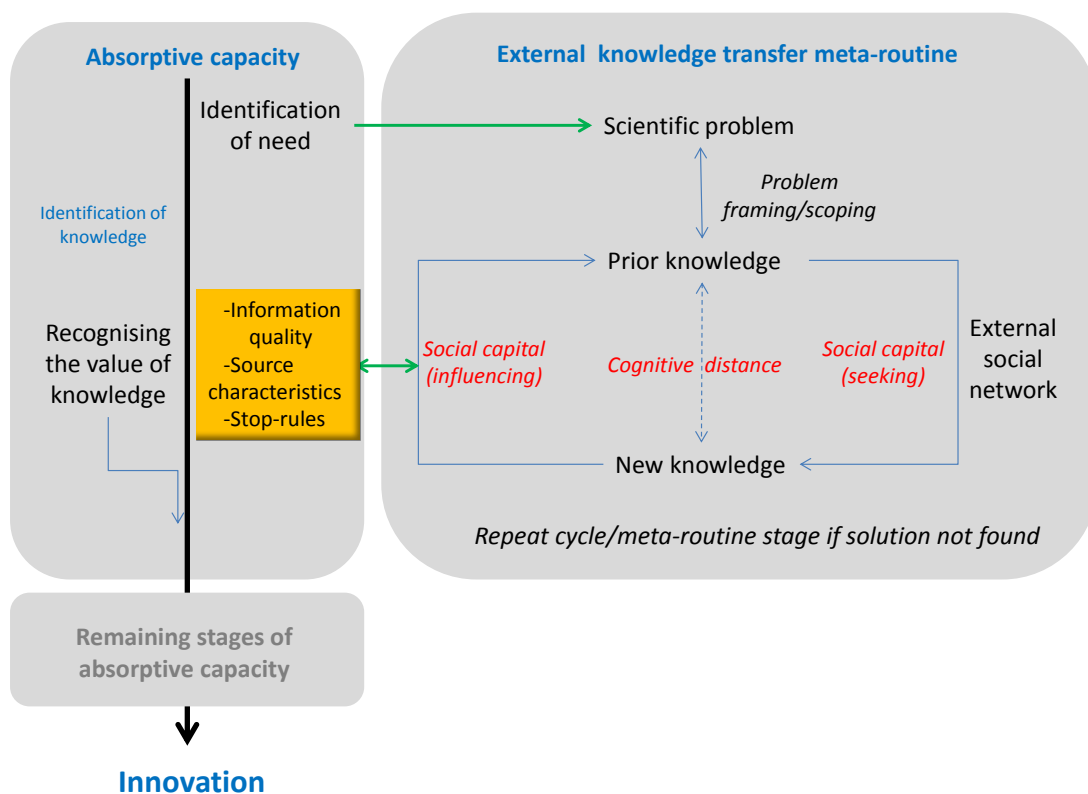


Figure 5.4 shows that problem solving routines enable external knowledge transfer through absorptive capacity via the recognition of value stage and this process is influenced by the relational and cognitive dimensions of social capital. The study has provided empirical evidence that the model and the factors which characterise value in new knowledge are valid, at least in the context of this study.

This research has found that factors which represent the relational dimension of social capital, such as reputation, authority and trust, were used to seek appropriate sources and were also found to influence the perceived value of the solution. Zahra and George (2002) have previously suggested that the cognitive dimension of social capital may contribute to potential absorptive capacity by mediating the influence of the relational aspects of social capital. This study has confirmed this suggestion by finding that cognitive factors such as shared mental models, knowledge and language overlap, contribute to understanding of knowledge, thus reducing the cognitive distance and enabling transfer.

There are a number of findings from this study which have provided useful insights into the micro-foundations of social networks, the use of templates in transferring knowledge and the valuing of new knowledge in the biopharmaceutical industry. The research questions are now considered in light of the key contributions to research in these three areas.

5.5.2 To ascertain how scientists use their social networks to transfer knowledge

The findings which are related to the use of social networks by scientists when they are seeking to transfer knowledge may also be relevant to other industries, forms of network and uses of networks. Much of the extant research supports the suggestion that older and more experienced firms are better at developing and modifying knowledge transfer, problem solving, absorptive capacity routines, and selecting partner firms and transferring tacit knowledge (Argote, 1999; Cohen & Levinthal, 1990; Macher & Boerner, 2012; Parmigiani & Mitchell, 2009; Mayer & Salomon, 2006). This study cannot confirm these findings and supports the conclusions of others that have studied knowledge transfer in the pharmaceutical industry and found that there is little difference in organisational age and their ability to transfer knowledge (Gray & Meister, 2004; Yli-Renko, Autio, & Sapienza, 2001). Indeed this study has found some evidence that a smaller, less experienced biopharmaceutical organisation tended to rely on their external knowledge transfer routines more than a larger

counterpart. Using their social networks for problem solving in a way that might result in a more dynamic and innovative practice.

The first finding in this respect is that scientists in the biopharmaceutical industry may be recruited for the benefit of their personal social networks. This provides an interesting dimension to social network research which has already recognised the importance of social networks for recruitment. However, the extant literature has not recognised the positive discrimination that may accrue from the scale and scope and quality of networked contacts that are associated with a scientific recruit, and this may be an important contribution to an organisation's relational capability. Professional social network websites can provide an interesting way to view and consider this information.

This study has also made evident that social networks may be used to actively search for information. The proactive use of social networks has been widely demonstrated, in particular in the problem solving and information seeking literature, however it has been previously assumed that this is an individual action, performed for the benefit of the individual. This study has identified that it may also be undertaken with strategic intent where a number of scientists search for specific information on behalf of the organisation. Whilst this may not be common practice, it is a strategy that can produce knowledge rewards by focussing the search criteria around the strategic knowledge requirements of the organisation. This finding has not been widely reported in the social networking or knowledge transfer literature.

According to Cross and Sproull (2004) there are five reasons for seeking information and in this study all five reasons for information seeking have been demonstrated. However in addition to these five reasons, this research has shown that sources were also sought to invalidate or disqualify potential solutions, thus allowing the problem solver to move on to other approaches. It is possible however, that this reason to seek a source is a characteristic only when information seeking to solve a problem. Whilst no evidence has been found in this study, a seventh reason may be proposed as information may be sought from some sources solely to develop or maintain relationships. These contributions need to be reaffirmed in larger scale studies and in other types of organisations.

5.5.3 To ascertain how scientists use templates in knowledge transfer

There are a number of interesting findings in the use of templates in the transfer of knowledge that contribute to the extant literature in the field. The recognition that specific resources may be related to protocols has been previously recognised and has been linked to the robustness of routines (Winter & Szulanski, 2001). However, the use of the resources belonging to the source of the protocol has not been widely reported. From a scientific perspective there are many inconsistencies that may be generated by the conjunction of a complex protocol and the associated resources. In order to reduce the complexity and potential failings of the protocol, consistency was aided by the use of the ‘teacher’s’ own laboratory and the resources within it. Once there is successful ‘proof-of-use’ by the ‘student’ in the established environment, then the potential variability of the ‘student’s’ own resources might be an issue but is one that is recognised.

This study has provided a useful insight into the way that templates can evolve and be re-coded to include significantly more tacit information. A model that illustrates the development of an enhanced template has been created (Figure 5.1) which also demonstrates the interaction of all four quadrants of the SECI model (Nonaka, 1994). This practical scientific methodology clearly establishes the concept that tacit knowledge may be made more explicit through the use of observation and practice, or in D’Adderio’s terminology, ‘a socio-technical transformation’ that involves both actors and artefacts (D’Adderio, 2011, p. 205). The fact that some degree of tacitness may be encoded also provides some evidence to the idea that explicit and tacit knowledge exist at the opposite ends of the same continuum and that there are degrees of tacitness (Nonaka & von Krogh, 2009).

A ‘caterpillar tractor’ model which illustrates the movement from a simplistic ‘principles-based’ template to one that is tacit, and is therefore more useable, has been proposed (Figure 5.2). It makes a useful contribution to the literature by bringing together a number of theories relating to template evolution (D’Adderio, 2008), observation and questioning as a means of making tacit knowledge more explicit (Nadler, Thompson, & Van Boven, 2003). It also supports the notion of an intermediate template which acts in the role ‘mediator’ or a ‘virtual prototype’ in the co-creation of knowledge (D’Adderio, 2001; Latour, 2005; Jensen & Szulanski, 2007). Multiple forms of these templates existed and were used depending on the scientist’s familiarity with the technique. This finding has not been previously studied and is

worthy of research, as it is likely to directly influence the capture and use of organisational knowledge.

It is also apparent from this study that the practice of method transfer did not just require knowledge of the subject itself, but in the understanding of the mechanics of method transfer. The scientists that were involved in knowledge transfer recognised the importance of a scientific grounding. However, the knowledge of biochemistry (ostensive component), for example the attributes of the protein, was less important in the knowledge transfer process than the practical implementation (performative component), for example the use of instrumentation. Knowledge diversity did not necessarily result in a lack of shared mental models, it was more important that there was a sufficient joint understanding in the task (Paletz & Schunn, 2010). Indeed it was stated that there was a positive advantage to being an outsider to the particular field, as the ‘student’ had the need and excuse to ask ‘simple’ questions (Cross & Sproull, 2004), and not to merely accept the practice as being common knowledge. This finding supports Hautala’s (2011) proposal that diversity is beneficial if the actor’s needs intersect with the task, project or other organisational aim.

5.5.4 To establish the micro-foundations of absorptive capacity in the recognition of value

The subject of the third research question is the micro-foundations of external absorptive capacity in the valuing of new knowledge. This question brings together a number of research streams, each of which contributes a perspective on valuing knowledge, a topic that has been subject of multiple calls for research (Kane, 2010; Lewin, Massini, & Peeters, 2011; Yoo, Vonderembse, & Ragu-Nathan, 2011).

Previous studies on information seeking behaviour have tended to consider factors which represent data and information quality. Psychological and behavioural studies have considered learning styles such as the use of analogy and cognitive representations of quality when influenced by source characteristics. Whilst research into decision making has traditionally considered factors such as ‘satisficing’ and stop-rules when solving problems, these research streams have provided a range of determinants when valuing knowledge. These have been re-confirmed in this study and have been put together for the first time in a single holistic model (Figure 5.3), which also includes two new findings, the use of benchmarks and the importance of simplicity.

This study extends Laughlin's (1980) model by demonstrating that the valuing of intermediate solutions may be aided by benchmarking against previous experience, thus providing one (usually the lower) of the two dimensions of acceptability and making the judgement of stop-points significantly easier. This finding builds on work on analogical decision referencing which includes 'reference class forecasting' (Kahneman & Tversky, 1979), 'case-based decision theory' (Gilboa & Schmeidler, 2001) and 'similarity based forecasting' (Lovallo, Clarke, & Camerer, 2012). However it is important to note that these theories have been the subject of research into decision making, rather than valuing solutions.

A key finding of this research relating to the recognition of value is the importance of simplicity. Simplicity has been previously identified in the information seeking literature in the form of seeking a source which provides clarity of information (Cross & Sproull, 2004; Daft & Lengel, 1988). The extant literature also recognises the benefits of perceptual filters which amplify relevant information and attenuates irrelevant information (Walsh, 1995). However, simplicity has not been previously identified in the mainstream literature as a recognised characteristic of quality, as being beneficial in disseminating new information. The importance of simplicity in the valuing of information is worthy of further research.

5.6 Contribution to organisational practice

This research has studied the individual problem and through this conduit has explored the micro-foundations of information seeking routines, in accordance to the ‘strategy as practice’ school of thought (Whittington *et al.*, 2003). One of the key aims of a DBA is to provide an output which has direct applicability to the practice of business administration (Trafford & Leshem, 2009) and there are a number of findings from this study which have direct relevance to organisational management in general and biopharmaceutical management in particular. The exploratory findings support suggestions that some pharmaceutical companies are less than strategic in their knowledge management and technological development (Macher & Boerner, 2012). The findings of this study can contribute to management practice in three ways, through the strategic management of social networks, the management of knowledge and by recommending specific staff training and development.

