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The Social Construction of Technical Innovation in the UK Oil and Gas Industry

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DBA THESIS

THE SOCIAL CONSTRUCTION OF TECHNICAL INNOVATION IN THE UK OIL AND GAS INDUSTRY

I HEREBY AGREE THAT THE WORK IN THIS DBA DISSERTATION IS THE RESULT OF MY ORIGINAL RESEARCH AND HAS NOT BEEN SUBMITTED FOR A UNIVERSITY DEGREE OR OTHER SIMILAR QUALIFICATION TO ANY OTHER COLLEGE OR UNIVERSITY OR INSTITUTION OF HIGHER EDUCATION.

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DEDICATION

This work is dedicated to my loving wife, Justina, and our son and daughter, Harold and Jessica for their undying love and unflinching support throughout the duration of this research. Without their love, tolerance and support, it would have been difficult if not impossible to complete this study.

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ABSTRACT

Innovation and '*creative destruction'* should thrive in the competitive, high risk and high cost environment of the North Sea. Paradoxically, uptake of new technology is slow. The focus of this research was to understand how new technology is developed and how end users make decisions about innovation.

Innovation process in the literature can sometimes come across like a 'black box' without much explanation of what happens inside the box. This study seeks to explicate what transpires inside the 'black box' to improve our understanding of the innovation process. The linear models of technology-push and market-pull are too simplistic to account for the complexity of relationships and engagements that affect innovation at small and medium enterprises' (SMEs) level. Subsequent models of innovation are suited to how large corporations manage innovation but neglect patterns of social interactions at the micro level where SMEs operate. These innovation models are incomplete because they relegate the importance of context and how it shapes understanding, action and outcome.

This study, rooted in a social constructionist paradigm, takes a process-relational stance on entrepreneurship and innovation, recognising the dynamic relationships between social actors and context. Taking Heidegger's explication of how we relate to the world, this thesis submits that innovation occurs when actors move into the 'occurrent' mode. The happenings and doings in the innovation process are treated as the results of perpetual social constructions.

This study is based on extended interviews with eleven individuals in relevant roles and with direct experiences of the technical innovation construction in the oil and gas industry. The purposeful sample of research encompasses a variety of roles including technology entrepreneurs, end users of technology and venture capitalists.

This study makes a number of contributions. Firstly, the research improves our understanding of how different social constructions are welded together to develop shared understanding. Secondly, a conceptual framework is presented that bridges a number of theoretical concepts, which allows us to see that innovation cannot be properly understood using simplistic models that ignores the social constructions human actors instantiate. Thirdly, the research claims that problem framing is foundational to innovation construction, where social actors collaborate to develop shared understanding, and mentally represent in the present a future that is not totally knowable. Fourthly, an alternative model of innovation construction is presented that is relational and accounts for the social constructions of process participants. Finally, a number of research implications for academics and insights for practitioners engaged in the technical innovation construction are offered.

Keywords:

market-pull, innovation, innovation process, shared understanding, small and medium enterprises, social construction, technology entrepreneur, technical innovation, technology-push, UK oil and gas industry

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

1.0 Introduction

> "The important and difficult job is never to find the right answer, it is to find the right question. For there are few things as useless – if not as dangerous – as the the right answer to the wrong question" (Peter Drucker, The Practice of Management, 1955)

Chapter one describes the structure of the thesis, the issues to be addressed, background to the study and the motivation for exploring different dimensions and assumptions about innovation and its nexus with entrepreneurship using the Oil and Gas industry as the context of action and investigation. It draws on the literature and critically examines innovation and entrepreneurship using existing concepts to challenge our taken-for-granted assumptions about innovation in general, but with particular focus on entrepreneurship and technical innovation construction within the oil and gas industry.

Innovation has been, and continues to be, a subject of intense interest and debate among academics, politicians, business leaders and other segments of the society because it is central to the growth and prosperity of nations and companies. It is recognised in different forms and intensities including incremental, radical or disruptive innovation. In the academic arena, it has been an important subject area of research in business, economics, engineering, sociology, and to some degree, in the scientific fields too. Notwithstanding the intense interest in innovation among academics, there is no universal understanding of what constitutes innovation; the concept means different things to different academic disciplines (Damanpour and Schneider 2006). Although there are some overlaps between various definitions of innovation across these disciplines, there is "no clear and authoritative definition of innovation" (Baregheh, Rowley and Sambrook 2009) in the literature.

Setting aside the ambiguity associated with definition of innovation (Cooper 1998; Garcia and Calantone 2002), there is a widely shared acceptance of the importance of innovation to economic growth. Because of the plethora of definitions, it can be difficult to focus on the essential features of innovation. Using different attributes of innovation, broad categories of the phenomenon can be made based on the contents and intensity of innovation. Although innovation can be classified into different categories: product, process, and technological or radical, incremental, continuous, discontinuous, revolutionary and evolutionary, these labels obscures the social dimension and meaning of innovation (Massa and Testa 2008). Looking beyond different definitions for innovation in the academic literature, at its core, innovation is a transformative process through which ideas and other resources are combined into outputs with enhanced customer value and from which economic rent can be extracted (Ceccagnoli and Rothaermel 2008; McFadzean, O'Loughlin and Shaw 2005). Innovation often starts with new ideas or new combinations of existing resources with the end goal of introducing something new (Dosi 1990; Pleissis 2007) that can be commercially exploited for the survival and growth of the business (Bessant et al. 2005).

Innovation is often discussed along other concepts like invention, creativity and design, but innovation is different from an invention for an important reason. As Schumpeter (1934 [2008]) famously demonstrated, an invention is something novel or new to the world that has no customer value. An invention becomes an innovation when it is transformed into a form that has customer value. Therefore, innovation is the creative application of inventions. Creativity is a phenomenon through which social actors create something new and it is an essential building block of, and may even be an antecedent to, innovation. Although creativity entails novelty and originality, it is not the same thing as innovation. The creative process consists of many faces: preparation, incubation, illumination and verification (Wallas 1926) and elaboration (Kao 1989) during which the idea can be structured and packaged in a form that can be communicated to and understood by others. Communication and use of language is central to the process of presenting to and co-opting others in the support of tentative but yet unproven but potentially transformative ideas. Design is a transformative process during which an idea or set of ideas is transformed into a tangible (product) or intangible (service) end state. The design process relies on the creativity of social actors and their experiences to resolve tensions and competing forces in accessing sticky information and transforming information into tangible end states. Exploitation allows social actors to consciously transform selected ideas into commercial offerings to meet users' needs. The design process can thus be construed as a bridge between invention and exploitation stages in the innovation development process.

Innovation is inherently risky because success is not preordained and novelty or newness alone does not guarantee success. Therefore, it has to be expected that some innovations will be unsuccessful and therefore fail. In Schumpeter's economic analysis, the entrepreneur introduces 'new combinations' creating market ripples and disequilibrium. The resulting disequilibrium erodes competitive advantage of established products and destabilises pre-existing market order. In the realignment of market forces that follows such perturbations, new products and services have the opportunity to establish and displace previously established products and services.

The success of any new technology is time limited until a superior technology emerges. Over time, market dynamics, profit erosion, emergence or new competitors, and ultimately new innovations overtake previously successful innovation. This is especially true in the oil and gas industry, an environment where innovation is central to the efficient and safe extraction of oil and gas (hydrocarbons), therefore it provides an appropriate context to observe 'creative destruction' in action as described by (Schumpeter 1942). In this environment, one would have expected to see new technology from small and owner managed firms competing and displacing established technologies from the multinational giants in the true spirit of 'creative destruction' that Schumpeter (1942) describes.

In spite of a continuing need for innovation in the oil and gas industry, most industry experts believe that it is difficult for new technology to gain acceptance within the industry, an indication that 'creative destruction' is not happening in the oil industry on a scale consistent with technology-driven activities of oil exploration and production. The oil industry faces a lot of challenges including difficult subsurface environment, depletion, competition for resources since most players operate on a global basis and high cost environment among others. With much of the 'easy hydrocarbons' already produced, the industry is faced with the challenge of extracting oil and gas from increasingly difficult environment, a task that requires new and sophisticated technology (Lord 2007; Paul 2007).

Technology has the power to improve commerciality but if wrongly applied has the potential to lead to significant cost overruns and turn promising assets into unprofitable fields. These challenges combine with other socio-economic and cultural factors to increase the risk premium associated with hydrocarbon extraction and influences decision making in relation to innovation and new technology. The North Sea is a very challenging operating environment where these problems are magnified and where new technology should be most beneficial. However, there is no evidence of rapid development and penetration of new technology in the North Sea. If creative destruction is not the dominant process through which new, technical innovation emerges in the oil industry, what then is the mechanism through which innovation emerges?

Schumpeter had famously demonstrated how innovation creates entrepreneurship, and the link between entrepreneurship and innovation is a critical one in this study because, entrepreneurship is one means of bringing innovation to the marketplace and it is the medium through which this study attempts to understand the innovation construction process in the oil and gas industry. This research is about innovation – what it is, how it emerges, how contextual factors catalyse or impede its development, antecedents to its acceptance or rejection, and the very nature of the phenomenon. There are different players and stakeholders involved in the development of innovation in the UK oil and gas industry, but it is unclear if innovation emerges through a linear, mechanical process or via a multilayered, recursive and socially determined process. The purpose of this study is to examine, using a *sense-making* lens, the triggers and processes for innovation construction, and how the social and situated context is implicated in the innovation construction process.

1.1 Background to the Study

It is widely accepted within the oil and gas industry that innovation is critical to efforts to maximise hydrocarbon recovery. In the 1980s to the mid 1990s, hydrocarbon finding and development costs steadily declined because of use of technology (Schroeder 2004). The pace of innovation in the industry slowed down from the late 1990s in the wake of 1998 oil crash of 1998 due to increased focus on cost efficiency, reduced R&D spending and increase caution about expensive mistakes. This period has also witnessed reduction in the rate of discoveries and reduced production from mature fields (Kozicz 2007). In recent years, there has been an uptick in the pace of and investment in new technology because exploration and production (E&P) companies see technology as a strategic priority (Kulkarni 2011; Parshall 2011).

However, it is a paradox that although various stakeholders attest to the power of innovation and central place of new technology, the evidence suggests that new technology and innovation, especially from SMEs and technology entrepreneurs, struggle for acceptance (Daneshy and Bahorich 2005). For example, end users of technology in the industry demand for case histories, testimonials and other examples of technology application before they are willing to consider using them. Anedotal evidence also indicate that even new but proven technology are not readily accepted by end users and used in niche applications for considerably longer than necessary because of users' resistance (Mody 2008). In practice, SMEs involved in technology developments are unlikely to have the history to convince doubting end-users of the capability of new technology until they have been given the opportunity to use it in the field. Why do individuals who support innovation find it difficult to commit to and accept use of technical innovation in dealing with the day-to-day challenges they confront? This is a complex issue that require an appropriate research design to investigate and understand the dynamics that may inform and shape end-users' reluctance to use new technology.

United Kingdom crude oil and natural gas production in 2013 was the lowest since production peaked in 1999 leading to increasing importation of gas to meet UK energy needs, as shown in Figure 1-1 from the Department of Energy and Climate Change (DECC).

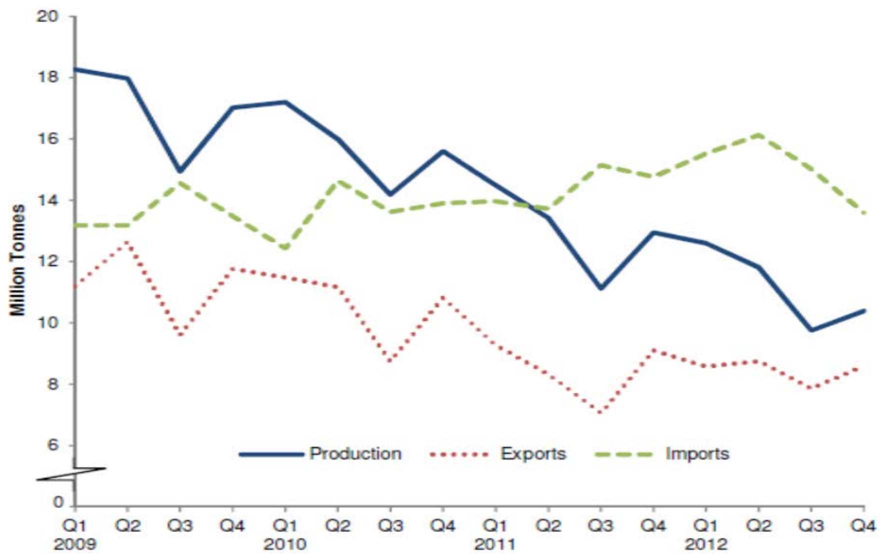

Figure 1-1: Production and trade of crude oil and natural gas liquids (source: DECC)

The UK oil and gas industry depends on technical innovation to maximise hydrocarbon recovery from its ageing oil field in a way that is most economical and does the least harm to the environment. An environment that is in need of innovation would have been expected to support technical innovation and provide empirical demonstration of Schumpeterian 'creative destruction' where new technologies supplant older and less efficient ones. However, anecdotal evidence point to slow acceptance of new technology (Daneshy and Bahorich 2005; Perrons 2013).

In 2006, the Department of Trade and Industry (DTI) estimated reserves in the United Kingdom Continental Shelf (UKCS) to be about 21billions barrels. Since then, production from North Sea oilfields has declined significantly and, most of the producing field can be classified as or approaching brown field status, a stage characterised by declining productivity, rising operating cost and declining profit per barrel of oil produced.

Industry experts (Ellix 2006; Lord 2007; Paul 2007)) have acknowledged the transformative capacity of innovation and technology in reducing the cost of production from oil and gas fields (Levett and Brandt 2005). Some estimates put oil production from brown field at 67 -72% but most of the new technology developed in the industry are for new frontiers exploration and deep-water environment (Economides, Demardios and Saputelli 2002). This suggests that the pace and distribution of new technology in the industry ignores the need of brown fields. Part of the argument for the skewed distribution in innovation efforts and attention has been traced to slow uptake of new technology to rejuvenate brown and maturing fields.

Concerns about risks and high cost of failure associated with early adopters of technology condition attitude of industry practitioners to adopt the safe position, preferring to be fast followers (Daneshy and Donnelly 2004). Hirsch, Luppens and Shook (2005) submit that most of the current managers in the industry, who were just starting out when the oil price crash of 1998 occurred, made their careers by driving down cost. Their laser focus on cost reduction has had a negative impact on attitude towards new technology with associated doubts about performance and cost uncertainty. Doubt about reliability of new technology and performance uncertainty makes it difficult to assess commercial impact of new technology (Brandt, Isaksen and Friedemann 2009). Aside from some of the factors already mentioned, the slow uptake of new technology in the industry is also driven by factors such as insufficient reward for early adopters, organizational structure that discourages making risky choices, inability to quantify and strike a balance between risk and “added value” of new technology (Hirsch, Luppens and Shook 2005).