5.6.1 Recommendations for the strategic management of social networks

Watts (2003) has previously recognised the importance of building organisations which are capable of solving complex problems, by helping individuals manage ambiguity by searching through their social networks, rather than contributing to centrally designed databases. Social networks have been demonstrated in this study to be particularly useful to biopharmaceutical organisations, which lack the resources and the internal contacts that the larger pharmaceutical companies possess. Biopharmaceutical organisations have developed an important means of identifying scientists with potentially useful contacts, which may be used by the organisation to gather information in strategically important areas. This strategic use of employee networks may be beneficial to pharmaceutical companies and other organisations that work in dynamic, knowledge intensive environments. There may also be some opportunity to learn from different sectors, for example by studying how newspaper journalists gather and collate information from their networks of contacts.

An implication of this study for practicing pharmaceutical scientists is that they should actively build trust and establish close network ties with their collaborative partners, translating the positive effects of social capital into a sustainable competitive advantage (Witt, 2011). This may be achieved by developing relational competencies and dynamic capabilities to identify new sources of knowledge; and may begin with the assessment of

early stage relationships for their degree of competence, reliability and compatibility with the partner's organisational structure and culture (Davenport, 2003).

Following on from studies on the positive influence of superordinate groups on knowledge transfer, it may also be possible to stimulate dynamic group membership and CoP's or project based work (Lewis *et al.*, 2007; Wenger, 1998) in order to promote an employee's identification with external biopharmaceutical collaborations. Organisational support in the form of incentives to reward 'actor-orientated' collaborations (Fjeldstad *et al.*, 2012) will benefit the organisation as it will act as a motivator for individual learning and the sharing of best practices between social network partners.

5.6.2 Recommendations for the management of organisational knowledge

It is apparent from this research that large pharmaceutical companies are especially concerned about the leakage of proprietary knowledge, and in order to 'manage' this, they actively discourage and restrict the sharing of scientific knowledge with other external parties. This study suggests that most useful knowledge comes from the tacit activities of scientists and that the inherent nature of tacit knowledge tends to place it outside the influence of contractual and intellectual property agreements (Roberts, 2000). The recognition of the importance of tacit knowledge to organisational learning, innovation and competitive advantage is an important step in moving towards a learning organisation.

Effective relational and knowledge exchange systems also need to be designed to ensure that problem solving processes may be supported and that social information may be captured in order to meet organisational objectives. In particular existing knowledge management systems should not just enable data storage but should support relationship building. These new 'relational knowledge management systems' (Xu, Kim & Kankanhalli, 2011) could be designed in conjunction with social networking web-sites, enabling the development of friendship networks and encouraging the use of virtual 'gift exchange.'

The author suggests that a pharmaceutical company's focus on intellectual property and explicitly coded knowledge is somewhat misplaced and perhaps is only relevant to the final stages of drug development. The effort, time and resources that were required for the successful coding and transfer of tacit knowledge were very apparent in this study. This finding should be considered when an organisation determines its IP protection strategy and should perhaps place less emphasis on restricting knowledge transfer and leakage, and place

more emphasis on finding ways to embed tacit knowledge deep into organisational routines, thus making it more difficult to appropriate (Hurmelinna, Kylaheiko, & Jauhiainen, 2007).

The author's proposal for more openness is supported by recent research which has demonstrated that for many organisations a relaxation of IP enforcement can benefit the industry. For example, an industry-specific consortium has been formed between several biopharmaceutical organisations to share early stage genetic research without compromising IP (Ekins & Williams, 2010). IP protection is however still rigorously enforced at the later stages of drug development and will contribute to each organisation's competitive products, demonstrating the potential for diverse patterns of IP-based competition in the industry (Alexy & Reitzig, 2012).

Another increasingly important form of sharing of knowledge without any of the constraints of IP is 'crowd sourcing' or the outsourcing of a task or problem to a community of people. A biopharmaceutical example is the freely accessible online drug discovery database Drugbank (www.Drugbank.ca). It would appear that scientists are creating new ways to source ideas and solve problems and are using on-line databases as one means to reach out beyond the formal organisational structures; this is a trend that should be supported by the pharmaceutical industry.

5.6.3 Recommendations for training and development

The role of gatekeepers is widely recognised (Volberda, 1996) and this pivotal position could be enhanced with additional support, possibly with personal coaching and attendance at networking events. A gatekeeper's role should align the view of the social experts with the organisational objectives such that a social influence may be developed around the organisation's R&D (Xu, Kim & Kankanhalli, 2011). As someone who understands the internal research profiles, the gatekeepers could provide assistance to scientists in framing problems as well as providing guidance to possible sources of help. The gatekeepers could manage the adaptive tension and knowledge transfer meta-routines between the organisation and its external environment, by preselecting and focussing assistance to appropriate sources and by providing guidance to what knowledge may be beneficial (Lewin, Massini, & Peeters, 2011; He & Wei, 2009).

This research has also contributed to an organisational understanding of the nature of knowledge transfer and the use of protocols. From this study's finding it would appear that

the writing of protocols appears to be solely for the benefit of the scientist who devises them, and usually ends-up in their laboratory workbook. These short ‘aid-memoirs’ of essential scientific conditions lack sufficient contextual detail to make them useable elsewhere. It was also found that other versions of the same protocol might exist which could cause confusion. This is perhaps an opportunity for management to review their processes in order to capture the organisational knowledge that exists in these templates. Scientific institutions could save significant time and resource by ensuring that these protocols are of sufficient quality at inception and are regularly updated, and a version control system is implemented.

The process of knowledge transfer with the use of templates has been found to be a highly complex and resource intensive procedure that can only be performed by someone with significant laboratory bench experience, over a period of time. It is apparent from this study that scientists were not selected for the knowledge transfer assignment on the basis of their methodology transfer experience, but were selected rather on the basis that they are related to the project and might benefit from additional learning in the area. Scientific organisations that expect to undertake methodology transfer would certainly benefit from having specialist ‘knowledge transfer scientists’ with a broad range of laboratory experience in order to build an expertise in the area.

Evidence from this study suggests that the use of interdisciplinary scientists or technicians may provide advantages over a scientist who is more focussed and deeply immersed in the area. It is also clear from this study that undertaking a methodology transfer project is considered to be a responsibility that is taken seriously by the participant and a significant achievement when it comes to fruition. In summary, the organisation should seek to build specialist expertise in the area of methodology transfer, possibly by establishing a community of practice (CoP) (Davenport & Hall, 2002). This CoP could provide an induction to the principles and details that are required during methodology transfer, and also provide the opportunity for scientists to shadow a ‘specialist knowledge transfer’ scientist at least on their first occasion.

Finally a greater understanding of the recognition of value (quality) has been achieved by this study. A key finding in this area is that value in science is often a subjective measure and is influenced by a number of factors including the source of knowledge and the involvement of stakeholders. It is therefore crucial that organisations optimise routines around the determination of value in external knowledge transfer, in order that organisational resources

are appropriately and optimally used. The proposed model (Figure 5.3) goes some way to recognising the key influences on valuing knowledge and might act as a template to optimise external absorptive capacity meta-routines which ultimately feed into the innovation potential of the organisation.

5.7 Creditability of the study

This study investigated the individual and social dimension of problem solving and knowledge transfer from a Pragmatic Critical Realist stance. When viewing the research from this philosophical perspective labels such as ‘validity’ and ‘reliability’ do not readily apply; terms such as these are more appropriate for studies that are more Positivistic and quantitative in their nature (Corbin & Strauss, 2008). It has however been suggested that the term ‘creditability’ might be more appropriate for Pragmatic Critical Realist research that is by its nature, more Interpretive (Rolfe, 2006).

This author has endeavoured to undertake this research in a manner that is consistent with both the philosophical approach and methodological rigour that has been previously applied to empirical studies. The study has set-out to undertake deductive research using established social research methodology and has achieved this aim by providing additional evidence to support theoretical concepts and organisational practice in a number of areas. The findings have broadly agreed with previous empirical studies, which help to support the validity of the findings.

The author does not claim that the findings are a version of the ‘truth,’ but believes that they have been generated through an insightful, transparent and reflexive process. The researcher considers the study to be valid in that the findings are an accurate representation of the participant’s recollection, and to this end has used verbatim narrative extracts that are traceable back to the original recordings. The author has also over a two year period, revisited and reconsidered the narrative output, in order to ensure that it most accurately represents the reality as perceived by the participants. He does however recognise that despite the transparency of the methodology, other researchers studying similar phenomenon in similar contexts may not be able to directly replicate the findings. Neither does the author assume that the findings of this study are representative of all problem solving routines that are found in all industries, but does consider that the findings will represent and be broadly applicable to those found elsewhere (Flyvbjerg, 2004).

The research has been designed to be broad in scope in order to capture the range and variety of behaviours and to provide a rich insight into the complexity of the subject. A deep understanding of the participant’s practice and industry norms, has helped the researcher to conduct the research with empathy and respect (Davies & Dodd, 2002). This has resulted in

the author being able to capture the ‘real-life’ experiences of the participants, some claimed to have found the interview experience ‘interesting and somewhat cathartic’ and were even surprised at their own conclusions. Feedback from the scientists who have read a draft version of the thesis, also recognise the themes that are reflected in the study findings and that they found the results to be ‘thought provoking’. They also believed that the findings were ‘actually quite important’ as they hadn’t previously considered how they solved their scientific problems. These comments suggest that the study has succeeded in its aim to uncover tacit problem solving behaviour.

During the research study period several different research methodologies have been considered and pre-tested (Silverman, 2006). The study was originally designed using semi-structured interviews, however it was quickly identified that this form of data collection would have provided a set of narratives which significantly differed in emphasis, depth and form. Whilst the output from semi-structured interviews might have provided some useful narrative examples of knowledge transfer; the participants would not know what was required of them and the divergent findings would have been difficult to synthesise. The use of the critical incident technique provided a valuable method to provide focus and boundaries for both the participant and the researcher. Whilst the critical incident technique has been widely used in past research, it has not to the author’s best knowledge been used in conjunction with problem solving, but has been found in this research to provide a useful mechanism to investigate knowledge transfer through this means.

The techniques of cognitive and causal mapping were also trialled, and whilst these techniques showed promise the conclusion was that neither technique illustrated the findings in a useful way. Both techniques result in a diagrammatic output which made a comparative analysis and the linkage to narrative very complex and unhelpful. The use of a thematic analysis in conjunction with a two dimensional matrix design enabled the capture of key themes which could also be applied to a temporal sequence of events, thus enabling a cross comparison between stages of problem solving and the supporting narrative at each stage. Through the testing of these different methodological approaches, a more creative methodology was developed which enabled both the complexity of knowledge transfer to be captured with the staged process of problem solving to be depicted and analysed. This methodological advance may in itself be recognised as an important contribution to research into organisational routines and knowledge transfer.

5.8 Recommendations for further research

There are a number of recommendations for further research that have come from this study and have been previously identified in this chapter.

This study has uncovered a difference between biopharmaceutical organisations and their larger pharmaceutical counterparts, in the nature and intent in how they use their informal social networks. It has been previously suggested that these factors are linked to the differences in innovation and growth of the industry. Further work however needs to be undertaken to establish a causal link and the potential influence between these factors; possibly through the use of a large scale longitudinal study with a quantitative methodology. Whilst the author recognises the difficulties in establishing appropriate variables for the degree of secrecy and the use of informal social networks in a study of this type, it is only by this form of methodology that the connection will be finally determined.

The use of informal social networks for problem solving in a scientific environment appears to work in a different way to other forms of information seeking behaviour, in that sources are solely selected on the basis of their knowledge rather than from a ‘cost-benefit’ or ‘ease-of-access’ perspective. This difference in emphasis may be unique to the biopharmaceutical industry, but the author suspects that it also applies to other knowledge-based problem solving environments. Future research could seek to determine if there is a correlation between problem complexity and specificity of knowledge, and simpler forms of knowledge where ‘cost-benefit’ or ‘least effort’ may be the prime motivator. Thus resolving the debate that has, to date, relied on data from small scale and single industry studies.

Research has previously suggested that the evolution and development of routines may involve the use of ‘intermediate templates.’ This study has found clear evidence of these and suggests that additional work in this area might consider the theoretical potential of the ‘caterpillar-tractor model’ when evaluating other organisational routines. The proposed model also provides the potential to link learning to template development through the use of the SECI model; thus providing the means to integrate several theoretical processes when evaluating the development of templates in organisational routines.

The degree of overlap of knowledge when transferring or enhancing templates has also been shown to be an important issue. Preliminary results suggest that with respect to knowledge transfer, an overlap of process knowledge is often more important than scientific knowledge;

indeed a lack of scientific knowledge may actually enhance knowledge transfer. Research in this area is developing rapidly, and further studies measuring knowledge types and degrees of overlap when performing knowledge transfer would provide a valuable contribution to the theoretical foundations and organisational practice in this field.

It has been previously suggested that recognising the value of new knowledge is a key intermediate stage in most absorptive capacity models. This study has started an evaluation of the micro-foundations of value recognition and has proposed a model which includes the influences and antecedents in the decision making process. This model may be used as the basis for deductive research in the area and will aid in the development of a fuller understanding of this important factor in the micro-foundations of knowledge transfer.

Finally this study has demonstrated a link between problem solving and absorptive capacity through the action of valuing information, and has demonstrated the importance of understanding the micro-foundations at the individual level, in order to provide an insight of how aggregated knowledge transfer may work at the organisational level. The author encourages more qualitative research at an individual level and proposes that investigations into the subsequent stages of absorptive capacity will provide a fuller model of the micro-foundations of absorptive capacity and will serve to establish its role in the transfer and creation of new knowledge and innovation potential of the organisation.

5.9 Conclusion of the discussion chapter

The discussion and conclusion chapter has considered the findings of the study in relation to the extant literature and the research questions. The chapter has confirmed much of what has been proposed by theorists in different research streams and has contributed to theory and research practice by providing new insights and models in a number of areas.

The chapter started by comparing the use of social networks of the pharmaceutical and biopharmaceutical participants in the exploratory study and this indicated a difference in organisational and cultural approach, with the biopharmaceutical participants being more willing and able to network and share information than their pharmaceutical counterparts. The possible reasons for this have been discussed.

The findings that are associated with the first research question were discussed in the context of the extant literature. One key finding indicated that a source was most commonly selected

on the basis of their experience and knowledge rather than other criteria which had been previously cited in the literature. The second research question compared the extant literature to the study findings. Three forms of template development were identified (initial, incremental and enhancement). The use of the SECI model in enhancing templates was demonstrated through a schematic diagram derived from the study data. It has been argued that the incorporation of tacit knowledge into a template occurs with the aid of intermediate templates. The process has been portrayed through a 'caterpillar tractor model.' The findings with regard to valuing new information were discussed in the context of existing theory. A model has been proposed which illustrates the influences on judgement and decision making. Many of these factors have been previously recognised in the extant literature but this model brings them together and adds at least one new dimension, the importance of simplicity as an aid to dissemination.

The chapter returned to the holistic model that was originally proposed in the literature review and this now illustrates the potential role of external absorptive capacity and social capital in problem solving. The pivotal position of 'valuing new information' in the diagram has been demonstrated by the study to be an important factor for the effective transfer of relevant external information.

The discussion and conclusion closes with a review of the most important theoretical contributions of the study and suggestions of positive measures that could be implemented by biopharmaceutical organisations. It also critically evaluates the quality of the research and closes by proposing follow-up research that would build on the findings and add to the growing body of theory in knowledge transfer and absorptive capacity.

6 Personal development whilst completing the doctoral thesis

As an academic I am used to supervising undergraduate and postgraduate dissertations and did not think that conducting my own doctoral research would provide too many project management or intellectual challenges. As a manager I routinely conducted meetings and through various sales and consultancy roles have over the years interviewed thousands of people. I have previously written a text book and have contributed chapters for other books. I have also taught at master's level for a number of years and felt I had a good grasp of the theoretical literature. However, the learning that I have taken from this research study has still been significant in a number of ways.

Most significant was the volume of reading that I had to undertake. This resulted in many hundreds of papers being read and summarised, and numerous mind-maps and diagrams produced in order to formulate and integrate the theory that I was investigating. The research started from a premise of a study into innovation which is an interest of mine and with the biopharmaceutical industry which I am familiar with. However, my early notes and diagrams demonstrate how far I have come from my early ideas of alliances and the resource based view. It was clear from my early reading that relatively little quantitative work had been published in the literature on absorptive capacity and ultimately papers such as Lewin, Massini and Peeters (2011) provided the impetus and ideas for the final study into knowledge transfer and absorptive capacity.

A 'breakthrough' came when I realised that I could use problem solving as a proxy for knowledge transfer, thus providing a conduit into the model of absorptive capacity. This realisation was quickly followed by the recognition that the critical incident technique would fit this paradigm well. It was clear from early on that the main form of data processing would be by thematic analysis; but the form that these themes would need to take to provide a useful comparative insight, took some months to resolve. Initially cognitive and causal maps were undertaken for each of the interviews but despite looking 'pretty' they did not provide the necessary tools for synthesis, or divulge the comparative information that I was seeking. Subsequently the final concept of a 2D matrix was developed and trialled and has since proved its worth.

As a relatively fast typist I did 'try my hand' at transcribing the interviews, but quickly I discovered that to do this efficiently would take too long, so this was outsourced to a

specialist company who did an efficient and professional job. I was a little disappointed that I had to resort to this, as I thought by doing my own transcription I might get 'closer' to the data, however listening to the interviews and reading the transcripts several times have provided much the same experience.

I have always been highly motivated and logical in my approach to large projects and found the thesis to be no different. I created my own challenges, for example to complete a draft chapter in a summer break and then broke this down to tasks for each week and day, attempting all the while to keep to my self-imposed schedule. The final writing up was little different to my authoring of a book or chapters, I found it more challenging trying to keep an element of criticality, clarity and focus. This was particularly difficult due to the breadth of the study and having to clearly interlink the theoretical areas in a tight word count. It was tempting to delve deeply into other related areas such as the psychology of decision making and it was often difficult to decide what to include and to exclude from the study. Many thousands of finely crafted words and hundreds of citations have been excised in this process, which wasn't as painful as I might have imagined as I could immediately see an improvement in clarity.

Whilst I knew the basic premises of research philosophy and research methodology, at least well enough to effectively supervise at master's level, I nevertheless found the NBS taught sessions and numerous guest speakers valuable in focussing my thoughts and providing a deep foundation for my research. Another learning outcome from this study has been the different ways in which supervisors and peers undertake their research. Conversations with my peers that were undergoing their own doctoral research produced a surprising array of approaches, ranging from writing a succession of literature reviews at an early stage, to collecting data before undertaking any literature searches, writing the thesis from back to front etc.

My own preferred approach was to undertake significant reading and to draw models, mind-maps, tables and flow charts in order to provide a theoretical grounding. However, I was also keen to collect data in the form of an exploratory study, with the dual purpose of providing evidence of the use of social networks and to practise my data processing skills. Writing the mid-point progression report was the first major opportunity to formalise my thoughts and was useful in this regard, although my final research focus differed in some respects from this document.

High points in the three and a half year part-time research project were when after days of reading I had ‘eureka moments’ which often occurred when the theory or methodology fell into place in the form of a diagram. Low points were the interminable reading and note taking, often spending days searching for relevant papers only to find that they were not what the abstracts indicated, or that the research was yet another large scale quantitative study based on spurious variables and without significant conclusions. With exception to the information seeking literature, there was very little qualitative research that was based at the individual, micro-foundation level or indeed that related to organisational practice.

In summary there have been a number of challenges in undertaking the research and writing the thesis, but there have also been many beneficial learning outcomes. All of which will help me in my future research, teaching and supervision. For example, I intend to write a new post graduate module based on my interests in innovation, social networks and knowledge transfer. I hope to publish at least one paper from this study based around valuing new knowledge and possibly another on the uses of templates in the knowledge transfer process. During the course of this study I have also collected interesting data on the nature of scientific problem solving and have created a new model which I intend to further explore. I am considering appropriate journals and may submit to Management Science, Technovation or the Journal of Knowledge Management. I have also been provisionally allocated a second supervisor role to a new doctoral student who is undertaking research on open innovation and I hope to assist him with the benefit of my own experience.

7 Appendices

Appendix 1: Examples of open questions used in exploratory study

- How do unsuccessful experiences of searching for information influence future searches?
- Are there occasions when you really don't know what you need to know... how do you approach this?
- Have you given up searching for information do to difficulties or other priorities?... why?
- Do some sources frustrate you but you persevere with them regardless?... why?
- Are there specific occasions when you decide to no longer use a source of information... why?
- How do you recognise if someone is approachable or not?
- Have some of your contacts become friends... in what way does this help?
- Would you approach some contacts in different ways to others?... why?
- If asked would you always recommend your sources to others... if not why not?
- Do you find yourself in demand as a source of contacts or information?... do you mind?...why
- are you motivated to help?... why?

- Have there been other occasions where you have been used as a source of information & in the process it has helped clarify an issue for yourself?...how has this affected your approach to helping others?

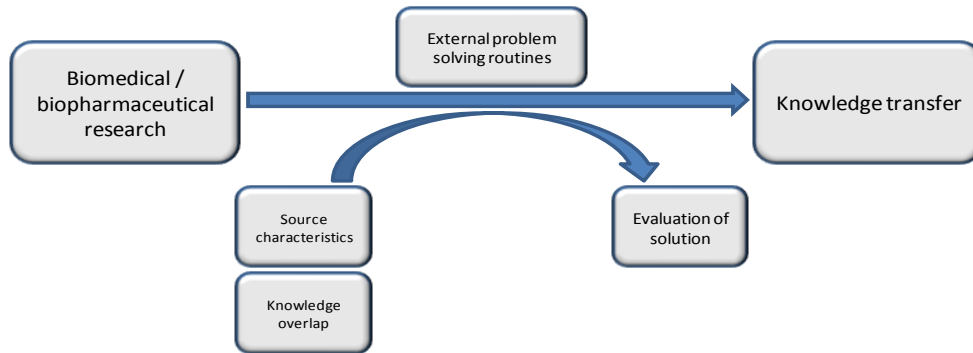
- If the information you received was false would you use this source again?...why/why not?

Appendix 2: Overview of research provided to each participant

Working title:

An investigation into the micro-foundations of external absorptive capacity in biopharmaceutical research.

Overview of research objectives:



Research Objectives:

1. *To establish the importance of social networks in the biopharmaceutical industry as a means of problem solving*
2. *To evaluate the informal micro-routines for external problem solving*
3. *To determine the key influences on the identification of an appropriate solution to a scientific problem*

Participant's consideration:

Please recall one or more examples of when you had to find information in order to solve a scientific problem and sought a contact from outside your organisation to help you find a solution. The person you contacted may have been previously known to you, have been recommended to you or you may have contacted them directly without detailed knowledge of them. It is also acceptable to the boundaries of this research to use an example of seeking data in order to solve a problem, but this should still involve the use of external contacts.

Ideally your example(s) will highlight a problem that was inherently difficult, such that it took several attempts to find an appropriate solution/answer. But this is not essential.

During the interview you will be given every opportunity to discuss the experience(s) and we will unpick the thought processes and consider the approach at each stage. It is just equally important to this research, to understand what was not an acceptable solution and why, as well as what has been an acceptable solution and why.

This research aims to evaluate the social interaction and tacit considerations behind the *external problem solving process* and will not require a detailed explanation of the problem or the solution. Your attention is brought to the ethical considerations of anonymity and confidentiality on the ethical approval form, supplied separately.