A two-day SPE Applied Technical Workshop on Accelerating Technology Acceptance in 2005 explored some of the issues militating against technology development and acceptance in the oil industry. In summarising the proceedings of this conference, (Jacobs and Dirks 2005) identified the following factors that may be responsible for slow uptake of new technology:

- Inadequate communication between oil company personnel and new technology developers

- Technology developers do not pay sufficient attention to feedback from oil companies
- Technologies are developed without fully understanding oil company needs
- Technologies are developed for limited niche applications that cannot sustain new profitable venture
- Lack of universally acceptable method(s) of assessing new technology value proposition
- Income from legacy (old) technology is greater than income from new technology

Venture capitalists (VCs) make investment decisions based on weighted risk returns but as (Schroeder 2005) argues, the oil industry has one of the highest lead time (the time it takes innovation to achieve commercial penetration) of industries tracked. Therefore returns on investment for early investors is poor putting technology developers seeking funding at a disadvantage. Attitude about making risky choices by industry practitioners, long payback periods for technical innovation, poor communication and, incomplete understanding of user needs all combine to make it difficult to secure funding for technology development in the oil industry especially by SMEs.

These barriers to innovation acceptance make it challenging to develop technical innovation in the oil and gas industry. The half-life of exploration and production (E&P) technology, which is broadly defined as 'the time it takes to gain 50% share of the available market' is 31 years, in comparison to telecom industry (15 years), medical (12 years) and consumer products (8 years) with faster cycle times (Bates and Coyle 2005). This is evidence that it takes a long time for new technology to be accepted and adopted within the wider industry even after the advantages of the technology has been demonstrated in the field (Mody 2008). It is unclear why the rate of adoption of new technology is slow, but possible reasons are different perception of risks between technology developers and end users of technology, social cost associated with deploying unsuitable technology and a strong desire to avoid expensive mistakes.

These factors suggest that there is a need to develop better insights into and understand why technical innovation uptake in this setting is slow. The situation calls for a careful exploration of the nexus of entrepreneurship, innovation and the socio-cultural factors prevalent in the oil and gas industry.

1.1.1 The Research Context

The oil industry is capital intensive and wrongly applied technology can be expensive economically, environmentally and do real damage to company reputation. Consequently, end-users are very cautious in their approach to technical innovation. Applying innovation may be risky and unpredictable, hence outcomes are always surrounded by uncertainties. It is impossible to know in advance whether a new technology will be effective and meet the needs of the users. Since technology effectiveness cannot be predicted in advance, entrepreneurs-led technical innovation construction in the industry is intertwined with uncertainty, risk perceptions of end-users and bound by other contextual factors including prior experiences of likely customers with new technology (Amado 2009).

Cultural barrier and communication, budgetary cycles and swings in oilfield finance are some of the reasons for the slow acceptance of new technology (Rajan 2011) while information asymmetry hampers the understanding and management of risks associated with new technology adoption (Rao and Rodriguez 2005). Larger companies buy innovation through acquisition of small companies as way of reducing investment in and risks associated with R&D (Schroeder 2005). The type of companies attractive for acquisition are those with a customer base, have good cash flow and an attractive order book to minimise the risk associated with the acquisition. Therefore, companies likely to attract attention and resources need to have established some credibility in the market based on their technology. This approach is unlikely to be helpful for any technology developer working on innovative solutions that is untested and unproven in the market place.

Nonetheless, innovation is critical to the long-term health and survival of the UK oil and gas industry, therefore technology entrepreneurs have a major role to play in developing technical innovation necessary to help oil companies maximise recovery from the ageing

North Sea oilfields. The technology landscape in the industry is dominated by big multinational oil servicing companies like Schlumberger, Halliburton, Weatherford and Baker Hughes who provide most of the technical innovation to the industry. Although big multinational service companies have the resources to develop new technology, the slow rate of innovation in the industry is influenced in part by the desire of big multinationals to maximise revenue from existing technologies in use. Small firms are more likely to develop innovative technologies (Hatten 2012) in an attempt to challenge the dominance of the multinationals but technology developers have a hard time getting end users to consider using new, innovative alternatives. To make this point Hatten (2012) wrote “small businesses are the driving force of change that leads to creative destruction, especially in the development of new technology” (p. 13). Different initiatives, by the industry and government, have been created to support small and medium enterprises (SMEs) to develop new technology for the industry through initiatives like Cost Reduction in the New Era (CRINE), The Industry Technology Facilitator (ITF), etc but hurdles to acceptance of new technology from SMEs remain.

1.2 The Research problem

In the oil industry, the North Sea is one of the most challenging operating environments for hydrocarbon extraction. Nonetheless, the industry has pushed the limit of technology, making possible extraction of hydrocarbons from increasingly difficult locations. Escalating cost of hydrocarbon extraction especially from challenging locations has driven innovation in the industry. Rajan (2011) listed access to difficult to reach resources (deep water, high pressure high temperature, depleted reservoirs, shale and tight sands), operational improvements (cost and time efficiencies), competitive advantage (enabling technology to fill identified gaps) and strategic investment (anticipation of future needs) as drivers of innovation in the industry. These innovation drivers are same as or similar to other industries where new technology adoption is easier. Therefore, the central question in this research is why is the oil and gas industry slow in taking up new technology even when its need for innovation is at least as acute as other industries?

This research takes as a given that there is no settled definition of innovation but argues that the lack of consensus on a definition is a symptom of a deeper issue – innovation is a process that cannot be reduced to either economic or technological understanding. Rather innovation is a social process that is context bound and cannot be divorced from the social construction of process participants. For example, classifying innovation as incremental and radical innovation is predicated on subjective criteria that does not increase our understanding of innovation process (Roseno 2005) and ignores the social and cultural aspects of innovation (Massa and Testa 2008). Aside from issues surrounding definition of innovation, different players in the innovation process hold different perspectives, misaligned goals, and contrasting opinions, thereby accentuating the social and technological challenges surrounding innovation development (Massa and Testa 2008). Danneels and Kleinschmidt (2001) and later Roseno (2005) argue that the criteria used in classifying innovation ignores or does not give credence to the perception of the individual social actors which should be of interest in our efforts to develop better understand of innovation. Often what constitute innovation and 'newness' depend on the perception of a social unit or group (Zaltman, Duncan and Holbek 1973), and as Green, Gavin and Aiman-Smith (1995) argue what qualifies as radical innovation in organisational settings depends on the perceptions and experience of people within an organisation. These findings support the idea, rooted in social constructionism, that innovation is a social phenomenon.

In recent years researchers have started to adopt (Weick 1995) theory of 'sense-making' as a lens within a social constructionist framework for the study of innovation and entrepreneurship. The underpinning logic and rationale is that it is impossible to avoid or neglect the influences of perceptions and experiences of different actors in the innovation construction process. If researchers acknowledge the different perspectives on innovations among different stakeholders in the innovation construction process, then the right questions can be asked about how these interpretations shape innovation outcomes and how conflicting understanding of problems and potential solutions are resolved within innovation construction process.

One of the drawbacks of economics research on innovation is that focus is disproportionately on inputs into the innovation process such as resource allocation, research and development and outputs such as effect on market share and growth of companies or nations, without taking into account the influences and implications of the socio-cultural context. This approach treats what happens within innovation process as a 'black box' (Fagerberg 2003; Rosenberg 1982, 1994). Although research in entrepreneurship, organisational science and sociology has increase our understanding of what is going on inside the 'black box', our understanding is far from complete. It is true that there is no universal definition of innovation, this research is predicated on the view that the real challenge in innovation research is to explain how innovation occurs and explicate what is going within the 'black box'.

There have been significant developments in trying to draw innovation out of this 'black box'. The literature on innovation process has evolved from technology-push (first generation) to market-pull (second generation) and the coupling model (third generation) popularised by (Rothwell and Zegveld 1985). The first two depict innovation as a linear process. Although the third generation model of innovation acknowledges the role of feedback, the process is still presented in a somewhat linear format as the first two. Subsequent models of innovation process like the integrated model (fourth generation) based on management of innovation by Japanese industries to networking model (fifth generation) and to the current (sixth generation) open innovation model have highlighted the complexity and multi-layered character of innovation. The increasing complexity of these models of innovation reflects deepening and widening understanding of the complex, multilayered and multidimensional character of innovation. The complexity inherent in the innovation process and its ties to the social system suggests that this phenomenon is better investigated in a way that attempts to capture the different perspectives, experiences, interpretations and understandings of process participants. Therefore, to capture the subtleties and inherent complexities of the innovation process, a phenomenological approach that allows researcher to understand lived experiences of participants in the innovation construction process is required (Creswell 2007).

This study explores the phenomenon of innovation through the medium of technical innovation constructions in the UK Oil and Gas industry with a research population including entrepreneurs (technology developers), end users (engineers and managers within oil companies), and providers of financial resources (VCs and bankers). This theoretically selected population of research respondents, on the basis of key stakeholders, enables the phenomenon of innovation to be investigated from different phenomenological perspectives. Consequently, how innovation is constructed and the socio-cultural, political and economic factors that help or hinder technological innovation emergence can be explored.

The starting point for the study is the proposition that innovation occurs in a unique social space that is context bound but unfixed to a particular locale. A social constructionist stance underpins this study because it provides the framework for understanding how social actors use existing plausibility structures through intersubjective, human-to-human and human-to-context interactions to create socially meaningful forms like technology artefacts. Since meaning emerges from coordinated social action (Gergen 1994), participants in the innovation construction process in the oil industry must coordinate action and develop shared understanding to engage in successful technical innovation construction.

This study treats the environment or context of innovation process as socially constructed since through power of agency, entrepreneurs acting in concert with others, have the power to transform structural barriers into resources that can be deployed towards certain ends or desired outcomes. This study attempts to chart the relationships between entrepreneurial action, the social constructions that participants bring to the innovation construction space, and how participants coordinate to make sense of uncertainty and ambiguity that is intertwined with the innovation process, then we can explicate the underlying nature of the entrepreneurial and innovation process.

The ontology that underpins this study is guided by Heidegger's relational view of practical, involved action of human agency. As practical, involved agents, human actors live in different modes at different times but open to possibilities, and by extension innovation construction, only when in a particular mode (Heidegger 1963). Human involvement with the world makes use of habitus to adapt to circumstances and instantiate action but only within the constraint of what is socially meaningful and legitimately acceptable to other actors. In adopting a Heideggerian perspective, this study explores why, how and when human actors shift between different modes of being, from the routine, unreflexive day-to-day mode of living to the engaged, reflexive and questioning mode moving actors to the innovation space where innovation construction can take place.

1.2.1 The Research Question

This study emerges from my personal curiosity about the challenges and difficulties technology developers in small and medium enterprises (SMEs) face to develop new technology and successfully introduce it into the market place within the UK oil and gas industry. Most of the technologies used in the industry come from the big multinational companies. Without question, resource constraint is a lever that can catalyse or impede innovation construction (Smith 2006) in part because larger companies have advantages over small companies because of their process know-how and financial resources. However, and anecdotal evidence from within the oil industry suggests that resource constraint alone cannot explain for the difficulties technology entrepreneurs face in developing new technology. To meaningfully explore the process of innovation in the industry, this study will focus on how entrepreneurs create new combinations by trying to map the human-to-human and human-to-context interactions that precede and mediate the process of technology innovation emergence.

To investigate this phenomenon, the research question that is the focus of this study is “what is the process of technical innovation construction within the UK oil and gas industry and can we understand it?”. The main research question is supplemented by other sub-questions designed to explore the different dimensions of the social nature of innovation and its antecedents.

1.3 Purpose of the Study

This purpose of this study is to identify and describe the social construction of technical innovation in the UK oil and gas industry through the lived experiences of those who have participated in the process. Different players in the innovation construction process come to the innovation space along different trajectories of experience (habitus), occupy different roles within the structural architecture of the field of action and are motivated by different ends.

How can we chart the multi-layered set of interlocking transactional and transformational exchanges that produce innovation through the exploration of human-to-human and human-to-context interactions? In a nutshell, there are likely to be as many social constructions as there are many actors coming together to collaborate in the innovation construction process. The tensions and conflicts between and among these social constructions have to be resolved to create the social space in which shared understanding can develop and technical innovation nurtured. The different dimensions of the innovation process and sub-processes will be explored through the perceptions, understanding and social construction of research respondents.

1.3.1 Objectives of the Study

To fulfil the purpose of the study, the research will attempt to achieve the following objectives:

1. Explore why, when and how technical innovation (new technology) gets developed for the North Sea oil and gas industry.
2. Investigate the social character of information exchanges and development of ideas that form the seed for innovation construction.

3. Explore how the conflicting motivations, multiple perspectives and understandings, different experiences and overlapping interests of key stakeholders in the innovation construction process influence the process of innovation development.
4. Explore the reasons for implicit and explicit acceptance of innovation offered by industry practitioners while simultaneously demonstrating apparent reluctance to try new technology
5. Identify and chart the process that delivers innovation in the industry and compare and contrast to what is presented in the literature about innovation process.
6. Explore how the social system influences innovation construction process and why and how some entrepreneurs may be more adept at transforming structural impediments into resources in support of innovation construction.
7. Explore the implications of findings for our understanding of innovation and entrepreneurship. Make some recommendations on practice of entrepreneurship based on findings.

1.4 Significance of the Study and Justification of Research

Innovation is essential to the growth of the UK oil and gas industry. Cumbers (2000) posits that about 40% of the firms in the Aberdeen area are involved in new product development and testing. Given the number of firms and actors engaged in innovation in the industry, the industry should be expected to provide ample evidence of 'creative destruction' with new technologies displacing old technologies. However, technology adoption in the industry is slow and existing technology retained commanding share of the market. If many firms are engaged in innovation construction and new technology development but end users remain loyal to field proven technologies, the question then arises, how is technical innovation developed in the industry?

There are many models of innovation process with each succeeding model increasing our understanding of the innovation process. Although our understanding of the innovation process and why people accept or reject innovation has improved (Mascitelli 2000; Rogers 2003; Smith-Doerr, Manev and Rizova 2004), existing models of innovation process still leaves much to be understood about innovation construction. These models and explanatory framework do not provide us with sufficient insights to explicate the interactions that mediate the pace of new technology acceptance (Bower 2005). This lack of understanding has economic and policy implications.

If any innovation is to succeed, it must address users' needs and have potential to match anticipated future needs (Davidsson 2004), therefore innovation developers must pay attention to cues and source information from different stakeholders to increase probability of success (Chorev and Anderson 2006). Entrepreneurs anticipate, influence and proactively seek to shape opportunities through information search and use of scripts to validate potentially viable options by relying on their experience and coordinating with others to create future value (Blanco 2007). In attempting to match possible technical solutions to present and potential future needs, entrepreneurs engaged in technical innovation construction must also rely on their experience, pattern recognition ability and the skill to connect seemingly unrelated information to potential future value (Baron and Ensley 2006). This suggests that the process of innovation construction is deeply social, multi-layered and shaped by the interactions and experiences of the participants.