Appendix 3: Example of interviewee consent form

Title of Study	<i>An investigation into the micro-foundations of external absorptive capacity in biopharmaceutical research (working title).</i>
Person(s) conducting the research	Chris Jeffs <i>Senior Lecturer</i>
Programme of study	Doctoral research
Address of the researcher for correspondence	Newcastle Business School Post Graduate Strategic Management City Campus East, Newcastle upon Tyne
Telephone	0191 2273332 (dir)
E-mail	Chris.Jeffs@Northumbria.ac.uk
Description of the broad nature of the research	The purpose of this study is to investigate biopharmaceutical innovation networks, in particular to evaluate the characteristics of social capital on the perceived value of sought information. This study will ultimately contribute towards a doctoral thesis.
Description of the involvement expected of participants including the broad nature of questions to be answered or events to be observed or activities to be undertaken, and the expected time commitment	An interview will be arranged at a mutually agreed time and place. The interview questions will be highly generic and exploratory in nature and will relate to the experiences of the participant in seeking information within their professional networks; rather than an investigation of organisational data, processes or products. The interview will last approximately 1 hour. Further details will be provided prior to the interview. All interviews will be recorded with a digital voice recorder and will be transcribed. The transcript will be returned to the participant by their preferred means of email or post, for final approval. You will be asked to view the transcript for accuracy & content; this may take approximately 1 hour and may involve amendments, deletions or additions.

Cont.

A follow up meeting or email is possible in which you may be asked to comment on the synthesised output from your interview.

All information in this study will be anonymised, with the names of participants and organisations changed. Organisations and participants that are named during the interview process and any other unsolicited confidential data will be changed or deleted prior to the participant reviewing the transcript. The researcher wishes to make it explicit that they are not seeking to investigate or document any confidential or sensitive information as part of this research.

All data will be stored securely either electronically or in a hard copy form in a locked filing cabinet. As part of the doctoral supervision process hard copies of the anonymised transcripts may be shown to the supervision team, but will be returned to the researcher for safe keeping.

Data obtained through this research may be reproduced and published in a variety of forms and for a variety of audiences related to the nature of the research (i.e. doctoral publication, conferences, peer reviewed journals, articles etc.). However no product names or any other forms of information that could lead to the identification of the organisation or its employees will be disseminated in any way.

Information obtained in this study, including this consent form, will be kept strictly confidential (i.e. will not be passed to others) and anonymous (i.e. individuals and organisations will not be identified unless this is expressly excluded in the details given above). Data obtained through this research may be reproduced and published in a variety of forms and for a variety of audiences related to the broad nature of the research detailed above. It will not be used for purposes other than those outlined above without your permission. Participation is entirely voluntary and participants may withdraw at any time.

Appendix 4: Blank 2D spreadsheet matrix for template analysis on a temporal basis

**	Contextual (role)	Contextual (nature of task)	Situational (characteristics)	Personal (behavioural style, cognitive ability)	Informational (knowledge credibility)	Informational (quality)
Step #	Routine stage <i>(routine or digression)</i>	Staged objective, motivation, audience, constraints	Mechanism of approach; access/ convenience	Source characteristics <i>(goals, relationship, trust, respect)</i>	Knowledge characteristics <i>(explicitness and familiarity)</i>	Evaluation of solution <i>(solution and considerations)</i>
1						
2						
3						
4						

Appendix 5: Form for ethical clearance for research to be conducted in the organisation

RESEARCH ORGANISATION INFORMED CONSENT FORM

Newcastle Business School

University of Northumbria

Completion of this form is required whenever research is being undertaken by NBS staff within any organisation. This applies to research that is carried out on the premises, or is about an organisation, or members of that organisation or its customers, as specifically targeted as subjects of research.

The researcher must supply an explanation to inform the organisation of the purpose of the study, who is carrying out the study, and who will eventually have access to the results. In particular issues of anonymity and avenues of dissemination and publications of the findings should be brought to the organisations' attention.

Researcher: Chris Jeffs, *Senior Lecturer, Newcastle Business School*

Researcher's Statement:

Research Purpose

The purpose of this study is to investigate biopharmaceutical innovation networks, in particular to evaluate the characteristics of social capital on the perceived value of sought information. This study will ultimately contribute towards a doctoral thesis.

Participants

Several research scientists at differing levels of seniority. Organisation and individual participation is entirely voluntary and may withdraw at any time. Individuals will be initially contacted by email by the researcher but are otherwise under no obligation to participate.

Research methods

Participants will be provided with a brief overview of the interview objectives and an individual consent form, which they must sign before the interview can take place. Following the return of this form as a hard copy or by email, an interview will be arranged at a mutually agreed time and place. The interview questions will be highly generic and relate only to the experiences of the participants rather than to organisation data, processes or products. All interviews will be recorded with a digital voice recorder and will be later transcribed. The transcribed interview will be returned to the participant by their preferred means of email or post, in order to confirm that it is an accurate record of the meeting.

Timescale

The data collection timescale is from November 2010 to July 2012

Time commitment

The interview will last approximately 1 hour. The checking of the transcript, which is likely to be some weeks after the interview, will take approximately 1 hour and may involve amendments, deletions or additions. A follow up meeting is possible with each participant where they may be asked to comment on the synthesised output, which is most likely to be in a diagrammatic form.

Anonymity

All information in this study will be anonymised, with the names of participants and organisations changed. Organisations and participants that are named during the interview process and any other unsolicited forms of confidential data will be changed or deleted prior to the participant reviewing the transcript.

Confidentiality

The researcher wishes to make explicit to the organisation & participants that they are not seeking to investigate or document any confidential data as part of the research. In the event that there is an accidental divulgence of confidential material it will be deleted from the record and not be referred to in any way. All data will also be securely stored either electronically or in a hard copy form in a locked filing cabinet. As part of the doctoral supervision process hard copies of the anonymised transcripts may be shown to the supervision team, but will be returned to the researcher for safe keeping.

Research Dissemination

Data obtained through this research may be reproduced and published in a variety of forms and for a variety of audiences related to the nature of the research detailed above (i.e. doctoral publication, conferences, peer reviewed journals, articles etc.). No forms of information that could lead to the identification of the organisation, its products or its employees will be published or disseminated in anyway.

Queries

Please direct any queries regarding this research to:

Chris Jeffs

Newcastle Business School

Post Graduate Strategic Management

Tel: 0191 2273332

Email: Chris.Jeffs@Northumbria.ac.uk

Any organisation manager or representative who is empowered to give consent may do so here:

Name: _____

Position/Title: _____

Organisation Name: _____

Location: _____

Anonymity is offered to the organisation if it does not wish to be identified in the research report.

Confidentiality is more complex and cannot extend to the reviewers of staff work, but can apply to the published outcomes. If confidentiality is required, what form applies?

- No confidentiality required
- Masking of organisation name in research report
- No publication of the research results without specific organisational consent
- Other by agreement as specified by addendum

Signature: _____ Date: _____

This form can be 'signed' via email if the accompanying email is attached with the signer's personal email address included. The form cannot be completed by phone, rather should be handled via post.

Appendix 6. Table 1: The development of a social network (Exploratory study).

Description of finding	<i>Illustrative narrative extract</i>
The exploratory study showed that social networks are important to many biopharmaceutical research scientists.	<i>They [biopharmaceutical scientists] maintain er a strong er academic network which I personally believe is also essential to further long-term success [P1:16]</i>
Biopharmaceutical companies use their networks to solve problems, and in order to stimulate creativity. This effort is expected to return benefits to the organisation.	<i>If you get a critical mass of people like that around all of a sudden you get a nucleating effect and you actually become much more creative [P3:632]</i> <i>It works very well, kind of reaping what you sow really [P3: 561]</i>
It is also evident that scientists are recruited on the basis of the contacts that they can bring to the organisation	<i>People can make a huge difference [bringing their social networks to the organisation] [P1:634]</i>
It is clear that large pharmaceutical companies have the advantage that they can more readily solve problems internally and without resorting to their external social networks.	<i>I think probably again large companies em you know I would say does anybody know anyone in chemistry that can to help me with this issue or this question and almost always somebody internally that knows could answer your question that's the benefit of a big company [P3:526]</i> <i>I stay in touch with quite a few people from my old er my former position em I don't I very seldom you know ... if I wanted to pick someone's brains I would find someone internal [P3: 511]</i>
The biopharmaceutical social network appears to be strategically used to seek specific information in biopharmaceutical companies.	<i>I think it's important and there are let's say seven or eight different patent strategies we have written down confidentially and so people know about this and try and should think along those lines if they can find anything in that respect [P1: 497]</i>
The terms 'alert filter' and 'osmotic barrier' have been used to describe this information seeking process.	<i>You try to guide people and when you even say to them ok if you communicate with the outside world just just keep in mind what we are interested in yeah so there is some type of alert filter for this osmotic barrier [P1: 867]</i>
A scientist's social network tends to grow and develop to adapt to	<i>Yeah I would definitely say that er actually that the social network actually still increases I would still say that it increases but in parallel</i>

<p>different scientific needs as products are developed</p>	<p><i>to the change of focus [P1:614]</i></p> <p><i>At the beginning they were also working on different targets simultaneously erm so the idea was working towards many more targets and that meant that from a discovery point of view the social network was more tailored towards let's say very very early discovery er work and networks particularly also with respect to different biological targets [P1:593]</i></p>
<p>The use of contacts was very considered; different contacts are used when they have been proven to be reliable for certain situations. But it was recognised that it is also important to refresh the network with new contacts, in order to gain a new perspective.</p>	<p><i>I would use certain existing contacts erm especially when it comes to certain business decisions there are certain people in my social network er which I consider to be quite reliable and erm I would discuss certain aspects with them but I always would also try to get some new people which look which don't know me personally and erm who have never been exposed er to any particular question [P1:668]</i></p>

Table 2: Organisational restrictions of use of social networks

Description of finding	<i>Illustrative narrative extract</i>
<p>The larger pharmaceutical companies place more emphasis on confidentiality in a social situation than smaller biopharmaceutical companies do.</p>	<p><i>We're [large pharmaceutical company scientists] encouraged to go to meetings but you're to actually get to talk at a meeting and get your talk sort of approved is quite difficult [P3:353]</i></p>
<p>This makes interaction at scientific conferences difficult for the individual, as they are aware that they are presenting old data.</p>	<p><i>I'm very aware that they're very very cautious about em any disclosures on that sort of line I feel like sort of makes you would feel mealy mouthed that's my problem is you know we go to conferences and we can't actually we're presenting data from sort of three and four years ago for various reasons [P3:308]</i></p>
<p>Through the pharmaceutical company's policies and procedures the organisation tries to restrict the</p>	<p><i>So anything that's written or say presentations or papers and that sort of stuff all have to go through a</i></p>

<p>deliberate or accidental transfer of intellectual property.</p>	<p><i>vetting procedure which is far more em require far more levels of sign off than you'd ever have needed at at prev- sort of small companies em in terms of other and we'd have to sort of comply with various policies regarding what we we what we can say and what we can also what we can listen to what we can hear bizarrely [P3:434] ... Actually obliged under [company name removed] processes to leave the room so you can't accidentally overhear what they're talking about [P3:442]</i></p>
<p>This behavior is recognised to have been very different in the biopharmaceutical industry</p>	<p><i>I just think I think you always think well I used to think twice[in a biopharmaceutical company] I now think three or four times [in a pharmaceutical company] before saying things [P3: 303]</i></p>
<p>The biopharmaceutical companies appear to be less constrained in this respect and might seek confidential information from external sources.</p>	<p><i>Whereas with a biotech company you you'd sort of purposely lean over with an ear trumpet [laughs] and find out what they were working on! [P3:445]</i></p>
<p>Image is more important to the pharmaceutical company than the smaller biopharmaceutical company</p>	<p><i>A positive corporate ethical image is obviously very important but it's something that doesn't matter so much to biotech if the [company name removed] or whoever I worked for got a reputation as being a bit sort of [pause] you know bit sort of leery at conferences or whatever it wouldn't really make any difference [P3:453]</i></p>
<p>There is a recognised risk of inappropriately sharing confidential information</p>	<p><i>The detail they [biopharmaceutical scientists] probably give away far too much and at that point they should be saying to the university you know what can I say to this guy and actually they've just developed a relationship with him they are very happy to chat and they start telling him about stuff [P2:718]</i></p>
<p>This restriction on exchanging knowledge is clearly tied to the competitive nature and the funding regime of the industry.</p>	<p><i>I suppose in science is quite a bit of competition and obviously if you know it's harder and harder to get money so that obviously works against that openness I mean especially I mean some of these meetings you notice that people are just talking about things they already published because they basically don't dare</i></p>

	<i>to show... anything else because somebody might overtake you. [P3:44]</i>
<p>However it is also suggested that the relaxed means of exchanging a certain amount of confidential information may actually benefit the organisation by helping establishing trust and to develop long term relationships.</p>	<p><i>You could probably exchange such an idea in an informal manner and then say ok if you agree then yeah then we need some kind of formal agreement [P1:226]</i></p> <p><i>You didn't need any type of confidentiality agreement [in a biopharmaceutical company] so it was a type of closed shop where erm it was where you had the objective really to disclose even confidential information what is classed as confidential matters erm and those people that have been part of that group er I think that laid also quite a good foundation of long-term relationships [P1:114]</i></p>
<p>Although there is always the danger that they may not appreciate the true of the IP that they own</p>	<p><i>People don't really understand the value of what they've got sometimes and they undersell it [P2: 803]</i></p>

Appendix 7: Example of completed 2D spreadsheet matrix

Participant 6. Seeking a biological model

	Contextual (role)	Contextual (nature of task)	Situational (characteristics)	Personal (behavioural style, cognitive ability)	Informational (knowledge credibility)	Informational (quality)
Step #	Routine stage <i>(routine stage or digression)</i>	Staged objective and motivation	Mechanism and form of approach	Source characteristics <i>(relationship, trust, respect)</i>	Knowledge characteristics <i>(explicitness and overlap)</i>	Evaluation of solution <i>(solution and decision)</i>
1	<p>Material requirement. <i>I was looking to try a better more reliable technique (M6b:70). I knew that there was this person in America who had this 'knock-out' animal and I knew that it was good (M6b: 14). This was the option that was kind of I felt more comfortable with because I though well you know it is moving closer it's a good model to the human condition (M6b: 71).</i></p>	<p>New funding requires further justification and to overcome concerns of the critics. <i>Its kind of satisfying my critics, but also my own sort of you know why I am doing this (M6b: 74). She's got a model and then there was a there's another model in Germany so they're like two bigwigs of the field (M6b: 74a). The German mouse.... It's a good model but there are certain things that you could criticise it on (M6b: 74b). I was looking to apply for further grants em little grants that I'd applied for this was always a criticism (M6b: 75) So that kind of motivated me but also em just my own personal interests you know I wanted to get closer to sort of human condition myself (M6b: 76) More reluctantly I suppose for two reasons I feel the mouse model [German] isn't as good and secondly I just don't have the contacts (M6b: 97-98)</i></p>	X	X	Only two sources available	A more reliable technique is needed, only two solutions available one preferable to the other.

2	Approached a work colleague for a recommendation	Has established relation with source, wanted referred contact. <i>I went to him and said oh do you know this person and they were like of yes they're really nice (M6b:15)</i>	F2F communication with in-house colleague. <i>So I got his approval you know went to him and said look would it be OK to approach ths American person ... can I say your name?... Yeah they're [source] always willing to collaborate (M6b: 84-85).</i>	Senior colleague, respected mutual acquaintance. <i>His research was quite close to mine so I mean that's why he was one of my assessors (M6b:15). They-ve always been very supportive in everything I've done (M6b: 82c)</i>	Known to have access to contact. <i>He'd actually been to her lab and you know so they had a kind of a professional relationship (M6b: 86).</i>	Able to assist in providing contact <i>Why don't you get in contact and see if they would you know maybe want to collaborate, tell them your ideas (M6b:15)</i>
3	Approach external source	Obtaining access to biological materials <i>The most successful was going to be using their [referee name] (M6b: 87). I had to approach this in the right way in a professional way... I had to be serious and professional (M6b: 80-82). I always respond to them [requests from people] but like if someone says oh this person said that you would be the ideal you kind of think of right so that person knows them so it must be OK (M6b: 83). I always think like well if it was me getting the email what would I want to know (M6b:90b)</i>	Renowned researcher, serious professional contact required, flattery and mutual acquaintance used. <i>I got in contact and just emailed them and said look, no I always say oh well I know this person in case they think I'm some crazy person (M6b:16). I know you've got this knock- out animal... I'm in love with you that sort of thing (M6b:18). I suppose you know slightly intimidated...they-re up here and I'm down so a bit inferior to them (M6b: 77). It was slightly intimidating at first you know slightly overwhelming (M6b: 82b).</i>	Established reputation in field	Commonality established. <i>These are my papers I'm very interested in this...I've been following your work for a while (M6b:17). Yes [source] we are always interested in collaborations (M6b: 19)</i>	Reputation and limited options
4	Arranged to meet external source	Further establish need and requirements. <i>We're [source] going to this American Society of Nephrology meeting are you going too? be good to meet up (M6b: 20)</i>	Met at conference (use of conferences to meet is common). <i>We met up and now we are still collaborating (M6b: 21)</i>	Highly respected in field. <i>I would trust her because she is very good (M6b: 96a)</i>	Common technological interests. <i>I would take her ideas on board but I would also have my own ideas as well you know so I'd kind of merge the two together (M6b: 94)</i>	Good technological fit. Overcame potential criticism. Problem aims met. Trusted but will check quality for own satisfaction. <i>I would always make you know have controls to make sure that they were un-mutant... just for my own satisfaction (M6b: 94-95). She could have easily swapped the samples by accident you know and so</i>

						<i>it'd be always good to double check you know (M6b: 96b). You've got to feel comfortable with it yourself (M6b:36)</i>
5	Maintained communication and visits	Bi-directional recommendations <i>She would trust my judgement if I recommended someone to get in touch with her (M6b: 93)</i>	<i>Reciprocal arrangements. She's been over here to give a talk.... There's a good relationship now and I've been across to her lab... built up you know (M6b: 91). Would use her name for someone else to contact (M6b: 92).</i>	X	X	X

Appendix 7 cont.: Example of completed 2D spreadsheet matrix

Participant 9. Methodological transfer

**	Contextual (role)	Contextual (nature of task)	Situational (characteristics)	Personal (behavioural style, cognitive ability)	Informational (knowledge credibility)	Informational (quality)
Step #	Routine stage <i>(routine or digression)</i>	Staged objective, motivation, audience, constraints	Mechanism of approach; access /convenience	Source characteristics <i>(goals, relationship, trust, respect)</i>	Knowledge characteristics <i>(explicitness and familiarity)</i>	Evaluation of solution <i>(solution and considerations)</i>
1	<i>We had to go to an external source to kind of get more advice [MS9:1]</i>	<i>It was quite a small project and it was going to take a lot of time and a lot of money well no sorry a lot of effort to do it [MS9:4b] I think success was the most important thing and it was the best way to get to that successful point to get the study finished with results [MS9:18]</i>	<i>When the project had started I started looking internally first at the help so it was basically the the group that my boss had previously spoken to for the expertise in the first place so I went to kind of the postgrad there and it certainly became clear that this was going to cost a lot more than what we'd initially thought and what we'd written the.... grant for and so she had then suggested that there was an alternative method and it's at this point that the the the kind of the the project really kind of took off [MS9:5]</i>			
2	Further internet research	<i>I went back to the office I did a literature search and found like a really good paper and on that was referenced a specific group at Sanger Institute in Cambridge [MS9:6] Referenced in the paper as the two well there was ... a few methods in there em and these were the two that seemed the most appealing to us [MS9:17]</i>				

3	Supplier contact	<i>They described some methods in which I then looked into more detail em at the two different methods which were developed by two different companies as well [MS9:7a]It was basically target enrichment for next generation sequencing. And the best target enrichment method and it just compared a number of... different methods [MS9:17b]</i>	<i>Em and so the first instance what I did is contacted two these two external companies that we were particularly interested in using [MS9:7b]</i>		<i>The first company em gave us some details further details on the kit em and that they actually had a new kit coming out in a few months' time as well that would be more suitable for our needs[MS9:7c] The second company that we contacted em gave us updates on their process and they offered us a more expensive price but it was still cheaper than the initial project [MS9:8]</i>	<i>It was more it was a better method as well it was more robust [MS9:9]it was more you could repeat the the data it was more you know you could replicate itEm better and em like I say it was more specific so it was better for our our needs [MS9:19]</i>
4	Confirm experience with separate group		<i>We then contacted a group over in Munich as well for experience on what they were doing em [MS9:10a]</i>			<i>We ruled that method out at the minute because it wasn't as high throughput as what we wanted [MS9:10b]</i>
5	Querie regarding published protocol	<i>Once we'd spoken to the two companies and we'd settled on the methods then there was something there was em a step in the protocol that hadn't really been well it wasn't in routine use by any other group they'd tried it at Newcastle University and hadn't got it working [MS9:10c]</i>	<i>I went to them [suppliers] with specific questions ... it was mainly email based as well so they would... get back [MS9:23] It was very much kind of me doing it and then getting advice from them if I came across... a hurdle [MS9:24] Well it was actually it was a more enticing you know opportunity because they were actually doing everything for us so the experts were doing it [MS9:25]</i>	<i>I think from that point of view they were quite happy to get in touch (laughs) with us and you know and give us positive feedback [MS9:28] You know it's not you you trust them (laughs) a little bit more than somebody novel you know you doing it [MS9:26] yeah it was it was it was a nice it was like I say it was more it it made me want to go into you know business (laughs) per say with them more[MS9:27]</i>	<i>They were actually they were really helpful so in the first instance you always talk to the rep [MS9:20] When we'd actually chose to go down that route you have to design the kit yourself which are quite it's quite difficult and when you're doing it for the first time as well and using you know databases for the first time and so that's when I approached the technical department there [MS9:21] were very helpful in kind of giving feedback and the best way to design it [MS9:22]</i>	

6	<p>It was it was kind of a stab in the dark to ask them for their help [MS9:42] I designed the kits and helped with the two companies with the help from the two companies and then I took those kits down to the Sanger Institute and did the protocol down there and everything down there em with the help from the Sanger Institute [MS9:12]</p>	<p>[SANGER] it's like this big bubble you know and it's just it's got its own gym its own tennis courts and em swimming pool it it's great it was really it was I think you kind of you feel very em (laughs) proud just to be driving in coz like you ... say you see it everywhere and and it was yeah it was it was a really nice experience [MS9:32] I think I would have been a bit more apprehensive about it being my first time and with the kits costing so much money you had to get it right the first time [MS9:37]</p>	<p>I have to say that the person that I was learning the technique from was probably a lot a lot busier than what I initially thought because you know you kind of headless chicken running (laughs) around all over the place and it was I was I was left to my own devices quite early on [MS9:33] So they provided everything basically you know they they provided all the kits and em the the tags they let us use their own tags to get this this design working em and also it was the knowledge that they passed on [MS9:34]</p>	<p>it's all really organised to be as high throughput as possible you know I walked into one room and so I think one of the sequences at the time was like half a million pounds and they must have had forty or sixty of them lined up[MS9:41] I think they're em they lived up to their reputation [MS9:45]</p>	<p>I don't think we could have done it without the help from those three companies either or from the two companies and the Sanger Institute [MS9:13] Yeah if I had the protocol I think I could have made an attempt at it but like I say the protocol isn't published so it was something that is specific to what they're doing at the Sanger Institute and secondly I don't think the results... would have been as good [MS9:36] A learning short-cut definitely it's like an intense learning period about next (laughs) generation sequencing [MS9:39]</p>	<p>Like I say it's these little techniques and the tips that you get em told er with experience you know comes naturally [MS9:38]</p>
7		<p>But you know I also found out about other stuff that was going on there at the time as well and they had like the next next generation sequencing that they were testing out ... at the time which was great [MS9:40]</p>		<p>They've continued to be very helpful as well [MS9:45]with whatever method we chose em from what we learned at the Sanger and I think for them that was to have their name on the paper you know em I think they were quite happy to do that [MS9:74]</p>		