Early models of innovation depicting the process as a series of linear and sequential activities, and even recent models of same phenomenon that acknowledges the recursive and multi-layered aspects of innovation do not take sufficient account of the context of action nor provide a means for exploring the different meanings, perspectives and world views that stakeholders bring to the innovation construction process (Green, Gavin and Aiman-Smith 1995; Massa and Testa 2008; Roseno 2005). Our understanding of the innovation process is therefore limited because these models do not provide with insights into motivations for the choices individuals make or allow us to explore how contextual and individual factors shape the innovation construction process and emergence of new technology.

Although there is an extensive body of knowledge and research on innovation, very few researchers take as starting point for investigation, an acceptance of different social constructions of participants and with what implications for innovation construction process. A limited number of studies have explored the social forces shaping the innovation process and how social actors make sense of associated ambiguity and uncertainty in the construction of technical innovation (Hall et al. 2011; Rothschild and Darr 2005; Peschl and Fundneider 2014). If social reality is inseparable from human actors with each shaping the other (Cunliffe 2008; Heracleos 2006a), then exploration of shared meaning and inter-subjectivity should enrich our understanding of the innovation process. Any innovation is inherently risk because success is not certain therefore human actors engaged in technical innovation construction must grapple with the inherent risks and uncertainty of outcome. Exploration of how participants in the innovation process handle uncertainty and making sense of ambiguity is under-researched and under-theorised in the innovation literature. Furthermore, at the time of writing, no studies were found that directly explores the construction of innovation from a sense-making perspective within the setting of the UK oil and gas industry. Therefore, this study addresses a gap in the literature as well as the anticipated theoretical contribution of understanding what goes on in the technical innovation construction process and why.

This study contributes to a better understanding of how social actors engage in the innovation development within contextual and structural boundaries. There is an extensive list of barriers to innovation in the academic literature but with little exploration of why these barriers persist and endure. By exploring the different perspectives and understandings of critical actors in the process, this study presents some insights on how different social constructions may impede sense-making and development of shared understanding thereby reinforcing structural barriers.

By exploring the world views of human actors who are engaged with innovation space, this study points to new ways of understanding and action that may be more useful and productive for practitioners engaged in the innovation process.

1.4.1 Justification of Research

Innovation is central to the growth and competitive advantage of oil and gas companies. With the declining production from North Sea assets, oil companies need new approaches and technology to increase recovery from these oil and gas field. As previously discussed, this study approaches the study of innovation by trying to understand the social construction of technology in the oil gas industry is constructed. There are some studies on technology development in the oil industry exploring concepts like network and social capital, but this study tries to delve into how individuals, on their own and in concert with others, make sense of their day-to-day experiences and how these experiences drive or impede innovation. While the subject is about innovation construction, this study examines the evolutionary and unfolding sub-processes through the eyes and experiences of entrepreneurs who act in concert with other actors to create and develop innovations.

Entrepreneurship is a social and relational (Jack and Anderson 2002) process that is context bound and characterised by continuous change (Anderson, Jack and Drakopoulou Dodd 2007; De Carolis and Saparito 2006) but socially constructed (Smith 2006). Just like innovation which is about transformation and adaptation, entrepreneurship is a social process that is in part transactional but also transformational across spatial and temporal boundaries. The spatial and temporal dimensions of innovation construction and entrepreneurship anchor the processes to a social reality that is dynamic, constantly evolving and therefore should be examined with a processual view (Pettigrew 1997).

The study of entrepreneurship, as a complex social phenomenon, requires different levels of analysis (Davidsson 2003). Innovation construction as a social process consists, in part, of an articulation of a problem to be solved or a need to be met. However, the knowledge, experience, insights and know-how required to articulate what needs to be done is distributed among different players who arrive at the innovation space travelling through different passageways of experiences. Therefore, to explicate the social construction of innovation construction requires an approach that tries to understand the lived experiences of relevant actors and their interpretations and understandings of these experiences. The study will improve our understanding of how and why different parties in different roles with different motivations come to the innovation space and make sense of what needs to be done (*problem framing*), engage collaboratively and constructively to develop new technology. Innovation by its nature is risky and outcome uncertain (Kanter 1998; Pavitt 2005), therefore this study attempts to chart the drivers and social forces, that can align to catalyse, but can also combine to impede innovation depending on social context.

1.5 Methodology Overview

This study employed qualitative method of in-depth, open-ended interview with a purposefully selected population of respondents to explore the socials dimensions and nuances of the innovation construction process in the UK oil and gas industry. The study aims to understand how participants reflect on and contextualises their experiences as they engage in and with different technology development projects. To understand such a process, the researcher has to be able to understand the views and interpretations of social actors who have engaged with the process, therefore a purposeful sampling of selected owner-manager of small firms, managers and engineers within oil companies as end users and, VCs and bankers was undertaken to form the population of interviewees.

Field work (interviews) was done in two stages. In the first stage, a pilot study was undertaken designed to explore how actors' understandings and their experiences agree with or diverge from what is in the literature. Issues from the pilot study were then used to refine the research question that was used in the second stage of the field work. With this approach, the lived experiences, perspectives, interpretations and understandings of the different participants help shaped the evolution of the research, and the breadth and depth of issues explored.

Philosophically, the research and the methodology employed is rooted in phenomenological research design because the research was designed around understanding the phenomenon of interest through eyes of the respondents (Cope 2005). Phenomenology, like ethnomethology and symbolic interactionism, is concerned with how our senses apprehend the world in our day-to-day experiences and therefore suited to investigation of phenomenon through the interpretations of others (Cohen 1987), and understand the subjective world of research participants (Husserl 2001 [1913]). The use of quantitative techniques for this research would not have been sufficiently exhaustive nor provide insightful understanding of this complex phenomenon. While scientific approaches seek 'cause and effect', an interpretive approach such as one adopted in this study, seek to reveal meaning and understanding behind social action (Ritchie and Lewis 2003) and provide rich, broad, plausible explanation of social action and phenomenon. Because of human reason and will, this researcher believes that we can only claim to understand a social phenomenon when we understand the meaning it has for social actors engaged in the action (Potter 2000; Weber 1949).

This research is aimed at answering the 'when', how' and 'why' question about what is going on within the UK oil and gas industry. Qualitative approach is better suited to the study of 'processes' because it allows the researcher to acquire information about interactions between participants, account for the different experiences of actors, capture the fluid and dynamic character of the process and its sub-processes, and take account of the perceptions of actors engaged in the process (Patton 2002). This researcher starts with the assumption that participants in the innovation construction process create the reality they perceive and operate within. Therefore, a research design informed by phenomenological worldview provides the space to interact with the respondents in a way that draws out deep meanings of their actions and explore the influence of their social constructions on the process of technical innovation.

The full rational and justification for the research methodology will be presented in chapter 5.

1.6 Delineation of Boundaries of Research and Scope

This study is about innovation construction in the UK oil and gas industry by examining how entrepreneurs develop new technology and how it is accepted or not by users. The study is concerned with the social processes from the gestation of an idea through its evolution until new technology artefact is developed. The study does not make a distinction between innovation attempts that succeeded and others that failed. While some literature on innovation only consider successful innovation, this study takes the view that there is a lot we can learn from failed attempts to develop new technology (McKee 1992; Rehn and Lindahl 2012; Välikangas, Hoegl and Gibbert 2009).

Adoption of new technology is a worthy and economically desirable outcome but it is not the central focus of this study. By developing a better insight into how new technology is developed, this study will attempt to capture the process of innovation development using the UK oil and gas industry as the context of interactions and focus of study.

There is always a trade-off between scope and depth of understanding when engaged in qualitative research. A research based on in-depth interviews with a selected but small population of participants will provide depth of understanding given their intimate knowledge of and experience with the process of innovation construction. The depth of understanding gained from such a study is the goal of this study rather than research with a broad scope. Nonetheless the explanatory accounts will be conceptualised in such a way as to provide generalisable theory that may be applied to understanding a similar process in different contexts.

1.6.1 Limitations of the Study

The study is limited to a population of owner-manager (entrepreneurs) of small firms, engineers/managers, who make decisions about acceptance of new technology, and VCs and bankers. The sample may capture all the nuances and influences in the innovation construction process. While study provides new insights into our understanding of innovation construction in general and technical innovation development in the oil and gas industry, it does not attempt to generalise its findings across every form of innovation. The study acknowledges the influence of contextual factors that may empower, freeze or negate certain social forces that may be in play in other contexts of innovation construction.

As an interpretive research through qualitative methodology, this research is limited because it relies on the subjective interpretation of participants and the researcher's interpretation of participants interpretation which itself is not without its bias.

1.6.2 Unit of Analysis

This research tries to understand the process of technical innovation through the eyes of participants in the process, using the understanding of the interrelationships between the social actors and the contextual environment that mediates outcome of innovation as the unit of analysis. With the theoretical selection of respondents, individuals with relevant experience of and engagement with the process of innovation construction, the study allow us to explore the social forces underpinning technical innovation development.

1.7 Summary and Outline of Research

This study uses a qualitative approach in investing the process of technical innovation development in the UK oil and gas industry through the eyes of experienced practitioners. The thesis presents a review of the relevant literature, the research objectives, design and methodology adopted. The thesis is divided into eight chapters.

Chapter 2 introduces and reviews the concepts of innovation and entrepreneurship, exploring how different academic disciplines have treated these concepts. The chapter also explores the nexus of innovation and entrepreneurship including their complex and highly contextualised nature. Technological innovation, which is a sub-class or type of innovation, is argued to be a social process with multiple influences where the trajectory of emergence is shaped, moulded and encouraged or constrained by the social context.

Chapter 3 offers a continuation of the human-to-human and human-to-context interactions alluded to in chapter 2, the creation of technical innovation is re-examined using a Heideggerian perspective of modes of being and these modes sharpens or dulls potential for innovation construction. A critical examination of the power and limit of social action in relation to the social is followed by an examination of how habitus influence choices and gets deployed in the entrepreneurial game. The chapter concludes with an examination of how human actors make sense of their day-to-day experiences, the social construction and tentative solutions and, with what implication for what actors see and accept as innovation.

Chapter 4 presents the conceptual lens for the study rooted in social constructionist ontology. The chapter makes the case for how we construct our reality depending our mode of being in our engagement with human actors and nonhuman objects and context. In the appropriate mode, entrepreneurs and other stakeholders enter into the innovation space to frame problems and develop a series of tentative solutions that becomes the foundation for innovation construction.

An examination of the ontological and phenomenological stance that informed this research is presented in chapter 5. An extension of the theoretical basis for the conceptual lens is also presented. The chapter demonstrates how the methodology used in the research, the research design, operationalisation of grounded theory methodology is consistent with the ontological and phenomenological stance of the researcher. This chapter concludes with the reflection of the researcher and his journey, discussing the selection of conceptual framework, influences of the participants on his unfolding understanding of research issues and the evolution of his theoretical appreciation over time.

The descriptive accounts of the findings and their contextualisation are discussed in chapter 6 including the interpretation of these findings by the researcher. This chapter allows the voices of the research respondents to come alive to further our understanding about the doings and happenings in the innovation process as seen by these social actors.

An integration of the findings into a theoretical model of social construction of technical innovation is presented in chapter 7. In chapter 8, the conclusions from the study findings and recommendations arising from these findings are discussed.

1.8 Conclusion

In this chapter, the researcher has outlined the foundation for the research, the background of the research and how he became interested, introduced the research problematic and presented a justification for doing the research. A brief overview of the methodology used has been presented. Rationale for the scope of study and the limitations of the research has also been briefly discussed. In the body of the thesis, a detailed account of the research foundation, process and outcomes will be presented.

Chapter 2

2.1 Introduction

This chapter presents different views about innovation as portrayed in the literature. It explores how different academic disciplines have viewed, conceptualised, studied and presented innovation. By focusing on the multidimensional character of innovation and the nexus between innovation and entrepreneurship, the implications of these different portrayals for research and communication about innovation are explored. Through an overview of innovation management literature, the weaknesses of existing models of innovation process are explored. Different academic disciplines define innovation differently and emphasising different aspects, consequently the way researchers approach innovation study and communicate their findings also differs across academic disciplines. The varieties in approach create theoretical and pragmatic problems making it difficult to compare research results across disciplines.

Notwithstanding the differences in definitions and approaches, this chapter focuses on the nature of these phenomena – innovation and entrepreneurship. The lack of consensus around the definitions of innovation and entrepreneurship shape the analysis of the literature presented in this chapter. The chapter starts off with an exploration of the different definitions of innovation followed by evolution of our understanding about the innovation process. In particular, the chapter discusses types of innovation and how innovation evolves with time and a brief overview of what drives adoption. Although our understanding of the innovation process has improved immeasurably, recent process models of innovation are more suitable for studying large organizations and take little cognizance of what transpires at the micro and meso levels where SMEs operate. The technology-push and market-pull models (Dosi 1982) which are more relevant to SMEs are discussed showing their weaknesses and identifying gaps that should be filled in the literature.

Since innovation decisions are based on a view of the future without full information, it is not possible to separate innovation process from uncertainty (van Riel, Lemmink and Ouwershot 2004) and risks. Types of uncertainties and other contextual factors that may affect innovation and their implications for success or failure discussed. An exploration of the role of social networks, social capital, social embeddedness and trust is presented to demonstrate how contextual factors influence the process of entrepreneurship and innovation construction. Entrepreneurship is presented as a forward-looking process and how individuals perceive risk and make decisions with incomplete information is explored. The chapter concludes by looking at entrepreneurship as a process through time with implications for how to research it and make sense of the different dimensions to gain the best insights.

Through an exploration of the different perspectives on entrepreneurship and how they engage in the transformation of ideas into tangible products, an account of the social dimensions of innovation is conveyed. Innovation is seen as a product of a process over time but influenced by the surroundings and nature of socials actors involved. The recognition of the processual nature and social character of innovation presented here lay the foundation to explore relevant social theories in chapter 3 that can be employed in its study and develop a theoretical framework used in the study as presented in chapter 4.

2.2 What is Innovation?

Innovation as a phenomenon is probably as old as civilization because of inherent human tendency to adapt, survive and shape the environment to suit immediate and future needs. Innovation is important to economic growth therefore it attracts a lot of attention from across a wide spectrum of society. In western socio-economic and cultural discourse, innovation has become widely accepted an important driver of productivity and economic growth (Rosenburg 1986; Wennekers 1999; Wong, Ho and Autio 2005). Despite the pervasiveness of innovation in political and economic discourse, innovation definition in the literature is varied and discipline-centred making it is difficult to have clarity about its nature and understanding what it encompasses. To add to this complexity, innovation has been studied and analysed in the literature at different levels. Some scholars analyse innovation as it affects a country's economic and social systems (Lundvall 1995; Nelson 1993), as a force shaping industrial structure (Porter 1990), as a phenomenon at an organisational level (Rosenfeld and Servo 1991), or at a micro level as exhibited by individuals engaged with the process of entrepreneurship (Drucker 1985).