Appendix 8, Access and influences on the use of social networks

Primary theme	Secondary code	Description of finding	Illustrative narrative extract
Access	Who?	Sources within the company are often the first that are tried	<i>If it's a scientific problem my first [pause] point would be to talk to my colleagues [MS7:112]</i>
	Who?	But failing this a known external source in the scientist's personal network might be approached.	<i>...after that you get into well it's almost pot luck whether you have any broader network that you can draw on depending on what the nature of the er the problem is [MS7:115]</i>
	Who?	The use of suppliers for advice, for example to solve problems with cell growth media, analytical technologies or methodological issues, is common.	<i>They obviously they have sales reps as well in general they em are people who've come from an analytical background and have moved into sales; so they usually have a good er knowledge [MS11:33]</i>
	Why?	Sources are contacted for a wide variety of reasons but knowledge, reputation, access to resources and experience are commonplace in the biopharmaceutical industry.	<p><i>I wouldn't have any hesitation to contact him he had much more of the big picture ...which is why I chose him in the first place... mainly because of who he is [MT5:65-68]</i></p> <p><i>They were actually the best we could have contacted to do this...looking though their research publications and so on I think they are pretty good [MS8:19/20]</i></p> <p><i>The German mouse, well I'm saying that now because I'm more [laughs] biased towards her, but I mean it's a good model but there are certain things that you could criticise it on [MS6:74b]</i></p> <p><i>A lot of it's because I've been around forever and for a long time I was the only</i></p>

			<i>person here certainly doing the animal side of things because we were smaller and as we expand there are more people doing it em I've probably been doing it longest so people do still come to me [MS11:59]</i>
	Why?	A knowledge of who knows what in the network is useful	<i>I suppose as you build up your [external] networks as well and you realise who's doing what and things like that it becomes very useful you know [MS6:13]</i>
	Why?	Social contacts tend to be used in two directions both as seekers of information and sources of information, in this case based on experience	<i>It's a funny thing because because of the nature of my position I tend to be the person at the receiving end of the queries because I am a lab-based person ... will quite often contact me to ask my advice because they know that I've got that practical experience so... I do tend to be on the receiving end more than I do on the asking end [MS11:9-11]</i>
	How?	Approaches to initial sources maybe via the use of email, these 'set-the-scene' by explaining the problem in preparation to a follow-up, and if the email is carefully constructed it can in return provide working protocols.	<i>Email is good because you do collect all the things together and er not just like picking phone for a second oh how do you do that and you're just like also write down notes more carefully and then you just also get mail back so you have like a protocol rather than you do like you can lose some information on the phone sometimes so if you like small bits of information [MS12:29]</i>
	How?	Subsequent contacts throughout the life of the problem are made by telephone, email and video or face to face meetings. Webcasts are used where there are multiple parties involved in finding a solution.	<i>Communicated it by email to start with ... and then discussed how it was actually going to work you know subsequently in a teleconference [MS7:76]</i>

	How?	New social contacts are made at university and in the workplace and these contacts are maintained when they move on to new organisations	<p><i>I remembered that em I went to university with someone who's gone into neuroscience she's now a lecturer at UCL [MS6:1]</i></p> <p><i>I contacted first the person who'd taught me first taught me to do the em xenograft studies... and at the same time one of the postdocs who worked here when I first started work as a technician em who is now head of cancer studies at AstraZeneca and a friend of mine who I taught to do these kind of studies [MS11:3/4]</i></p>
	How?	Contacts are commonly made through scientific conferences	<p><i>Those conferences I mean it's it's great because you know you meet with all your old buddies yes there's the formal speed dating type sessions but... then afterwards you get together for all the socialising and and you're all good mates you know and you know yes you're there are business opportunities that spin out of that [MT4:136]</i></p>
		Contact may be made or maintained through social networking internet sites	<p><i>Ultimately what happened was somebody else another recruiter picked up the er opportunity through Linked-In [MT4:18]</i></p> <p><i>We've kept in contact but mainly via Facebook and that sort of thing she's not really like a close friend or anything like that but we you kind of know of each other and also we see each other now and again at conferences and things like that so what I did was I em emailed her [MS6:2/3]</i></p>
	How?	Although the scientific internet-based forums have not as yet been successful	<p><i>Well I think I've tried once with them [internet forum] just when I came to vectors and but I never got an answer [laughs] [MS10:41/] ...but I didn't hear back in this case but then quite often you might read other people's discussions and then find out</i></p>

			<i>from there [laughs] ... so you don't have to ask yourself sort of thing [MS10:41/43]</i>
	Referrals	Referrals may occur indirectly, when help has been sought and the seeker has been referred on. Or directly, as is the case of the biopharmaceutical recruitment example, when contacts have been used to recommend other sources	<p><i>You know that they'd be happy to advise you to to you know to get in contact with somebody else or they might even say oh I I've mentioned that you're after this information to you know Joe Bloggs and Joe Bloggs is very happy for you to contact him or her [MT5:85-87]</i></p> <p><i>I went to him said oh do you know this person and they were like oh yes they're really nice they're at John Hopkins University in Baltimore in America and he said why don't you get in contact and see if they would you know maybe want to collaborate tell them your ideas you know so I got in contact and just emailed them [MS6:15]</i></p>
	Reciprocity	Often when sources are contacted, there is an unspoken expectation from both parties that assistance or some other form of benefit may be returned as a 'favour' at a later date. Joint scientific publication, future business and assistance with a family member all provide forms of reciprocity	<p><i>Yeah I mean you'd want something back [laughs] yourself wouldn't you if you were to invest that much time and effort and money into ... training someone it's always nice to get something back ...definitely if they came to ne for advice definitely I would you know I would offer it, I wouldn't want anything back you know it's... 'cause it's repaying the favour [MS9:77/78]</i></p> <p><i>I think for them that was to have their name on the [scientific] paper you know em I think they were quite happy to do that so [MS9:74]</i></p> <p><i>There's something that they can gain from the other person as well and you know the end game is this is something which is greater than the sum of us just doing things separately can we help each</i></p>

			<p><i>other and if I help you what do I get?</i> [P2:662]</p>
	<p>Personal relations - History</p>	<p>It is quite clear from the interviews that deeper relations develop between social contacts, and that common characteristics and personal chemistry plays a large part in developing trust. This development of personal relationships was seen as a useful and pleasurable development</p>	<p><i>Shared languages and cultural narratives interpretations of certain scientific standards and so forth this defines to some extent a certain common ground [P1: 814]</i></p> <p><i>I think the adage is true you know, people like people like themselves [MT4:42]</i></p> <p><i>Obviously it makes it far more enjoyable but also you know I know that because of that strength of relationship that it does give me a solid you know foundation [MT4:138]</i></p>
Power	Influence	<p>Developing personal contacts has it benefits from a point of view of calling in favours, but it also makes it difficult if there is a power imbalance between the parties and issues have to be solved.</p>	<p><i>We have a working relationship with them, we can talk to them sometimes when the timelines get a bit frustrating [MS7:69]</i></p> <p><i>If you have some common interest in something then that obviously then that's part of you know getting to know someone and becoming friends with them it's sometimes there's a little bit of problem if you're very friendly with someone and then there's a professional conflict of interests ... Then you've got to find some way of resolving that [MS7:122]</i></p>
Luck	Serendipity	<p>Luck is often perceived as occurring through conversation, when the topic changes and interesting and useful knowledge is uncovered</p>	<p><i>You know conferences like you know I used to think oh it's time away from the lab I haven't got time this is you know it's a waste of time., and now well sort of through experience I look at it differently. Thinking well you know something could come up that I hadn't even thought about so it is very useful and I am getting input from other people you know, em so I kind of see it in a different way but that's what I mean by going to conferences, I'm creating the</i></p>

			<i>potential to have that luck [MS6:103-105]</i>
	Timing	Luck may also manifest itself as opportune timing of a contact or information	<i>He happened to em you know approach me er at the time when I was really starting to get my my thoughts in place you know he was in the right place at the [laughs] right time [MT4:54/55]</i>
	Intuition	It would appear that intuition and the sub-conscious plays a part in identifying like-minded people	<i>There's an interesting point at which the conversations go beyond kind of friendly hand-shaking where you can have a kind of surface level conversation with somebody ... I'm not a psychologist but something it sometimes seems to happen where there's almost a kind of snap and then people get into a very detailed conversation [P2:640]</i> <i>I first started the conversation it became apparent that personality wise, sense of humour wise, communicate ability to communicate wise, you know the guy was on the same wavelength as me [MT4:35]</i>
Benefits	Personal development	The reasons why scientists are motivated to solve problems and to provide help include a genuine interest, personal pride/reputation, developing new knowledge and making new friends.	<i>I thought it was a good idea I was quite happy to do it ...I thought it would you know one it was information that we needed because ultimately it will help me in some other aspects of my work, and two I genuinely thought that it would be relatively straightforward [MT5:26/27]</i> <i>It's a quite a small field you know people know each other em and so they would say well you still haven't tried... you know so that kind of motivated me but also em just my own personal interests [MS6:75/76]</i> <i>I just think you know you do come across people again and you don't know where they're going to fit in your life and also it it feels it feels great to help people [MS6:55]</i>

Appendix 9: The use and development of templates

Primary theme	Secondary theme	Description of finding	Illustrative narrative extract
Benefits of methodology transfer	Access to knowledge	Without assistance from the 'teacher' methodology transfer would either not happen, or would be time consuming and resource intensive	<p><i>It was actually it was a very technically demanding protocol you know it took forty five days to do the whole thing... from you know step one to step you know twenty em and so it could have gone wrong at any certain point and it was really I think like I say we would have generated results because we would have got something back but I don't think it would have been as specific or as good [MS9:60]</i></p> <p><i>It would have cost a lot more money and it would have been a very very steep learning curve [laughs] [MS9:61]</i></p>
	Access to resources	It would also appear that access to resources [equipment, disposables, control materials etc.] is an important factor in methodology transfer	<p><i>We didn't have the technology in the lab so this was whether we could potentially use their machine em or their technology and visit Munich and get it done over there [MS9:50]</i></p> <p><i>So they provided everything basically you know they they provided all the kits and em the the tags they let us use their own tags to get this this design working em and also it was the knowledge that they passed on [MS9:34]</i></p>
Use of existing protocols	Use of existing protocols	Sometimes the original rational behind the parameters and techniques has been lost in the initial codification, and a pragmatic approach is then taken and the protocols are	<i>Coz we're just doing it like this ok well if it's like this nobody has an answer so never change your running system Just accept it, if it's working yeah so it's accepted [MS8:69]</i>

		accepted as they are.	<i>That they don't even know because they already use an established method and they...they do have their control DNA for example or control cells which they used when they ran the methodology but they cannot really talk through all the steps how it was established before [MS12:12] .. so [they are] already losing the information [laughs] there [MS12:13]</i>
Problems with existing protocols	Degree of tacitly	When writing protocols, experienced scientists or those that are very familiar with the technique, often ignore the important skills and experiential detail that others might not be aware of	<i>There is on the protocol centrifuge which speed which beaker, where's the centrifuge? These details you just get used to when you're working there for years [MS8:37]</i> <i>People who you're talking to they have experience they give you like small tips which are very.. useful rather than from the paper they published nicely and correctly [both laugh] [MS12:17]</i>
Mechanism of understanding	Communication	Verbal communication was considered as essential in methodology transfer, other forms of communication were considered a poor substitute, lacking the 'richness' that was required.	<i>I always thought to transfer a technique you need to communicate otherwise you can't if you usually just get sent the devices with a description it's never good enough you need to have someone to speak to [MS8:79]</i> <i>I mean the communication is still a great thing ... communication is all and the better the quality of the communication the...the better quality because like through the mail still you lose information er it will be probably quite alright for something theoretical er points er and if so when they do like brain-storming and so on for</i>

			<i>ideas but when it comes to the laboratory experience [MS12:49]</i>
	Observation	Observation of the protocol working in the ‘experts’ own environment was always quoted as the best means for achieving rapid and accurate methodology transfer	<i>You know you can write it down but I think it’s actually seeing someone physically do it is different [MS9:64]</i> <i>It’s probably by watching is the best one you just get to it and then if it’s if you watch and you see a tube is different then you ask questions but you don’t really like think it’s er it’s the problem there [MS12:48]</i>
	Note-taking	Observation was active with copious notes being taken	<i>I’m taking a pencil and writing between for myself and then sitting down and re-write it and we’re going over this during the next days over and over again to not miss any points and details [MS8:29]</i> <i>So in the beginning I was having a protocol the first day and then I wrote so much on the page and the next morning and I was just writing it downwith arrows and everything and I wasn’t sure was it there or there was this step earlier step later and you ask again and then I was er doing it half days to really all the information to not... em changing the points [MS8:50]</i>
	Questioning	Repeated questioning, often to the point of irritation, was key to understanding the detail and background	<i>I again needed to ask again and again and again ...when you don’t really know much or you are new to the lab it’s normally more about the methodology how to do like it’s again different solving of the problems [MS12:41]</i> <i>I was constantly asking why so why</i>

			<i>we are doing it this way and why, why do we need for dialysis 3 litre and yesterday you were you using 5 litres is there any news or need to do this [MS8:42]</i>
Rewriting the protocol	Understanding	Writing the protocol with sufficient detail was not just a case of documenting the most important details of what had been observed, but also required the use of unambiguous language.	<i>You have to make it short make your notes and then you're sitting in the evening thinking how exactly was it now so we were doing it really slowly and yeah at the end I I remembered and could write it down and once you have the full text you can shrink it again to the details which you actually really need to know [MS8:41]</i> <i>When I write a sentence you might misunderstand it you might misinterpret it so I was actually going through every little step with her and was making my own notes and writing my own SOPs so to speak to come to a point and I understand what she's doing and then be able to transfer it to others [MS8:13]</i>
	Lack of understanding	A lack of understanding demonstrated a gap in the original protocol, which then became a source of enquiry	<i>So I do go in person I say why do you think you use this concentration or this ingredient in the solution and not that so I normally get their answer for it and I can then er decide do I change that or do I not change that bit [MS12:26]</i>
	Learning problems	Learning by rote and without understanding would appear to lead to unexpected consequences	<i>The other girl who taught a lot of people XXX were both left handed so they taught an undergraduate student how to do tissue culture [MS11:51]...and halfway through their project XXX went I didn't realise</i>

			<i>you were left handed and she went I'm not, because she'd just copied exactly what they'd done [MS11:52]</i>
	Encoding tacit behaviour	Decoding the methodology is an important part of making tacit skills more explicit and therefore transferable; but also explicit protocols are more useable with the incorporation of soft skills, this extra detail added significantly to the length of the protocol	<i>We do have SOPs for standard em procedures so I would be able to give someone an SOP to go and do em a piece of analytical work or some cell culture work and they should be able to follow that what they would need is a the knowledge how to use the HPLC if because that bit isn't detailed in there [MS11:50]</i> <i>[Is the new protocol longer?]</i> <i>Definitely yeah three times more yeah absolutely more detail [MS8:17]</i>
Knowledge overlap	Teacher/ student	It was clear from the methodology transfer examples that understanding the reasons behind the protocol stages was an important aspect of writing a successful protocol.	<i>I was just going there to say well here I am I want to learn from you [MS8:28]</i> <i>Any lab-based person could go and set up the experiments it's not I think it's more the understanding of and it was kind of my project so it's like how it all fits together [MS9:69]</i>
	Different knowledge base	One comment emphasised the benefit of coming from a different scientific discipline as a reason for asking the 'dumb' questions and taking less for granted. This also provided a form a respect for each other's experience	<i>Because the thing is they were doing their protein thingy they were antibody persons and I was coming from a cancer perspective so she was kind of respecting ok I don't know anything about what you're doing and you don't know what I'm doing so we are just telling each other [MS8:26]</i>
Benefits of previous experience in methodology	Benefits of previous experience in methodology	Previous experience in methodology transfer helped scientists to know what sort of questions to ask and the level	<i>Having had this job before in validation it was even slower so maybe that helped me absorb things faster [MS8:43]</i>

transfer	transfer	of detail to obtain	<i>It's a lot about experience because you're I mean you still need to understand what the things are doing and you still understand if there is a DNA purification it's not much going wrong there and it's quite simple like quite simple method and it's not many condition you can change and it's how it effects what if it's like PH different or it's something like that [MS12:51]</i>
Subsequent use of new protocol by others	In student's laboratory	The new protocol was not considered finished until it had been tried back in the 'student's' laboratory, and implemented by a less experienced scientist.	<i>There was another research associate and she was kind of my chimp in this thing and I said to her actually it's up and running I would be it would be nice if I just give you my protocol and you run through it and if it's working then it's really idiot safe because you never heard about you never touched anything you're completely new go on take yourself please some time and let me know where you struggle because you are the best proof for ... everyone else who's coming [MS8:76]</i>
	Final modification of new protocol	Occasionally the new protocol needed further modification, in particular to the wording of the document.	<i>She did it, and once or twice came how do you mean that or that because again it was personal for my language my words things like that and we amended it and then it was was fine so that was also very nice to see that you actually can make something do that others even whatever if I would have been ill or so not available they can go on and do it [MS8:77]</i>
Personal motivation	Personal motivation	Learning the practical component of science is often what scientists enjoy and this	<i>I think I've always been a believer of that as well that like the practical side</i>

		knowledge can be passed on for the benefit of others	<i>is where you really learn [MS9:73]</i> <i>There's other group members that are wanting to get into next generation sequencing and I can now help them and direct them and say well no you can't do it that way but if you do it a step here [MS9:63]</i>
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Appendix 10 Example Protocols (Templates)

Purification of recombinant XXXX from the periplasm (*before modification*)

- make an o/n culture in 2xTY, 100 µg/ml Amp, 1% glucose at 37°C (ca.20ml)
- inoculate 1 l of 2xTY, amp, 0,1% glucose with 10 ml of o/n culture and incubate at 37°C until culture reaches an OD₆₀₀ of 0.8-1.0 (takes about 2.5 - 3 h)
- add 1 ml of 1 M IPTG (final conc. 1 mM) and incubate for additional 3 h at room temperature (23°C)
- centrifuge cells for 10 min at 5000 rpm(JA-10, 4400g)
- resuspend cells in 50 ml/1l of PPB (periplasmic preparation buffer - 30 mM Tris-HCl pH 8, 1 mM EDTA, 20% sucrose)
- add 0.25 ml/1l of 10 mg/ml lysozyme in water (freshly prepared) final concentration = 50 µg/ml.
- incubate for 15-30 min at 4°C or on ice.
- add 0.5 ml 1 M MgSO₄ to 50 ml of solution to stabilize the spheroplasts.
- centrifuge for 10 min at 8000 rpm (JA-14, 9800).
- dialyse periplasmic preparation against PBS over night in the cold room.
- centrifuge for 15 min at 8000 rpm (JA-14)
- load supernatant onto a Ni-NTA column equilibrated with IMAC loading buffer.
- wash column with IMAC wash buffer (50 mM Na-phosphate buffer pH 7.5, 250 mM NaCl, 35 mM imidazole).
- elute bound proteins with IMAC column wash buffer (50 mM Na-phosphate buffer pH 7.5, 250 mM NaCl, 250 mM imidazole).
- combine peak fractions and dialyze o/n against PBS or appropriate buffer.
- store proteins at -20°C
- you can determine protein conc. by measuring absorbance at 280 nm. An OD of 1 corresponds to approx. 0.7 - 0.75 mg/ml scFv.

$$c \text{ [mg/ml]} = \text{MW [g/mol]} * (\text{OD}_{280} / \epsilon)$$

$$\text{mit } \epsilon = (\text{Anz. Trp} * 5540) + (\text{Anz. Tyr} * 1480)$$

Continued: Purification of recombinant XXXX from the periplasm (before modification)

Buffers:

PPB	1 l
30 mM Tris-HCl pH 8.0	30 ml 1 M Tris-HCl pH 8
1 mM EDTA	10 ml 100 mM EDTA
20% sucrose	200 g
5 x Na-phosphate buffer stock	1 l
(diese Stocklösung autoklavieren!!!)	
LowSalt (1,25 M; → 250 mM f.c.)	
250 mM Na-phosphate	37.38 g $\text{Na}_2\text{HPO}_4 \cdot 2\text{H}_2\text{O}$
	6.24 g $\text{NaH}_2\text{PO}_4 \cdot 2\text{H}_2\text{O}$
1.25 M NaCl	73.5 g NaCl
pH 7.5	
IMAC loading buffer	1 l
50 mM Na-phosphate	200 ml 5 x stock
20 mM imidazole	1.38 g
IMAC wash buffer	1 l
50 mM Na-phosphate	200 ml 5 x stock
30 mM imidazole	2.04 g
IMAC wash buffer	1 l
50 mM Na-phosphate	200 ml 5 x stock
35 mM imidazole	2.38 g
IMAC elution buffer	1 l
50 mM Na-phosphate	200 ml 5 x stock
100 mM imidazole	6.81 g

Purification of recombinant XXXX from the periplasm (after modification)

- make an o/n culture in 2xTY, 100 µg/ml Amp, 1% glucose at 37°C (ca.20ml)
 - inoculate 1 l of 2xTY, Amp100, 0.1% glucose with 10 ml of o/n culture and incubate at 37°C until culture reaches an OD₆₀₀ of 0.8-1.0 (takes about 2.5 - 3 h) → for good output of anti-CD33 are 3-6 liters required
 - add 1 ml of 1 M IPTG (final conc. 1 mM) and incubate for additional 3 h at room temperature (23°C)
 - centrifuge cells for 10 min at 5000 rpm (rotor: JA-10, 4400xg)
 - resuspend cells in 50 ml/1l of periplasmatic buffer (PPB - see recipe at the end), (vortex hard to resuspend all cells in homogenous solution as good as possible for maximum use of lysozyme later on!!!)
 - combine fractions (all of PPB cell solution) in one centrifuge beaker, close properly!
 - add 0.25 ml/1l of 10 mg/ml lysozyme (if powder, prepare every time fresh, solve in water), final concentration = 50 µg/ml
 - incubate for 15-30 min at 4°C or in ice bath
 - add 0.5 ml 1 M MgSO₄ **per 50 ml** of solution to stabilize the spheroplasts
 - centrifuge for 10 min at 9800 x g (~8000 rpm, use small tubes for centrifuge in bacteriology for best sedimentation of cell pellet, clear yellowish supernatant)
 - **dialyse supernatant (which is the periplasmic protein solution!) against PBS over night in the cold room (dialysis tubing from the roll for periprep, MWCO: 10000 Da)**
 - next morning: centrifuge content of dialysis tubing in 250 ml beakers for 15 min at 9750 x g (~8000 rpm) in new Beckman centrifuge instrument room 2nd floor or ground floor
- use **ALWAYS** an appropriate rotor and let the centrifuge only run when you are certain about the rotor name and the speed you want to use is not higher then the maximum

speed for the rotor, control if the right rotor name is programmed into the centrifuge before you run it, wait until maximum speed is reached nearby)

- prepare fresh Ni-NTA column, bed: 1.5cm; use 50ml 1xPBS (1 blue cap tube) to settle the beads and to equilibrate the column, discard flow through
- load supernatant onto column (ca. 100-150ml per column, bed max. 1.5cm), if possible with column pump (in Stuttgart: ismatec mp13, GJ-10, Germany; in NCL: use perista tubing pump) → **very time consuming (300ml about 5h!!!)**
- wash column with 50ml 1xPBS
- elute bound proteins with IMAC elution buffer (for anti-CD33)
 - use not more than 500ul each fraction, otherwise protein too diluted!!!
 - pipette elution buffer carefully on top of bed, no splash – destroys packaging of the bed and hinders maximum elution!!!!
 - **TIPP** for decision which fractions to collect: BRADFORD on 96 well plate, (900 ul 1x Bradford solution from Biorad + 100 ul flow through), collect drops in Eppis and combine the fractions with most blue in BF-test
- dialyze the “blue and combined” fractions o/n against PBS (Dialysis tubing, Snakeskin out of the tube, MWCO: 10000 Da)
- store proteins at 4 or -20°C (depends on the protein which is to prefer, for anti-CD33: 4degrees)
- wash Ni-NTA columns with 50ml 1x PBS, close them and store at RT in rack, columns 3 to 5x reusable

you can determine protein conc. by measuring absorbance at 280 nm with e.g. a Nanodrop (or with a spectrometer where an OD of 1.0 corresponds to ~ 1 mg/ml scFv):

$$c \text{ [mg/ml]} = MW \text{ [g/mol]} * (OD_{280} / \epsilon)$$

$$\text{with } \epsilon = (\text{Anz. Trp} * 5540) + (\text{Anz. Tyr} * 1480)$$

→ **you need to know the epsilon (or the sequence) and the MW for this calculations!!!**