Thompson (1965 p.2)	Innovation is the generation, acceptance and implementation of new ideas, processes or services
Drucker (1985)	Innovation is the specific tool of entrepreneurs, the means by which they exploit change as an opportunity for a different business or service
Albury (1993)	Successful innovation is the creation and implementation of new processes, products, services and methods of delivery which results in significant improvements in outcomes, efficiency, effectiveness or quality
Woodman, Sawyer and Griffin (1993)	Innovation is the successful implementation of creative ideas
Rogers (2003)	Innovation is an idea, practice or object that is perceived as new by an individual or other unit of adoption
Beacham (2004; UK DTI)	Innovation is the successful exploitation of new ideas
McFadzean, O'Loughlin and Shaw (2005)	Innovation is a process that provides added value and a degree of novelty to the organization and its suppliers and customers through the development of new procedures, solutions, products and services as well as new methods of commercialization
OECD, Oslo Manual (3rd edition, 2005),	An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method inbusiness practices, workplace organization or external relations (p. 46).
Carlson and Wilmot (2006)	Innovation is the successful creation and delivery of a new or improved product or service that provides value for the customer and sustained profit for the organization
Pleissis (2007 p. 21)	The creation of new knowledge and ideas to facilitate new business outcomes

Table 2-1: Selected definitions of innovation

There are many definitions of innovation in that academic literature (Garcia and Calatone, 2002) as demonstrated by selected definitions in Table 2-1. Although these definitions are informed by different paradigms, some common themes such newness, exploitation and implementation run through the definitions. Although these definitions are informed by different views of the phenomenon, they all acknowledge the transformation of an idea into something more tangible with economic value that can be exchanged between parties.

These definitions all point to a sequence of activities, patterned and ordered, in a process designed to achieve the transformation of idea(s) into tangible, profitable products and services. Innovation involves the exploration and exploitation of opportunities to produce new products or services using existing know-how in response to or with the aim to influence market conditions (Pavitt 2005). Introduction of new products or services also implies the notion of change, therefore, innovation cannot be considered in a vacuum because success depends on the attitude of others and their acceptance or rejection of change. These definitions of innovation and product innovation are sufficiently broad as to encompass the various attributes and characteristics of innovation and technology innovation that will be explored in this study.

The literature distinguishes between invention and innovation, where an invention refers to the first occurrence of an idea, innovation describes the totality of actions and activities involved in commercialising the idea (Gerhard, Brem and Voigt 2008). The series of actions and activities carried out to commercialise an idea suggest that innovation is a process that takes place over time and influenced by the environment. That is, innovation is process that is spatially and temporally bound to specific context of action. Fundamentally, innovation is about implementation of invention; the translation of an idea into a product or service that can be exchanged and from which economic rent can be extracted (Roberts 2007).

Innovation is not just about an idea, no matter how brilliant, but also the implementation and transformation into a tangible end. The transformation of ideas into tangible forms involves a series of actions and decisions by multiple stakeholders with multiple interests, the nature of interactions and the sequence of actions have to be carefully arranged, managed and executed.

2.2.1 Evolving Understanding of Innovation Process

In this section, an exploration of evolving understanding of innovation and how it emerges over time is presented. The description of the innovation process in the literature ranges from a simple, linear process to more complex, context-sensitive depictions. Through time, our understanding and description of innovation have become more complex and cognisant of multiple factors influencing its emergence. The progression from simple models to more complex variants demonstrates the complexity of the phenomenon and its multiple dimensions.

The five generation of innovation process models are summarised in the seminal work of Rothwell describing the evolutions and the socioeconomic framework of these models. Rothwell (1994) provides a historic overview of industrial innovation management in the Western world from the 1950s. His description of the evolution of these innovation models showed that each model was a response to significant changes in prevailing socioeconomic environment. The five models are therefore descriptive models of how manufacturing companies structure their innovation process in response to the competitive forces they have to contend with.

The five generations of innovation detailed in Rothwell's work are listed below:

First generation	technology-push model (1950s to first half of 1960s)
Second generation	market-pull model (second half of 1960s to early 1970s)
Third generation	coupling model (early 1970s to early 1980s)
Fourth generation	integrated innovation process model (early 1980s to 1990s)
Fifth generation	integrated, interconnected, parallel and flexible innovation process model (since early 1990s)

Early models of innovation depict innovation as a linear process and are commonly referred to as the *technology-push* and *market-pull* models of innovation. The technology-push model came out of the industrial innovation process of the 1950s to mid-1960s where fast economic growth created the room for accelerated industrial expansion and strong technology-push. Science and technology had the pre-eminent role of being seen as having the potential to solve society's problems and meet customer needs. In the technology-push model, market information is incorporated very late in the process, after products have been manufactured.

In the mid-1960s to early 1970s, a second generation model of innovation emerged known as the market pull model. This is a period when companies have entered into an era of intense fight for market share. Because of intense competition and the need for efficiency of R&D investment, emphasis shifted from development of new products towards responding to customer needs (Myers and Marquis 1969). While the technology push model suggests that innovation is developed to meet gaps in the market or customer needs and therefore proactive, market pull model relies on market cues and signals to direct R&D efforts and the direction and pace of innovation. One criticism of the market-pull model of innovation is that it is likely to produce predominantly market-driven, incremental improvements of existing products.

These two models of innovation are rather simplistic and no more than a schematic representation of an oversimplified process of activities and interactions. They both credit the source and driver for innovation to one set of factors to the exclusion of others without sufficient account of the contextual sensitivity of the process and the implication of interactional activities that underpin the process. The market-pull model has the advantage of recognizing the importance of satisfying customer needs in driving innovation thereby including the concept of interactions in the innovation process (Mowery and Rosenberg 1979).

As understanding of innovation deepened, it became clear that innovation is hardly the result of unadulterated technology-push or market-pull but through a combination of the two and matching means to ends. The third generation model extended the simplified, linear approach of earlier innovation models by linking businesses, research institutions and markets together (Rothwell and Zegveld, 1985). In the mid 1970s to mid-1980s, the strategic focus of large corporations shifted towards corporate consolidation and development of product portfolio in response to the inflationary pressure and stagflation being experienced by Western economies. Companies moved away from committing to expensive R&D activities, marketing became coupled with R&D to improve efficiency. The drive to reduce operational cost became the driver for the 'coupling model' or what is otherwise known as the third generation innovation process model. Berhout et al. (2006) refer to the third-generation model as the 'open R&D model' because it emphasizes technical (product and process) innovation and ignores non-technical (organizational and market) innovations, although this model is better known as the coupling model in the literature. The third-generation model remains a linear process but now incorporates feedback loops, recognising that in a lot of cases technology and market factors combine to mediate innovation, which led some to refer to it as the 'coupling' model (Rothwell and Zegveld 1985; Tang 1998).

In the early 1980s to mid-1990s, the focus was on integrated processes because of short product life cycle and downward pressures on corporate profitability. Companies started arranging their innovation process as parallel processes instead of the linear, functional, sequential process represented by earlier models. The fourth generation model depicts innovation as a set of parallel processes carried out by different functions that are interconnected with feedback loops (Kline and Rosenberg 1986) with greater emphasis on feedback. The fourth-generation model recognises concurrent learning and interchange of information and knowledge between consumers and suppliers. The essential features of the fourth-generation model are arrangement of parallel, concurrent activities and integration across functions within the organization. The fourth generation establishes a clear link between scientific knowledge and technology development, suggesting that science and technology are interdependent (Kline and Rosenberg 1986). This model recognises the importance of information, use of expert systems, communication technologies and networks, and the strategic role of cooperation between companies (Rothwell 1992). This approach to product development is best exemplified by the Japanese automobile and electronics industries in 1980s to the 1990s.

Since the early 1990s, resource constraints and opportunity costs have forced companies towards systems integration and networking to achieve flexibility and fast, speedy product development. The economic pressure created by the need for speed and flexibility gave birth to the fifth-generation innovation model. Although similar to the forth-generation model, the fifth-generation model integrates suppliers and customers along the entire innovation process and recognises time-cost tradeoffs. Speed of innovation can provide strategic and competitive advantage in areas with short product life cycle or areas of rapid technology change. However, as accelerated innovation increases development cost, so does the need of companies to balance the need for speed against development cost.

The framework proposed by Rothwell has gained wide acceptance and many other reviews of innovation in the literature (Cagnazzo, Botarelli and Taticchi 2008) are based on Rothwell's framework. Although the fourth and fifth generation models of innovation recognizes the multi-layered and complex character of innovation, these models are based on depicting innovation at a company level relying on internal processes and functions of companies. This understanding of the innovation process is limited and does not take account of the influence of the external socio-economic and cultural environment in which innovation develops. Also, it does not improve our understanding of how individuals and small businesses within the economy, without resources in R&D and other capital intensive components of the new innovation management models, engage with and produce innovation.

Taking a different approach, Marinova and Phillimore (2003) treat earlier innovation process models as conceptual and theoretical constructs rather than focusing on the historical development of innovation models. This focus of analysis separates Rothwell's and Marinova-Phillimore's work on innovation process. Using this conceptual approach, Marinova and Phillimore identified six generations of innovation models, which are:

- First generation (black box model)
- Second generation (linear model)
- Third generation (interactive model)
- Fourth generation (system model)
- Fifth generation (evolutionary model)
- Sixth generation (innovation milieu model)

The differentiation of innovation models by Marinova and Phillimore (2003) bears striking resemblance in a lot of ways to Rothwell (1994) models of innovation. The first three models of innovation are broadly similar. The same can be said for Marinova-Phillimore's fourth-generation model that is similar to Rothwell's fourth-generation model except that Marinova and Phillimore (2003) expanded on how systems thinking came to improve innovation process (Galanakis 2006). Although Marinova-Phillimore's fifth-generation model is also similar to Rothwell's, they identify the need for solving highly complex problems for product development as one of the reasons for its emergence. They agree with Rothwell on the basic features of this innovation model such as integration of key suppliers, customers, R&D organizations and universities in the simultaneous or concurrent engineering of product development.

In contrast to Rothwell (1994), Marinova and Phillimore (2003) identified a sixth generation of innovation process that is sometimes referred to as "technology innovation". The sixth-generation innovation process is predicated on modeling, simulations, virtual reality, artificial intelligence, creation of massive databases on customer decisions in relation to multiple service and product offerings, rapid analysis of data from multiple market segments, and accelerated product prototyping. Rothwell's analysis is focused not on the innovation model per se but on how innovation activities are carried out by different companies under different contextual environments. While Rothwell's model represents what companies do, the Marinova - Phillimore's analysis focuses on the innovation process models themselves, offering limited potential to examine innovation at different levels of analysis be it micro (individual) and meso (relational) levels.

2.3 Factors Influencing Innovation Adoption

Although this study is not about diffusion of innovation, it is important to examine what is known about why customers accept or reject innovation since it may provide a window into the thinking of customers when confronted by new products or services. History shows that it does not necessarily follow that innovation will lead to adoption (Brandyberry

2003). Technology Acceptance Model (TAM), which developed out of information systems research, identifies perceived ease of use and usefulness of technology as factors influencing acceptance and adoption of technology (Davis 1986, 1989; Davis, Bagozzi and Warshaw 1989). Other studies rely on user demographics like age, gender, education, and professional occupation to predict likelihood of adoption (Davis, Bagozzi and Warshaw 1989, Laukkanen et al. 2007; Morris and Venkatesh 2000; Venkatesh et al. 2008) but sociological studies have shown that technology adoption is affected by social embeddedness of potential users and social relations between actors (Granovetter 1973; Peng, Wang and Kasuganti 2011). MacVaugh and Schiavone (2010), using a multidisciplinary approach straddling marketing and sociology research show that innovation diffusion is affected by social, technological and learning conditions that are contextually bound. They argue that process of adoption should be investigated at three levels - the market/industry domain (the macro environment), the social domain (set of relationships shaping the social system or what is referred to as the meso environment) and the micro (individual) level. The macro, meso and micro levels are shaped by different interests, rules and norms making studies in innovation diffusion difficult or attempts to predict diffusion challenging. Users' decisions to adopt, MacVaugh and Schiavone (2010) contend, depend on whether technology is easy to adopt and useful.

One of the most prominent theories about innovation is the diffusion model of innovation from Rogers. According to Rogers (2003 p. 13), "technology is a design for instrumental action that reduces uncertainty in the cause-effect relationships involved in achieving a desired outcome". Uncertainty is an important obstacle that must be overcome in the innovation process to be successful but it is also a critical ingredient in the sense-making process of individuals and groups. To reduce uncertainty, there is a need for communication channels to provide individuals with information about innovation. Rogers (2003) posits that diffusion is a form of communication involving at least two individuals, an innovation and a communication channel for transmission and receipt of information. Therefore diffusion of innovation is a "social process that involves interpersonal communication relationships" (Rogers 2003 p. 19).

These interpersonal channels can be very powerful in changing attitudes or overcoming entrenched opposition to innovation. Communication through the channels may be between people who share similar beliefs (homophily) or individuals that are with different beliefs and attributes (heterophily). The relationship between a source and a receiver is an important one (Rogers and Bhowmik 1970) and has implications for innovation development and acceptance. Vissa (2011) submits that task complementarity and social similarity influence formation of interpersonal ties and the likelihood of economic exchange. Roger ascribes a strong role to the social system in which these interactions and communication take place, which he defined as "a set of interrelated units engaged in joint problem solving to accomplish a common goal" (Rogers 2003 p. 23). Rogers' innovation-decision process is an information-seeking-and- processing set of activities individuals use to reduce uncertainty and learn about the advantages and disadvantages of innovation. Through the five stages of the innovation-decision process (Figure 2-1) stakeholders acquire knowledge about innovation and seek to reduce doubts and uncertainty by working with others using different channels of communication.