- Epsilon anti-CD33: 50.1
- MW anti-CD33: 28.24 g/mol (=mg/ml)
- take care value from OD measurement at 280nm is between 0.1 and 0.9
(Lambert-Beer law, otherwise wrong protein conc estimated!!! Which causes failures in calculation for micelles and PI)

Alternative purification – faster Ni-NTA extraction

after first dialysis, centrifuge as indicated in protocol above, but then follow on with following steps:

- add 1ml well shaken Ni-NTA solution (QIAGEN) to supernatant in 50ml blue capped tubes and mix well
- roll it 3-4h at 4degrees Celsius
- spin 10' 1500xg and take off the supernatant, leave last 5ml in the centrifuge beaker
- collect these last 5ml in fresh 50ml blue cap Falcon and fill up with IMAC wash buffer
- wash three times with IMAC wash buffer, 10' 1500xg
- after last wash step: fill Ni-NTA in fresh column (SIGMA, bigger ones with blue ends)
- elute with elution buffer like in original periplasmatic purification protocol (here it needs longer to elute, peak fractions come later!!)

Continued: Purification of recombinant XXXX from the periplasm (after modification)

Buffers:

2xTY 2l 5x = 10x

16g peptone 160g

10g yeast extract 100g

5g NaCl 50g

PPB 1 l

30 mM Tris-HCl pH 8.0 30 ml 1 M Tris-HCl pH 8

1 mM EDTA 10 ml 100 mM EDTA

[MW=328.2; weigh for 1mM: 0.32g/l]

20% sucrose 200 g

5 x Na-phosphate buffer stock, pH=7.5 1 l

(autoclave stock!!!)

LowSalt (1.25 M → 250 mM final conc)

250 mM Na-phosphate 37.38 g Na₂HPO₄ · 2H₂O

6.24 g NaH₂PO₄ · 2H₂O

1.25 M NaCl 73.5 g NaCl

→ control and adjust pH

IMAC loading buffer	1 l
50 mM Na-phosphate	200 ml 5 x stock
20 mM imidazole	1.38 g

IMAC wash buffer (for anti-CD33)	1 l
50 mM Na-phosphate	200 ml 5 x stock
35 mM imidazole	2.38 g

IMAC wash buffer from original protocol (for anti-CD33 w/o NaCl used) 1 l

<i>50 mM Na-phosphate buffer pH 7.5</i>	<i>200 ml 5 x stock</i>
<i>250 mM NaCl</i>	
<i>35 mM imidazole</i>	<i>2.04 g</i>

IMAC elution buffer (for anti-CD33)	1 l
50 mM Na-phosphate	200 ml 5 x stock
250 mM imidazole	17 g

<i>IMAC elution buffer</i>	<i>1 l</i>
<i>50 mM Na-phosphate</i>	<i>200 ml 5 x stock</i>
<i>100 mM imidazole</i>	<i>6.81 g</i>

Appendix 11: Follow up questions: Organisational training in methodology transfer

QUESTION 1. Was any formal or informal training provided by our organisation [or any previous organisation] in methodology or methodology transfer?

ANSWER 1. No! I was sent barehanded and asked to learn it and bring it over. Simple as that unfortunately

ANSWER 2. Well, not me really. I kind of learned afterwards what I was supposed to do and found out that I did it the way that was recommended

QUESTION 2. In hindsight would there be any potential benefits to methodology transfer training?

ANSWER 1. Whatever they should have told be upfront I was doing anyway. But someone else without my 'change of subject history' might have done it differently and less easily

ANSWER 2. I would strongly recommend that everyone going into this, either coming from the teaching side or a similar background to me to get a proper induction really

QUESTION 3. If so, how might this be achieved?

ANSWER 1. Life experience unfortunately. I don't think someone fresh from university or having just finished their apprenticeship with maybe several weeks supervised lab work should be sent out to do it.

ANSWER 2. For these jobs I personally would like individuals which are able to think interdisciplinary.

ANSWER 3. I would look at their age, and judge their CVs, this is one where youth doesn't pay off

Appendix 12. Table 1: Task characteristics when valuing knowledge

Primary theme	Secondary code	Description of finding	Illustrative narrative extract
Problem task characteristic	<i>Clarity of solution-objective</i>	In most cases the explicitness of the solution was clear; this provided an identifiable stop signal that indicated when an appropriate solution had been found.	<i>I knew right at the outset that there were certain categories of stuff that I didn't want [MT5:30]</i> <i>It was quite black and white where the solution when you found the solution [MT5:81]</i>
	<i>Clarity of solution-subjective</i>	In some cases, such as determining an acceptable level of purity, the stop decision was more subjective	<i>It's not particularly clear maybe when you have succeeded or not because you seldom well it's percentage sort of thing it's never 100 [laughs] percent of the success rate [MS10:38]</i>
	<i>Simplicity</i>	The simplicity of solution was regularly identified as a benefit	<i>The more defensible and the more straightforward such a message is the easier it is for for those heads to sell [MT5:76/77]</i> <i>They kind of put it in a simple way and then I could go and read the journals as well you know so it was kind of a very much a starting point [M6a:10]</i>
Knowledge quality/ Measures of value	<i>Quality</i>	Quality can be a subjective measure and it is apparent that in science quality may also be a relative measure	<i>It's working better but [laughs] it hasn't solved it completely [MS10:13]</i>
	<i>Relevance</i>	Relevance was defined as 'appropriateness' Especially when data was sought	<i>None of the other columns that you know were of any were of any any use[MT5:36b]</i>
	<i>Specificity/</i>	Specificity and repeatability of	<i>It was more you could repeat the the</i>

	Repeatability	a solution can be important in scientific problems.	<i>data it was more you know you could replicate itEm better and em like I say it was more specific so it was better for our our needs [MS9:19]</i>
	Accuracy	Scientific papers are not always accurate and often need to be clarified, or worked on by both parties until an acceptable outcome is achieved.	<i>That's another thing just with papers then because the same even well the what they've stated in there is not really enough coz when we order them things then the one thing did not fit in the other so obviously there must be more than one [laughs] version of the same so then we have been in touch with by email [MS10:31]</i>
	Reliability	Reliability or robustness of the solution must be tested even if the source of the solution is reputable. It is recognised that anyone can make a mistake but the 'problem solvers' own reputation may be effected.	<i>It was more it was a better method as well it was more robust [MS9:9] I would take her ideas on board but I would also have my own ideas as well you know so I'd kind of merge the two together [M6b: 94] You've got to feel comfortable with it yourself [M6b:36]</i>
	Currency	Currency was demonstrated by the use of the latest equipment and the newest methodologies	<i>It's all really organised to be as high throughput as possible you know I walked into one room and so I think one of the sequences at the time was like half a million pounds and they must have had forty or sixty of them lined up[MS9:41] I think they're em they lived up to their reputation [MS9:45]</i>

Table 2: Knowledge quality and credibility

Primary theme	Secondary code	Description of finding	Illustrative narrative extract
Relational/ behavioural characteristics	<i>Weight to source credibility</i>	Once selected, the source often proved to be pivotal in providing credibility to the solution.	<p><i>They were actually the best we could have contacted to do this [MS8:19]</i></p> <p><i>Looking though their research publications and so on I think they are pretty good [MS8:20]</i></p> <p><i>So it was actually their advice gave me the confidence to say it's not something that I'm doing it it's probably ... something to do with the cell line [MS11:7]</i></p> <p><i>It made me think well he's presented this to a research forum so it's not going to be inappropriate information [MT5:69]</i></p>
	<i>Perceived experience</i>	Experience of the source can be either perceived or demonstrated through their extensive networks, or their experience is complementary to the problem solvers' experience and expectations	<p><i>He basically em convinced me that he was a good person to to work with [MT4:12]</i></p>
	<i>Knowledge demonstrability</i>	Knowledge in a subject can manifest itself in a wide variety of ways, recognition of this is important in reaching a decision	<p><i>He had more knowledge about these sorts of posts he could interpret it in a better way than I could [MT5:54]</i></p>
	<i>Authority</i>	Hierarchy and reputation provide cues with regards to	<p><i>Relevant, appropriate and trustworthy information I suppose mainly because</i></p>

		authority of the source and this impacts on the credibility of the information received	<i>of who he is [MT5:68]</i>
	Reputation	Reputation of the source is useful but it may still be treated with caution	<i>The paper we... I mean it's actually from the Scripts Group and it's a cancer cell paper so it's a very high impact [reputation] . [MS11:14]. Just because it gets into the highest impact factor... journal does not necessarily mean it's the best bit of research it's probably the most thorough bit of research [laughs] [MS11:15]</i>
	Trust and the source	Trust is a well-established indicator of reliability and is built upon reputation and authority. Trusting the source, positively influences the acceptance of the solution	<i>You trust them [laughs] a little bit more than somebody novel you know you doing it [MS9:26] You might not have built up that kind of personal trust, but because they were the person at that level of meeting presenting something, I would automatically think that you know it's a reasonable guess that this is a trustworthy this is a trustworthy source, certainly as an initial stab [MT5:97]</i>
	Trust and the technology	Reputation and 'proof of use' can also build trust in a technology or a proven methodology	<i>We just want to do what they do so we do it one to one which was then the safest also from my point of view because they could prove they do it with what they have in their hands and what they do so why change it and then standing there with nothing so</i>

			<i>really taking over one to one and then trying to amend it how...we need to do it [MS8:5]</i>
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Table 3: Knowledge overlap: valuing new knowledge

Primary theme	Secondary code	Description of finding	Illustrative narrative extract
Knowledge overlap	<i>Understanding</i>	Knowledge overlap is assumed when solving any form of problem; it provides understanding and a basis for an informed discussion	<i>You've got to put it into context and you've got to tell them why you're doing it in the way that you're doing it otherwise er I think it's quite hard to do those things in a complete vacuum [MS7:98]</i> <i>I think it helps them to see what the important issues are and then what other things that are negotiable [MS7:101]</i> <i>You have to give them a bit of the science to understand [MS7:102]</i>
	<i>Familiarity</i>	Things change, even actors that were once familiar with a subject can lose the ability to understand information, if it has evolved into a different form	<i>Information presentation has evolved over a number of years ... when they asked for it and got it in that format they just couldn't interpret it at all and you know were horrified what well what does this mean? [MT5:114/115]</i>
Decision making	<i>Judgement and decision making</i>	In the recruitment problem intuition also helped to influence the decision	<i>I'm kind of pretty well convinced it's not as good as I could get with the em with the new guy...so you're willing to make a punt on him yeah... regardless of the facts that that's more by</i>

			<p><i>intuition and the story he tells rather than perhaps direct experience... because I've got no I've had no direct experience of working with him</i></p> <p>[MT4:104]</p>
Stakeholders	<i>Stakeholders</i>	Other stakeholders that had a vested interest in the solution were often considered and were used as confirmation of a 'good' decision or solution.	<p><i>I didn't know the solution when I started off on that I probably had a bit of a feeling that that might be a way to go em but until you get sort of confirmation from people who are you know have a vested interest in it</i></p> <p>[MS7:18]</p> <p><i>He sort of impressed everybody that he met em so you know I was hoping that he would be the one that everybody was was comfortable with em and sure enough he er he scored very well when when we were actually doing the face to face interviews</i> [MT4:81/82]</p>

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