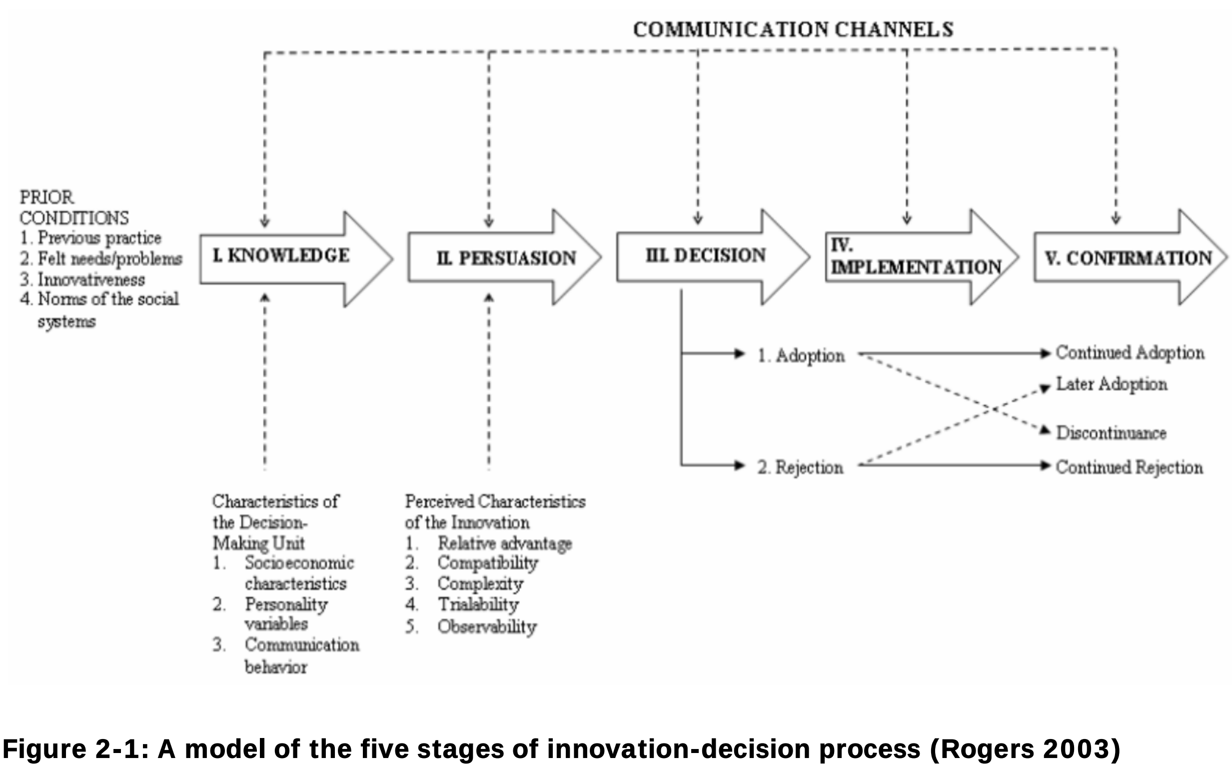

Figure 2-1: A model of the five stages of innovation-decision process (Rogers 2003)

Knowledge acquisition is the starting point of the innovation-decision process model. During this stage individuals learn about the innovation, seek out additional information about what it does, how innovation works, why it may be superior to existing way of doing things and ask critical questions about the product. Learning about how innovation works also allow individuals to learn about suitable applications, a knowledge that may become critical in deciding where and how innovation should be tried. Potential customers also acquire knowledge about the working principles of innovation which helps them to see how innovation can be integrated into their current work flows.

The formation of a positive attitude does not always lead to adoption while negative attitude does not have to result in rejection. With the information received in the knowledge stage, individuals start shaping their attitudes towards the innovation. Rogers (2003) argues that knowledge acquisition is more cognitive-centred while persuasion relates more to feelings. The degree of inherent uncertainty in the innovation and social reinforcement from colleagues and professional peers affect individual opinions and beliefs about innovation at this stage. Information from different sources, trusted or otherwise, at this stage can start to attenuate or accentuate feeling of unease about innovation uncertainty.

In the decision stage, stakeholders choose whether to accept or reject innovation. In the case of acceptance, users decide to adopt innovation accepting it as the “best course of action available” (Rogers 2003 p.177). Rejection can occur in two forms and it is possible at every stage of the process. If users decide to reject an innovation after a trial and evaluation, that is an active rejection. On the other hand, ‘passive rejection’ occurs where user(s) decide not to proceed with the innovation before the trial stage.

At the implementation stage, innovation is deployed. During this stage, users may need technical assistance and support as they gather more information about innovation and seek to reduce lingering uncertainty about innovation. Reinvention or modification happens at this stage in response to users’ feedback and evaluation of how innovation fits into existing work processes. Information from the early use or deployment of innovation feed into the final stage of the process – the confirmation stage. In the final stage, individuals look for support for their decision and choice. If decision makers are exposed to conflicting information about the effectiveness of innovation, it is possible for the innovation to be rejected.

Rogers' innovation-decision process highlight the importance of social interactions, experience of social partners who communicate with and influence decision makers, impact of negative or positive opinions from peers and colleagues and, matching of innovation to the problem that needs to be addressed. The innovation-decision process does not explain how developers of innovation decide on the problem that needs to be solved or tell us the nature of transactions and how to proceed from the problem definition stage to creating an artefact. Although Rogers' model acknowledges the social nature of diffusion process, it tells us nothing about how we get to the point where users have the opportunity to evaluate a product.

The interactions in the innovation construction model afford innovation developers to access different interpretations and priorities of needs. These are important because interpretations and priorities can become sources of uncertainty.

2.3.1 Uncertainty in the Innovation Process

Innovation implies the creation and introduction of something new into an environment, therefore carries with it a degree of uncertainty (van Riel et al. 2004). Uncertainties associated with innovation can manifest in different forms including technological uncertainty, market uncertainty, social and political uncertainty, timing uncertainty among others (Jalonen and Lehtonen 2011). Uncertainty exists when situations are complex, ambiguous, there is insufficient information or social actors are insecure about their own knowledge or state of knowledge about a particular area or thing (Brashers 2001). Since innovation has to be created without full information about impact of future market conditions, product or technology performance, social attitudes and development time, therefore innovation process has to be managed under conditions of uncertainty.

Technological uncertainty can arise from inadequately defined product specification because of newness (Tidd and Bodley 2002) or poorly defined functionality (Hall and Martin 2005). New products often require end-users to learn new techniques and demand that producers develop new business models. While users often engage in modifying existing products, they can also resist technologies that significantly alter existing ways of doing things (von Hippel 2005). The attitude of customers, insufficient clarity about customer needs (Corrocher and Zirulia 2010), competitors' response and availability and prices of substitutes all create market uncertainty (Naranjo-Gil 2009). Inability to predict in advance how competitors will respond to a new product or technology and future prices of substitutes may also cause uncertainty about how market will react to innovation (Gibbons and Littler 1979).

Innovation is an embedded process that requires social interactions with different stakeholders (Rogers 2003). Different interests of stakeholders and diversity of opinions can skew priorities (Ortt and Smits 2006). Although interaction with different stakeholders is meant to gather information that should reduce uncertainty, it is possible that these interactions can increase social and political uncertainties surrounding the innovation (Gales and Mansour-Cole 1995). Although information from stakeholders can reduce uncertainty, each of the stakeholders has social and political interests that may influence information given and the value judgement that underpins information exchange (Hannan and Freeman 1984).

Timing is critical to the innovation process because it can influence profitability (Bayus 1998), competitive advantage and optimum time to commit to innovation (Macdonald and Jinliang 1994) because knowledge increases with time. Therefore there is incentive in delaying investment decision as a producer but as a corollary, it is possible to argue that there is also incentive for the consumer to postpone the decision to commit to an innovation until others have done so.

The social effect of innovation, if we accept Schumpeter's creative destruction, is to disrupt the social order and engender change, but it may also create cognitive dissonance for individuals within organizations. Individuals may resist innovation if they believe that it is inconsistent with their current thinking or in conflict with their world view (Hurst 1982). If innovation is perceived as a threat by individuals, acceptance becomes uncertain (Geijsel et al. 2001) and a crisis of legitimacy for innovation may develop.

2.3.2 Trajectory of Innovation

The literature on innovation is replete with different labels and classifications of different types of innovation. These myriad form of innovations led Garcia and Calantone (2002) to criticise the plethora of typology that confuse and make it difficult to compare research findings. Although the various definitions in the literature are informed by disciplinary paradigms, there is enough broad agreement across the definitions to suggest that innovative process is iterative through which an invention is transformed into a product for end-users benefit and profit. An invention is transformed into an innovation when it reaches the market place with an economic value through production and marketing activities.

Some scholars argue that new technology enters an industry when old technology reaches the limits of its capabilities or when incumbents can no longer maximise innovation potential of existing technological architecture and platform (Foster 1986; Hill and Rothaermel 2003). New technology can also develop when existing technology can no longer be leveraged to exact greater value based on its inherent capacity (Paap and Katz 2004). Another source of change is when a fundamentally different science (based on a different paradigm) enters the industry changing how participants think of a problems and ways of solving them (Dosi 1982). Irrespective of how innovation enters an industry, it evolves over time and ultimately replaced by better and more efficient alternatives.

Once a dominant design is established, innovation becomes incremental building upon the dominant design (Sahal 1985) as technology travels along an ‘innovation avenue’. During this period of relative design stability, technology producers treat users’ preferences to be relatively stable, therefore customer needs can be satisfied via incremental innovation strategy (Utterback and Abernathy 1975). At some point, this period of relative stability is punctuated by technological ferment as users seek new solutions to existing ways of doing things or natural limits of scale and complexity makes it impossible to extract additional improvements from existing technology (Sahal 1985). During periods of stability, problem-solving routines focus on extracting performance improvements from the dominant design through elaborations until there is diminishing returns established elaboration routines making it economically less attractive to persist with elaboration, thereby forcing change (Dosi 1982). This evolution of technological innovation is exemplified in the S-curve showing that increasing engineering efforts is required to extract incremental performance improvement as a technology reaches its limit (Foster 1986). Fleming (2001) describes this point of increasingly expensive for marginal improvement in technology innovation as points of “recombinant exhaustion” when firms search for performance improvements forces a shift towards exploring radical new technologies.

Although the S-curve has useful explanatory power, research has found that the limit of technology alone cannot explain the shift from one technology to another. Christensen (1992) shows that although improvement in individual components in the disk drive industry followed an S-curve path, limits of a technology cannot be attributed to technological limits alone and there is a firm-specific component because the flattening out of the S-curve differed by firms. Expectations of future performance of any technology based on the S-curve presents an incomplete picture of what drives technology change based on a study of optical photolithography (Henderson 1993; Henderson and Clark 1990).

Tripsas (2008) argues that users’ preference for innovation evolves incrementally until it is suddenly punctuated by discontinuous change in preference. These periods of discontinuous change catalyse technological transitions increasing the attractiveness of technologies based on difference science. Tripas identified change in socio-political environment, customer experience over time and initiative of technology producers to shape users’ preferences by persuading customers of the wisdom to pay for new product or technology attributes.

Technological innovation, the subject of this study, creates change impacting on existing ways of doing things. To be of interest to customers, the change created by new technology must elevate performance level to a higher level than previously experienced. Abernathy and Utterback (1978) submit that product innovation occurs and continues until a dominant design emerges after which a shift towards incremental innovation begins. If the performance level delivered by the new technology is at par or below what is currently available or is deemed to be too expensive, there is little incentive for users to switch to the new technology. The relationship between performance level and what the customer expects in comparison to alternatives is a driver for innovation (Paal and Katz 2004). When customers no longer value additional or incremental improvements brought about by new technology, additional investment in delivering innovation does not lead to increased return on investment. Therefore, technology developers must follow the voice and wishes of the customer whenever they can if they are to deliver innovation that elevates performance to meet current and future needs of the customers. The degree of change and performance level that innovation offers is best categorised in the literature as either incremental or radical innovation (Abernathy and Utterback 1987; Dewar and Dutton 1986).

Kaplan and Tripsas (2008) argue that that the literature on technology life cycle and dominant design approach (Murmann and Frenken 2006; Suarez 2004) ignores cognitive factors in explaining the trajectory of technology evolution. Within any organisation, different people bring different cognitive understandings to confront any set of problems including assumptions about nature of the problem, how it should be solved and a set of perceived feasible solutions as shown in Figure 2-2. When social actors are confronted with complex situations, they employ frames to form simplified representations of available information (Goffman 1974) and project these interpretations to the present. In this case, the frame is the “lens through which actors reduce complexity of the environment in order to focus on particular features, make context-specific interpretations, decide and act” (Kaplan and Tripsas 2008 p. 791). In the context of technology innovation, “technological frame” refers to how actors make sense of a technology, evaluate one technology in relation to another and how these assumptions and understandings shape the selection of performance criteria used in evaluating new technology. The technology frames that social actors bring to the innovation process are formed from prior history (Beckman 2006; Burton et al. 2002), organisational experiences (Porac et al. 1995) and industrial affiliations (Spender 1989).

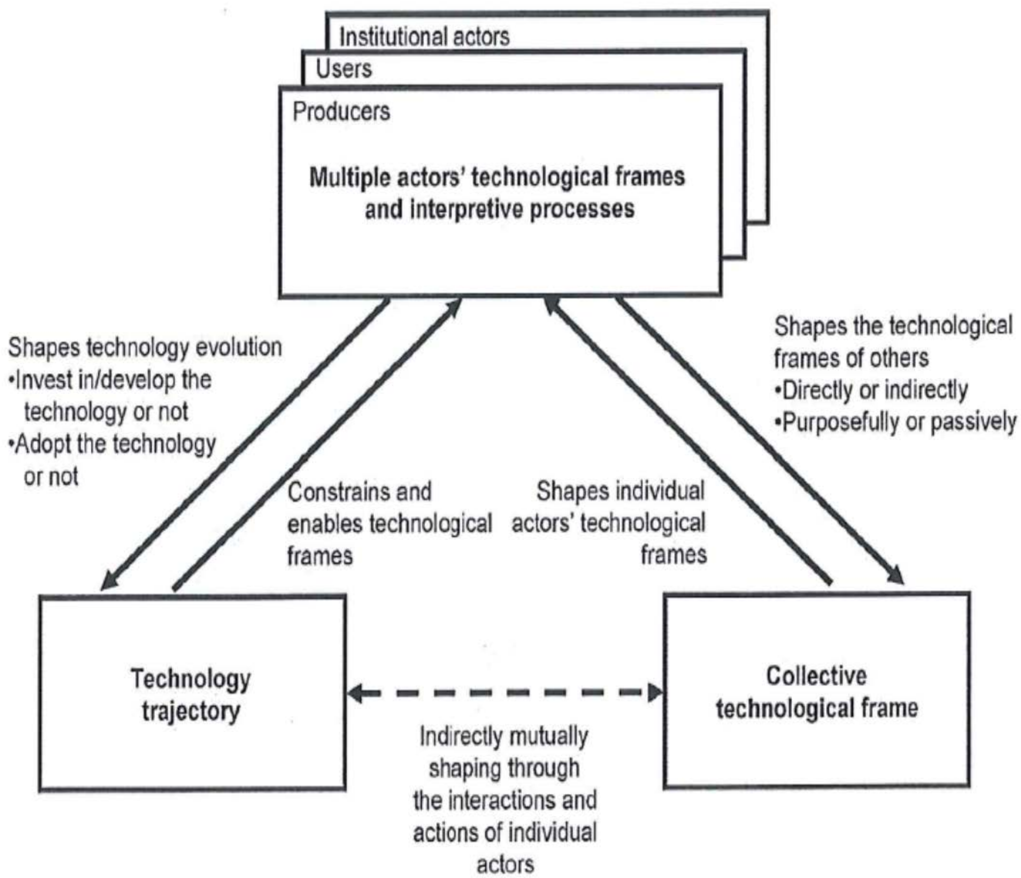

Figure 2-2: A cognitive model of technology trajectories (adapted from Kaplan and Tripsas 2008 p.793)

Kaplan and Tripsas (2008) argue that in order to understand technological evolution, it is important to take account of the technological frames that multiple actors bring to the innovation process. A lot of studies have focused primarily on the role of technology producer (Garud and Rappa 1994; Utterback 1996) with users assigned a passive role in the innovation construction process considering them important only in deciding whether to adapt an innovation or not (Rogers 2003). Increasingly, the voice and preference of the user have gained prominence in the study of innovation (Clark 1985; Tripsas 2008; von Hippel 1986).

In presenting a cognitive model of technology evolution (Figure 2-2), Kaplan and Tripsas (2008) focus on the dynamics and reciprocal relationships between technological frames of process participants, the presence or lack of a collective technological frame and the evolution of a technology. The idea of a collective technological frame is similar to the concept of "paradigm" which represents the predominant consensus about the prevailing technological architecture. The collective technological frame is constructed through social interactions and evolves over time. With many players involved in a technological innovation process, it is most likely actors' technological frames will be varied and event contradictory. These variations introduce uncertainty and political influences since individuals are likely to act initially to influence technological frame to adopt for innovation construction (Benford and Snow 2000).

The choices that are made during an innovation process are influenced by actors' technological frames. Technology entrepreneurs produce technology based on a set of assumptions about the nature of the problem and appropriate solution but users may or may not use technology if its features do not align with their frames. Therefore, the technological frames that actors apply in addressing a set of problems is shaped by the choices they make and the responses of users, hence the frame influences outcomes. To avoid mismatch between technology frame of producers and that of users, it is in the interest of all parties, especially technology innovation producers to seek to understand the users' frame and develop an inclusive emergent frame. Through interactions between actors, it is possible to develop a collective frame upon which collective, coordinated action can be implemented. Therefore the relationship between actors' technological frame and the emergence of a collective frame is reciprocal dynamic and mutually evolving. Based on the argument around the cognitive influences on emergence of technological frame, it is clear that technological evolution is intimately related to technological frames.

2.4 Types of Innovation

Innovation has attracted different labels by different scholars such as incremental, radical or discontinuous among others. From the literature, it is often unclear how to distinguish between these different types of innovation and whether these labels improve or cloud our understanding of innovation. Garcia and Calantone (2002) identified fifteen (15) constructs and at least fifty one (51) scale items in 21 empirical studies of New Product Development (NPD) looking at innovativeness. They argued that the lack of consistency in constructs used in the study of innovation has led to confusion as to what is being investigated and what research results tell us. Garcia and Calantone (2002) submit that, it is only when we understand the difference between radical, really new and incremental innovation that we can advance our knowledge of innovation and make research results useful for managers and practitioners.

Increasingly, categorization of innovation in the literature has fallen into two typologies: incremental and radical innovation, although Garcia and Calantone (2002) would have preferred a third category, which they labelled ‘really new’ innovation. These are innovations that are not new to the market in terms of technology platform but are new product lines. These innovations will create market or technology discontinuity on a macro and micro scales but not both. They are different from incremental innovations in that they cause marketing or technology discontinuity at the macro and at the same time result in micro level discontinuity too.

Without question, all innovations are not the same, therefore researchers classify innovation into typologies based on characteristic features or innovativeness or the degree to which the innovation is new. How innovations are labelled is important to our understanding of and knowledge about innovation. Consistency of constructs and measurements will also allow for ease of analysis and transfer of lessons across levels and contexts.

Abernathy and Clark (1985), by mapping technology competence against market environment, categorise innovation into niche, architectural, regular and revolutionary while Rothwell and Gardiner (1988) portray technological discontinuity in terms of improvements of existing innovation. Introducing new categories, Kleinschmidt and Cooper (1991) created low, medium and high innovativeness as classes of innovation. On the other hand Utterback (1996) describes discontinuous or radical innovation is terms of replacing old technology with the new and changing market conditions.

Garcia and Calantone (2002) analysis of new product development literature also reveals inconsistency in the way constructs have been operationalised to measure innovativeness. These inconsistencies show up along dimensions of modelling micro or macro perspective, marketing and technological discontinuities, single or multifactorial construct and innovativeness as categorical or continuous variable. Garcia and Calantone (2002) argue that one of the reasons for the proliferation of innovation labels is because researchers feel their work is new thereby creating new labels, which on examination is just a renaming of existing labels. Although these labels create confusion, the different categorisations of innovation have a common theme: "innovativeness is a measure of discontinuity in the status quo in marketing factors and/or technology factors" (Garcia and Calantone 2002 p. 118).

Categorising innovation as incremental, really new or radical makes for simple typology and analysis but also raises important questions about the nature of innovation. What makes innovation incremental or radical? With what criteria are we to judge what is incremental or radical? How important is this demarcation for consumers? Is the innovation process for incremental innovation different from radical innovation? It may be argued that the segregated view of innovation reflects evolving understanding of how uncertainty and risks affect human decision making and judgement about the future rather than a reflection of some innate properties of innovation.

2.4.1 Incremental and Radical Innovation

Having been critical of the segregated view and categorization of innovation, this study concedes that looking at two classes of innovation – incremental and radical – is helpful to see what may be similar and different about the way innovation emerges. Radical innovation produces new products and services that are new to the firm, market and consumers reshaping existing practices, creating new know-how based on new understanding of how to do things. On the other hand, incremental innovation introduces products and services based on tinkering with existing knowledge and know-how without fundamentally altering how users carry out existing practices and tasks. One could argue that incremental innovation is based on existing understanding of the world, proven practices and users' framework of knowledge and understanding. In contrast, radical innovation may offer a break with the past, a new framework of working and understanding. Therefore, this categorisation is useful to see how much of the past and investment in existing practices influence users attitude to innovation.

Tushman and Anderson (1986) describe the interplay between radical and incremental innovation, portraying the path of technological change as one of incremental, cumulative process with occasional interruptions of major breakthroughs. How people react to innovation is influenced in part by how innovation reshapes or reinforces existing practices and therefore influence attitude to innovation.

Radical innovations embody new technology and cause marketing and technological discontinuities on micro (individual or company) and macro (industry) levels. Because it seeks to upend existing users' preferences and practices, radical innovation creates demand for something previously unrecognised by the users. Therefore radical innovation creates new markets. On the other hand, the effects of incremental innovation are felt at the micro level where it causes either marketing or technological discontinuity but not both (Garcia and Calantone 2002). Incremental innovations provide new features based on refinement of existing technological architecture.

Product and technological innovation can be incremental or radical but Orihata and Watanabe (2000) argue that concept innovation is a prerequisite for technological innovation from which product innovation can subsequently develop. This suggests that concept innovation is foundational to and acts as trigger for technological and market innovation. More importantly, there are important antecedents that form the fabric of contextual background in which innovation, incremental or radical, can be developed with different degree of emphasis. Product innovation that seeks to exploit first-mover advantage requires existence of a collection of new essential technologies, core components and concepts upon which product innovation rests (Orihata and Watanabe 2000). This form of product innovation is predicated on clearly identified and understood concepts – a collection of ideas integrated into a coherent framework – that shapes innovation and new product development. Innovation developed this way will be incremental because producers and users are familiar with essential components of innovation, its architecture and how it works. This type of innovation development leaves little room for importation or diffusion of ideas outside existing and commonly accepted body of knowledge in a field to solve existing problems. The antecedents and support structure for this type of innovation clearly show that contextual factors are critical drivers to the emergence and nurturing of innovation.

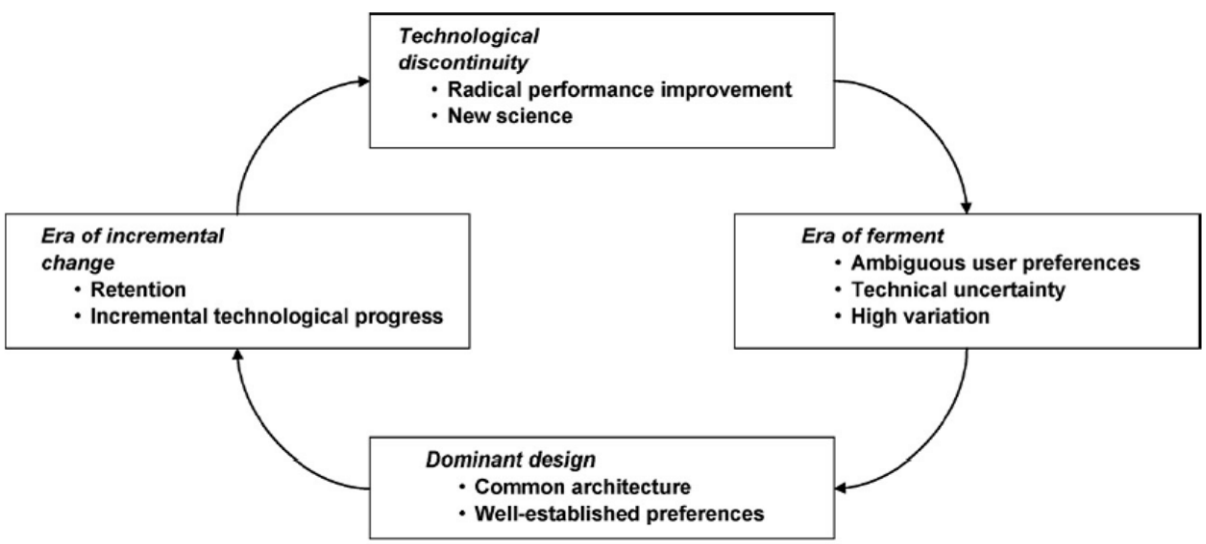

Figure 2-3: The technology life cycle (adapted from Kaplan and Tripsas 2008)

In the economics literature, technological breakthroughs are assumed to result from the influences of exogenous events (Dosi 1982). Although Fleming (2002) posits that breakthroughs emerge from creative combinations of knowledge, the path dependence of technological innovation between incremental and radical innovation is under-theorised in the literature.

Incremental innovation as described in the literature borrows from and relies on existing knowledge structures and practices, radical innovation is more akin to Schumpeter's idea of 'creative destruction' in which innovation breaks the practice link between the past and present. Innovation change existing way of doing things or shifts the paradigm from old to new concepts about how to define and solve immediate technological problems (Kuhn 1962). Dosi (1988) extended this argument in arguing that changes in the competitive environment renders competitive advantage of industry leaders less potent forcing them to produce radical innovation to regain or extend their advantages under new, prevailing circumstances. On the other hand, there is abundant evidence to suggest that in a relatively stable market environment, incremental innovation is rewarding and effective (Banbury and Mitchell 1995) demonstrating the spatial-temporal dimensions of innovation.

Kaplan and Tripsas (2008) identify four stages of technology life cycle: an era of ferment (variation), a dominant design (selection), an era of incremental change (retention) and a technological discontinuity as shown in Figure 2-3. The era of ferment is characterised by market turbulence and uncertainty where users are unclear about preferences and do not know the relative value that should be ascribed to different characteristics of innovation. In time, rivalry between competing technologies is resolved resulting in decreased technical and market uncertainty leading to the selection of a dominant design. Once there is a dominant design, a period of incremental change follows improving performance guided by a set of stable users' preferences. Eventually, technological discontinuity disrupts prevailing technological market stability resulting in a new era of ferment.

The literature suggests that dominant (selected) design is difficult to displace during the period of incremental innovation. Economists argue that strong network effect (demand side economics of scale) and user learning combine to create inertia stopping a shift to new technology and making producers to tinker at the edges of stable technology architecture (Henderson and Clark 1990). This behaviour, known as path-dependent learning (Levitt and March 1988), becomes prevalent in an era of what Dosi (1982) refers to as an era of normal problem solving based on a technological paradigm.

In the final stage, discontinuous technology is introduced into the industry creating a ripple effect, destroying establish patterns of decision making and acting as a seed for constructing an alternative technological frame. Economists argue that cost advantage and network effect (coordination of actors) can explain if a new technology can succeed in displacing existing and established technology. The new, discontinuous technology is introduced by outsiders with different capabilities, resources and experience (Tushman and Anderson 1986). This is similar to the often criticised technology-push model of innovation because this explanation does not improve our understanding of how agents outside of a particular industry can have the understanding of what technological frames is needed to address new and emerging needs. Alternative explanations for the emergence of discontinuous technology advance the argument that disruption occurs when old technology reaches its natural limits (Fleming 2001) forcing industry participants to seek new solutions.

The assumptions in the explanation about discontinuous technologies is that superior performance leads to users' acceptance without showing how users can effectively judge and compare technological frames. Henderson (1995) argues that people's assessment of technology's performance limits is more cognitive than technical. This claim is further strengthened by Utterback (1996) who showed that commonly accepted limits of technology have been exceeded by incumbent firms in responding to threats from new technology. Tripsas (2008) submits that radical shift in user preferences explains the timing of transition from old to new technology. Experience of technology-in-use differs from theoretical explanations provided by some of these theories. Kaplan and Tripsas (2008) cognitive model show that organizational inertia and technological limits are the results of the relationships between collective technological frame, institutional innovation processes and the interpretations of technology producers and end users. The combination and interactions of these elements in turn moderate the process and timing of technological change.

2.4.2 Technology-Push and Market-Pull Models of Innovation

In the earlier section discussing different models of innovation management process (Rothwell 1994), the first two models innovation process are criticized for being overly simplistic. However, later generations of innovation model are more suitable to large companies. The focus of this research is to investigate the process of innovation construction by SMEs in the UK oil and gas industry. These models of innovation process focus on how innovation is managed by big corporations and therefore neglect important behaviours at the micro level where SMEs operate.

Technology-push is a linear model of innovation which assumes that a creative individual with the necessary imaginations, knowledge and skills can recognise the potential of an idea, mentally constructs a path through which the idea can be transformed into a technical innovation product, and proceed to act on his belief to create a new product or technology. On the other hand, market-pull innovation emerges out of identified need of users in the market place or a reliance on the development of good understanding of market needs upon which technology development is predicated (Cantisani 2006). Presentations of technology-push and market-pull innovation in the literature appear to suggest that the fundamental difference between technology-push and demand-pull innovation is the source of the idea underpinning the innovation. Closer examination of these presentations of innovation process models reveal that either of these representations of innovation is incomplete and do not allow the observer to see the complete ecology of innovation for what it is and how its context shapes process and outcome.

Rogers (2003) argues that relative advantage, compatibility, complexity, trialbility and observability are critical factors in explaining why individuals accept or reject innovation. This view mirrors that of Cooper (1999) who submits that technology advances, intensified customer needs, shorter product life cycle and increased competition drive innovation. These drivers of innovation identified in the literature will appear to suggest, albeit obliquely, that users and developers of innovation see innovation the same way. However, if there is such a consensus between users and developers of innovation, it should be easy to introduce and develop innovative products, goods and services. Experience shows that on the contrary innovation is difficult to develop, the process is fraught with risks and the outcome often uncertain (Ortt and Smits 2006; Pavitt 2005). Reported difficulties associated with the development and introduction of innovation is a demonstration, if any is needed, that users and producers of innovation do not necessarily see things the same way at all times. Users and developers of innovation can only see innovation the same way if they share a common understanding on what constitute the problem to be solved, possible solutions, and what expectations they have of innovation to meet desired needs. In other words, one could argue that collective users-developer sense-making is a necessary precondition for creation of technological innovation.

Although Schumpeter (1934) points to 'creative destruction' as the driver for innovation, there is also credible evidence in the literature that market demand sometimes drives the rate and direction of innovation. Schmookler (1962, 1966) and Coombs, Saviotti and Walsh (1987), show that there is a relationship between patent applications and innovation to support demand-led innovation explanation. Dosi (1982) contends that demand-pull is more suited to incremental innovation while radical or disruptive innovations are better driven by technology-push. Adherents of demand-pull argue that demand steers resource allocation decisions, reduce uncertainty associated with innovation, adjust relative risk profiles of available choices and help technology developers in estimating relative payoffs associated with different innovation options (Nemet 2009).

Nemet (2009), based on his research on the trajectory of wind power technology in California in the 1980s, challenges the stance by adherents of technology-push and market-pull models showing that there is no positive correlation between demand-pull policies of the government and patents filled to develop wind power technology. In a different but related study, Garud and Karnøe (2003) compare the development of wind power technology between the US and Denmark and discovered that market-led but inferior technology in Denmark was successful and over time recorded higher market penetration and greater acceptance than in the US where superior technology was developed. The development of wind power technology in Denmark co-opted different stakeholders including end users in the technology development process providing proof that technology-push and market-pull are suited to different contextual environments and must therefore be seen within the context of socio-environmental interactions including market conditions.

Garud and Karnøe (2003) and Nemet (2009) show that the source of an idea for developing a technology does not prefigure the development path for the technology. Technology-push innovation is more likely to require massive investment in R&D to achieve 'breakthrough' innovation while market-pull innovation is likely to be incremental innovation, maximising benefits that accrue from using existing technology and gaining from users' familiarity with architecture of innovation. Market-pull innovation is likely to use existing product as reference for improvements (Herstatt and Lettl 2004) thereby allowing technology developers to work within existing framework of knowledge, know-how and practices that users are familiar and comfortable with to meet customer needs. On the other hand, the technology-push model implies implicit relegation, denial even, of the role social interactions, user feedbacks and access to tacit knowledge of end-users (von Hippel 1988) to help shape innovation and reduce uncertainty.

It can be argued that the technology-push model of innovation construction undervalues the importance of social networks network relations, embeddedness of entrepreneur, advantages conferred by social capital on the process of innovation. How can it be argued that it is possible for an individual to develop technology without social and environmental influences to meet perceived customer need? To accept such an interpretation and the premise of technology-push will run counter to an impressive body of evidence from prior research showing that social relations interject in the way people see the world, interpret, set priorities, choose between alternatives and relate to their environment.

In the preceding paragraphs, we have seen that innovation is more likely to be influenced by experiences of different stakeholders and their needs. Whatever the model that best describes technical innovation, it is clear from the discussion to date that is socially mediated. Given the influence of the antecedents and contextual factors, it is important to explore where ideas for innovation come from. In the next section, sources of ideas that can develop into innovation are explored.

2.5 Sources of Ideas for Innovation

There is an extensive body of evidence showing that lead users can be good collaborators and sources of ideas in the development of successful innovation (Bo Jeppersen and Laursen 2009; Mowery and Rosenberg 1979; Shah 2000; von Hippel 1986). Lead users are important collaborators because they are technologically aware, exposed to needs ahead of most users, have direct contact and experience of needs making them purveyors of critical market information that would otherwise be unavailable to technology developers (von Hippel 1988).

Although users are good sources of information for innovation, the pace and direction of innovation will be severely impacted if they are the only source of ideas and possible solutions for innovation. What happens where users cannot define the problem let alone suggest possible solutions? How are we to confront situations where the users – lead or follower – cannot envision a future where technologies with new attributes may be useful or even critical to instrumental action? Sanchez-Gonzales, Gonzalez-Alvarez and Nieto (2009), citing the work of Knight (1963), argue that technology-push can also be responsible for the rate and pace of innovation based on a study carried on the computer industry because limited user awareness of the technology and future possibilities can stunt the rate of innovation. This shows that contextual and market conditions are decisive factors whether technology push or market pull describes the mode of emergence leading Betz (2003) to argue that it is the ‘locus of sophisticated technical performance in the value chain that determines whether technology push or market pull act as main driver for innovation' (p. 302).

Nemet (2009) argues that while technology-push ignores the effect of social interactions and conditions, market-pull also ignores, or at the very least, downplays the power and capability of technology to shape the path of innovation. Applied in their purest presentational and conceptual forms, technology-push would appear to be more risky and with greater technological uncertainty than market-pull innovation. However, the question must be asked, is it actually possible to apply these models in their purest forms? There is empirical evidence that technology-push can be successful where technology producer lead and shape trajectory of technology development as in the computer industry (Knight 1963) and cases of radical innovation amplifying creative destruction (Brem and Voigt 2009; Schmoch 2007) but contextual factors are always in the background shaping the development of process and outcome (Lubik et al. 2013). Our knowledge of innovation suggests that it is unlikely that a technology-push innovation can be developed in complete isolation without interaction with the market place where success or failure will ultimately be tested. The degree of interaction and feedback during the development of the innovation and preceding its emergence will vary depending on contextual factors like type of industry, complexity of need, user experience and expectations, likely response of competitors among other factors.

Herstatt and Lettl (2004) argue that innovation emerges through a hybrid of technology-push and market-pull models. Although innovation may start with individuals or groups, over time product development involves multiple social beings with different traces of social history making it difficult to claim that any innovation is entirely 'technology-push'. Rather than focus on the dichotomy between technology-push and market-pull, Herstatt and Lettl (2004) argue that what is required for the successful management of innovation is to understand the features of and problems associated with marketing technology-induced development. If marketing of technology to end-users is critical, then communication, social interaction and ability to persuade become essential component in the innovation development mix.

Technology developers or entrepreneurs bring into reality value-creating innovations based on prevailing technological paradigms, what customers know and are comfortable with facilitated through a cumulative process of trial and error elimination (Martin 1994). The success or failure of technology-push innovation is determined by this selection process of trial and error. But we cannot argue that successful technical innovation emerges from a stochastic process or a game of chance. However, based on the evidence, it can be argued that success comes from the right combination of judgment and resources to create synergy between technological, entrepreneurial, managerial and environmental factors. Martin (1994) therefore argues that technology success depends on a fit between innovation and market conditions. For such a fit to exist, it is imperative that there needs to be a mechanism for accessing sources of information from the user community, filtration of environmental cues and ideas so that technology developers can create innovation that 'fit' into the gap between user needs and existing market offerings.

2.6 Creating a Fit between Innovation and the Market

Without question, techno-entrepreneurs must ensure there is a fit between innovation and market needs and conditions to be successful. To achieve this, innovation developers have to create a new customer base and persuade existing users of other products to switch to new product or service. The challenge lies in how to make users see the same appeal in new product or service as the developers recognise. Technology entrepreneurs must develop the means to collect information about customer needs, anticipate future market directions and ensure users can be persuaded to share the same frame of meaning that underpins innovation construction. In developing a technology-push innovation, entrepreneurs are confronted with a situation where users may not be able to articulate their preferences, adequately explain abstract technology preferences or lack the cognitive skills to make required mental leap to see the benefit of technology-push innovation (Weiss 2012).

Even when it is possible to access information from end users, technology developers may need to filter available information because end users interpretation is not infallible. Lynn, Morone and Paulson (1996) show that users can be wrong in their evaluation about technology capability or direction of technological progress with the implication that customer opinions is not always a reliable indication of success or future direction of innovation. Often information required to describe or capture the essence of needs and requirements maybe too sticky (Sanchez-Gonzales, Gonzalez-Alvarez and Nieto 2009; von Hippel 1994) and cannot be easily obtained without deep interactions and engagement with the users or user community. Apart from the practical difficulties of accessing tacit or sticky information that may be critical to understanding the problem and how it should be solved, products of innovation often mandate changes in procedures, take people out of their comfort zone and force people to do things differently, which may require re-training and re-education. These changes may induce resistance from end-users making it more difficult for them to accept technology-push innovation they are not familiar with.

Recognising the importance of accessing information and feedback from the user community, Lynn, Morone and Paulson (1996) advocate a “probe and learn” approach as the best way to pursue a technology-push model of innovation construction in which technology developers bring potential customers into the technology development process as the innovation moves through different stages of maturity. This approach offers technology developers the opportunity to learn from users, access tacit knowledge and tap into users’ experiences so that different stages of prototypes can be developed reflecting increasing degree of market knowledge and customers’ input. The “probe and learn” approach reduces market and technological uncertainty through the recognition and integration of customers’ input in the design and development process, implicitly recognising the limitation of pursuing a purely technology-push approach while supplanting it with a flexible approach based on iterative learning, information exchange between critical social actors. In this way, end users are co-opted into the technical innovation construction process as ‘critics’ and ‘co-constructors’ of innovation. It is an approach that allows innovators lead the innovation process while incorporating essential elements of market-led innovation into a product or service development process.

Probing and learning cannot magically resolve all the challenges associated with technology-push innovation but it makes it more likely that a technology-push innovation can succeed and gain market and user acceptance. The probe and learn approach suggested by Lynn, Morone and Paulson (1996) appear to mitigate some of the risks associated with a purely technology-push innovation pursuit. However for this approach to be effective, technology developers or entrepreneurs must develop an effective means of creating conditions for information exchange that will allow them to probe, access sticky information, receive feedback, learn, implement and confirm with potential customers if their inputs have been correctly interpreted and implemented in the innovation. Probing and learning can also have negative effects when there is negative customer feedback. Technology developers must develop ways of dealing with and segregating negative feedback that is due to lack of experience, inability to mentally imagine a future where technology might be needed and know-how with new technology (Lynn, Morone and Paulson 1996) from negative feedback based on product or service design flaws or inadequacy of technology. Innovators have to ensure that promising technology is not abandoned too early in the development phase because customers cannot make sense of the fit or capabilities based upon their limited or unrelated prior experiences.

2.7 Limitations of Innovation Typology

In the previous sections, different generation and evolution of innovation processes as presented in the literature have been explored. The newer generations of innovation management process presented by Rothwell (1994) have been shown to be more suited to describing what big corporations do while the earlier simplified model may be more representative of what small businesses with limited resources do without elaborate R&D capability. Although technology-push and market-pull may be better representations of innovation process at smaller scale, these models present a linear view of innovation construction that is flawed and does not fully account for the social forces that shape innovation emergence. Stakeholders in the innovation construction process carry with them traces of experiences and history that they bring to the forum for innovation construction.

It is clear from discussions in the previous section that entrepreneurs do not create innovation alone. Ideas of what problem to solve and possible solutions are influenced by our experiences, social interactions, network and information access, and even our mental representation of prior experiences. What appears as entrepreneurial opportunity is filtered through our experiences of the past gained from interacting with others. The burden of the past and the presence of the 'social others' in our interpretation of available information and extracted cues from the environment ensures that what emerges as potential innovative ideas cannot be attributed to the genius of an individual. The social character of innovation makes simple categorisation of innovation such as technology-push or market-pull an oversimplification of a complex, recursive and socially interactive process.

If innovation is a social process that relies heavily on social interaction, then one cannot begin to study the innovation process without an examination of the character and roles of the stakeholders who must act in concert to produce new products or services. Innovation often starts with an idea to solve an identified problem or improve performance or move from an undesirable situation to a desired state. In other words, innovation is created to solve problems either in terms of product performance or service quality. Most problems that innovation is intended to solve are often complex, fuzzy and laden with technical and behavioral uncertainties. Therefore, individual social actors have to work to develop shared understanding and meaning to define the problem and generate tentative solution from which innovation can finally emerge. The entrepreneurs is central to this process of meaning-making to translate distributed and tacit knowledge into some order to which establish routines can be applied to generate new solutions. Entrepreneurship is a means of manifesting innovation, translating intangible ideas into products and services. Therefore, in studying the process of innovation in the oil and gas industry by SMEs, the entrepreneur has to be a central character in the investigation.

After a careful review of existing categorisation of innovation, no matter what criteria is used for classification, no typology can accurately capture the vastness and complexity of the different dimensions and features of innovation. This difficulty stems from the nature and process of innovation construction. Consequently, the study of and researching into innovation should reflect this complexity. The rest of this chapter and others that follow will reflect this understanding and stance.

2.8 Linking Innovation and Entrepreneurship

In the previous section, innovation is presented as a process and not a single event (von Hippel 1994; Tidd, Bessant and Pavitt 2005) that needs to be managed. Some argue that innovation should be seen as a process and entrepreneurship its outcome, which implies that the end of innovation is the starting point of entrepreneurship (Brazeal and Herbert 1999). Treating innovation and entrepreneurship as two separate but related processes ignores the role of entrepreneur in the filtering of cues, development of ideas and articulation and matching of possible solutions to existing needs. It is not possible to draw such a neat boundary between innovation and entrepreneurship (Voigt and Brem 2008). The question of which comes first – innovation or entrepreneurship – ignores that these social processes are situated, socially embedded, concurrently and mutually implicated in the context of creating new combinations.

Although Drucker (1985) argues that innovation is the core instrument of entrepreneurship through which wealth creation is promoted, there is an obvious relationship between entrepreneurship and innovation that is not well explicated in the literature (Brem 2011; McFadzean et al. 2005). Through the process of creative destruction, entrepreneurs act as agents of change (Schumpeter 1934), creating new standards, products and services through the introduction of new products and services into the market place.

The importance of innovation to growth and business survival and companies (Dosi et al. 1997) and countries is well documented (Hamel 2000) and entrepreneurship is the medium through which the transformation that generates innovation is created (Butler 2004; Drucker 1985; Schumpeter 1934; Zhao 2005). Like innovation, entrepreneurship has been a subject of intense interest in academic research and from policy makers because of its perceived importance. Despite these interests, there is no universally acceptable definition of entrepreneurship. In the next section, an exploration of the different definitions of entrepreneurship is presented, drawing out the implication for different disciplinary approach to entrepreneurship research.

2.8.1 Entrepreneurship and the Entrepreneur – The Challenge of Definition

The question of who qualifies as an entrepreneur has exercised the minds of researchers to this day leading Gartner (1998) to ask 'who is an entrepreneur?' Later, Chell (2001) submits that Gartner's question remains a legitimate question indicating the absence of a satisfactory answer. Entrepreneurship is an elastic concept that has been used to describe myriads of social action in different contexts (Anderson and Starnawska 2008). Steyaert and Hjorth (2003) argue that focus, definitions, scope and paradigms informing entrepreneurship research suggest that different perspectives on entrepreneurship should be a starting point for scholars.

Definitions are important because they provide clarity of thinking and analysis and prevent the accusation of 'imprecision and looseness of thought' (Anderson and Starnawska 2008 p. 224). In studying entrepreneurship, it is important to first identify who qualifies as entrepreneurs and then engage with the question of what entrepreneurs do and why. At a fundamental level, entrepreneurs explore opportunities, develop innovations, create new ventures in recognition of and under the influence of socio-economic factors using and rearranging available resources to create new or improve existing products. Schumpeter (1942) argues that who is an entrepreneur is limited by what people do submitting that one is an entrepreneur "…. only when he actually 'carried out new combinations', and loses that character as soon as he has built up his business, when he settles down to running it as other people run their business" (p.78). This definition is time and process bound showing that the 'entrepreneur' label changes through the life of new venture but it is overly restrictive.

In Table 2-2, a selection of definitions of entrepreneurship is presented from the literature. From the definitions, entrepreneurship is a process that happens along temporal and spatial boundaries. A careful look through these definitions highlight important concepts such as creation of new combinations, recognition and perception of opportunities, novelty, new venture creation and value creation among others. These definitions span a range of contexts including new ventures, actions within existing organizations, introduction of new products in existing markets and creation of entirely new markets. These definitions also emphasize different aspects of the process of entrepreneurship ranging from process to outcome; some acknowledge antecedents while others are silent on what comes before entrepreneurship. Whatever interpretation one imposes on these definitions, the entrepreneur and entrepreneurship are bound with the process of developing, exploring and exploiting opportunities through a spatial-temporal engagement with contextual factors.

Entrepreneurship is an elastic concept that is probably too broad to be enshrined in a universally accepted definition. In a way, lack of agreement on definition can contribute to a richer understanding of the phenomenon. Gartner, Bird and Starr (1992) encourage scholars in the field of organizational studies to 'borrow boldly' from other disciplines to develop stronger theoretical foundations and richer explanation of social phenomenon. This is advice is apt for studies in entrepreneurship given its complex character and factors that influence it.

Whatever definition of entrepreneurship we adopt for convenience and suitability to context specific investigations, what is important is to show that it is a process through which social actors bring something into existence while acting in concert with others. It is therefore simultaneously transactional and transformational. In our state of *Being* we use our mental state to grasp what is real about the environment while retaining the capacity and freedom to imagine what is potentially possible. Through entrepreneurship, individuals deploy their mental understandings of what is possible to extract meaning from the environment, rearranging and forming new combinations. Through the process of entrepreneurship, social actors choose personal meanings to suit situations, interpret experiences in light of new understandings and bring forth that which has been previously imagined through engagement with the social world and interactions with others. Understood this way, entrepreneurship can be construed as a process through which individuals transform mental frames of what is available into a coherent set of meanings and create a universe of what is possible through social interactions. In other words, entrepreneurship is orientated towards the future but firmly anchored in the present and indebted to the traces of memory from the past. In fact it is only in hindsight we can see who is an entrepreneur.

Author	Definition
Schumpeter (1934)	Entrepreneurship is defined as new combinations including the doing of new things or the doing of things already being done in a new way. New combinations include (i) introduction of new good, (ii) new method of production, (iii) opening of a new market, (iv) new source of supply, (v) new organizations
Kirzner (1973)	Entrepreneurship is the ability to perceive new opportunities. This recognition and seizing of opportunities will tend to "correct" the market and bring it back towards equilibrium (*entrepreneurial action has a corrective influence in restoring market equilibrium*)
Drucker (1985)	Entrepreneurship is the act of innovation that involves endowing existing resources with new wealth-producing capacity
Stevenson, Roberts and Grousebeck (1985)	Entrepreneurship is the pursuit of an opportunity without concern for current resources of capabilities
Rumelt (1987)	Entrepreneurship is the creation of new business, new business meaning that they do not exactly duplicate existing business but have some element of novelty
Low and MacMillan (1998)	Entrepreneurship is the creation of new enterprise
Gartner (1988)	Entrepreneurship is the creation of organizations, the process by which new organizations come into existence
Bygrave (1997)	An entrepreneur is someone who perceives an opportunity and creates an organisation to pursue it.
Venkataraman (1997)	Entrepreneurship research seeks to understand how opportunities to bring into existence future goods and services are discovered, created, and exploited, by

Author	Definition
	whom and with what consequence
Morris (1998)	Entrepreneurship is the process through which individuals and teams create value by bringing together unique packages of resource inputs to exploit opportunities in the environment. It can occur in any organizational context and results in a variety of possible outcomes, including new ventures, products, sevices, processes, markets and technologies
Sharman and Chrisman (1999)	Entrepreneurship encompasses acts of organizational creation, renewal, or innovation that can occur within or outside an existing organization
Bygrave (2004)	Entrepreneurship process as "all the functions, activities, and actions associated with perceiving opportunities and creating organizations to pursue them
Hindle (2010)	Process of evaluating, committing to and achieving, under contextual constraints, the creation of new value from new knowledge for the benefit of defined stakeholders.

Table 2-2: Selected definitions of entrepreneurship and entrepreneurship process

The range of qualities and attributes implied in the definitions listed in Table 2-1 shows that defining who is an entrepreneur is a complex and multi-layered question. Rather than be lost in the debate of who is an entrepreneur, it is more productive to realise that the variations in the definition point to the wide variety of contexts where social actors can assume the role of entrepreneurs or where entrepreneurship manifest. These definitions show that no single entrepreneur, no matter how resourceful and connected, has complete control over available or required resources to successfully create and sustain innovation. Implied in the definitions, is the social character and distributive nature of what it means to be an entrepreneur. Important as it is to have a working definition of who is an entrepreneur and what is entrepreneurship for clarity and guide discourse, it is more intellectually and economically rewarding to study what entrepreneurs do.

What entrepreneurs do and how it is studied is influenced by the ontological assumptions of the researcher and the tools chosen for the investigation. The different academic disciplines with different paradigmatic views treat entrepreneurship differently. In the next section, these different perspectives of innovation and entrepreneurship will be discussed and their implication for this research further explored.

2.9 Entrepreneurship in the Economic Literature

2.9.1 Neoclassical Economic Theory of Entrepreneurship

We have already established that definition and boundaries of what constitute entrepreneurship vary across multiple scholarly disciplines. The same is true of the field of economics. In this section we trace the origin of economic thought on entrepreneurship and explore the role entrepreneurship has played in economic thinking.

There are different schools of thoughts with the field of economics on entrepreneurship including classical and neoclassical economics, Keynesian economics and Schumpeterian economics. Each of these views of economics provides a coherent framework and consistent way of thinking about economics, economic activities within which entrepreneurship is a subset. Since entrepreneurship and innovation are major drivers of economic change and progress, it is no wonder that these schools of thought also influence the way economists look at and analyse innovation and entrepreneurship. Some like Francois and Lloyd-Ellis (2003) examine relationship between economic growth and entrepreneurship. As a demonstration of the paradigmatic influences on how economists see entrepreneurship, Hébert and Link (1989) identified twelve different themes describing the entrepreneur in the economic literature.

These different economic schools of thoughts are fundamentally different in the way they see innovation and entrepreneurship. These differences stems from what subscribers to these frameworks see as being important in the economy and the mechanisms that drives these important economic activities. The emergence of the three economic doctrines has been moulded by different social, economic, political, cultural and historical contexts. Most of the interest of economists in entrepreneurship relates to understanding how it contributes to economic growth on a macro level (Loasby 1982; Romer 1990) but not in the social forces that shape entrepreneurship. It is against this historical bias that we can fully understand why innovation and entrepreneurship is treated as an input-output process with a black box in between to this day.

Classical economic theory is based on the assumption that the economy behaves in accordance with deterministic laws where the future can be predicted based on the analysis of the past. Classical economics draw heavily on the work of Adam Smith and David Ricardo that gives primacy in economic thinking and analysis to market forces. While the entrepreneur has always existed in the shadow of classical economic thinking, for so long very little theoretical attention is devoted to his role (Baumol 1968; Hébert and Link 1989). Classical and neoclassical economists are primarily concerned with how to achieve the most efficient allocation of resources given the distribution of wealth and income in a society. For neoclassical economists, price mechanisms and markets provide the best means of resource allocation to produce goods and services to meet consumer demand. Within this framework, market participants are rational and all decisions made by firms and individuals is regulated or at least influenced by market-determined price signals. Since all market participants are deemed to be rational, information in the market place is assumed to be perfect and market-determined price information is available to everyone. If all participants in the market are rational and all available information is contained in market-determined prices, then it is easy to see why market participants will see price information as signalling cues for decision making and action.

In the second half of the twentieth century, Solow (1956) extended the reach of neoclassical economics by acknowledging the role and importance of technological change in economic development. In Solow's work, the key to economic expansion lies in increasing investments in physical capital – plant and equipment - but the contribution of technological change was not accounted for in his growth model. He treated contributions of technological change as a residual that cannot be explained by the model. To Solow, innovation is important but exogenous to the growth model and cannot be explained by neoclassical growth model. Fonseca (2002) submits that innovation is caused by an exogenous, independent variable that rational managers can control to a degree but cannot influence its pace of change. The mechanism of innovation is deemed to beyond the understanding of neoclassical economic theory.

Economics as a social science helps us understand how individuals make decisions, how and why actors initiate economics actions and with what consequences. Entrepreneurship fosters innovation, drives knowledge diversity, encourage investment in human capital development (Audretsch and Keilbaach 2004; Acs et al. 2004)) and aid wealth creation. Given what entrepreneurship is and what entrepreneurs do, recent thinking in economics have focused on attributes, functions and uses of capital thereby expanding the boundary of investigation and developing new insights about the emergence of the firm (Minniti and Lévesque 2008) including the study of entrepreneurship.

Economists substitute rationality for public interest arguing that the invisible hand of the market is ever present to correct market deficiencies and distortions, create competitions, and drive markets towards equilibrium. In line with this view, as market respond to market forces producers and consumers change their behaviours putting downward pressure on prices of goods and services to which supply and demand must respond to meet aggregate market demand. These neoclassical assumptions desensitize analysis from contextual variations and institutional differences across time and space. Atkinson and Audretsch (2010) summarise this attention deficit in neoclassical economic thinking as follows:

> "*It is for this reason that neoclassical economics largely overlooks factors such as economic history, culture, norms, and institutions, preferring instead to dwell in the more universal world of prices, costs, and mathematical models. It is also for this reason that most neoclassical economists reject the notion of a new economy emerging in the last decade, because for them, the economy is still based on price signals and supply and demand (p.10)*".

Entrepreneurs dream about the future based on their understandings of the present. These dreams and aspirations are the ingredients of entrepreneurial visions and ideas that are subsequently developed through interactions with others to create value. Fundamentally, until a product, service or technology is available in the market place, there is no market-determined price and therefore cannot be accommodated within neoclassical economic analysis. The assumption of perfect information and market-driven prices as signals that are freely available to everyone leaves out important ingredients of innovation taking no account of the uncertainty and recursive activities and practices that underpins much of entrepreneurship and innovation activities (Chorev and Anderson 2006).

2.9.2 Evolutionary Economists and Study of innovation and Entrepreneurship

Scholarly works in entrepreneurship embracing the neoclassical economics equilibrium model (Shane 2000), predicated on perfect information and foresight, have failed to explain entrepreneurship. It is to this challenge that Austrian economics have risen with alternative paradigm based on limited market participants' knowledge, context sensitivity, action-process-institutional interactions (Chiles, Bluedorn and Gupta 2007). Austrian economics contribution to the economics approach to entrepreneurship and organisational studies is profound and far reaching (Ventakaraman 1997; Shane 2000) because entrepreneurship is now seen and studies as a disequilibrium phenomenon.

Schumpeter explains the process of economic development as a dynamic process that cannot be explained by the stability-seeking structure of the theory of equilibrium. Innovation in the Schumpeterian sense centres around making new combinations of which he identified five types of innovation:

i. The introduction of a new good – that is one with which consumers are not familiar yet – or a new quality of a good
ii. The introduction of a new method of production, that is one not yet tested by experience in the branch of manufacture concern, which need, by no means, to be founded upon a discovery scientifically new, and can also exist in a new way of handling a commodity commercially.
iii. The opening of a new market that is a market into which the country in question has not previously entered, whether or not, this market existed before.
iv. The conquest of new source of supply of raw materials or half-manufactured goods, again irrespective of whether this source already exists or whether it has first to be created.
v. The carrying out of the new organisation of any industry, like the creation of a monopoly (for example through trustification) or the breaking up of a monopoly position.

(Schumpeter 1942 p.66)

Schumpeter theory of ‘creative destruction’ and Kirzner’s theory of ‘entrepreneurial discovery’ are dominant in the field of entrepreneurship. In Schumpeter’s view, through innovation entrepreneurs disturb existing market equilibrium (Schumpeter 1934), creating perturbations that ripples through the market rearranging or reorienting actors preferences in the process. On the other hand, Kirzner (1973) submits that the disruption wrought by innovation is time-limited and a state of equilibrium is ultimately restored through the actions and interventions of arbitraging entrepreneurs. The common thread in these two approaches is that the state of market equilibrium is a common reference point; Schumpeterian entrepreneurs move existing markets away from equilibrium and Krizner's entrepreneurs restore market equilibrium. One can argue that Schumpeter and Kirzner positions are complementary; Kirzner's entrepreneurs exist to complement and complete the action initiated by Schumpeterian entrepreneurs (Boehm et al. 2000; Cheah 1990). If we are to accept Schumpeter's analysis, the natural state of the economy is to be in equilibrium and entrepreneurs disrupt a state of equilibrium and create a new equilibrium in time.

Schumpeter is widely regarded as first modern economics scholar to contribute significantly to our understanding of process and theory of entrepreneurship. Schumpeter's entrepreneurs work against existing social order to introduce 'new combinations' – products, technologies and services – and in so doing disrupt market equilibrium, attack and destroy the foundation of existing order of comparative advantage. This act of bravery by entrepreneurs creates value and generates profit but also invites imitators, who over time erode the gain of the entrepreneur and create new equilibrium (Schumpeter 1934).

Although Schumpeter's concept of 'creative destruction' has increased our understanding of how innovation emerges, it endows entrepreneurs with heroic qualities who achieve transformational economic changes through their force of will. This analysis ignores the role of social interactions and contextual factors that may empower or impede entrepreneurial action. Although Schumpeter's analysis increases our understanding, it is lacking in explaining how innovation emerges. According to Witt (1992), a key question that Schumpeter's analysis cannot answer is, why should entrepreneurs suddenly intrude into equilibrium, a system in which all options have been considered and the best choices already made? Vaughn (1994) argues that criticisms and short comings of Schumpeter stem from his desire to pursue Austrian themes in his analysis while holding on to neoclassical assumptions. Schumpeter's analysis could not reconcile the static equilibrium assumptions borrowed from neoclassical economics, rooted in objectivism, with the dynamic framework of Austrian economics, predicated on subjectivism (Langlois 2003).

Kirzner (1973) argues that because economists focus on equilibrium rather than the process through which equilibrium is attained, neoclassical economists and their models ignore the entrepreneur – an arbitrager who uses his or her superior alertness to discover opportunities, correct inefficiencies created by disequilibrium, and through a process of proactive coordination moves market toward equilibrium. In Kirzner's view, entrepreneurs do not create opportunities but rather 'discovers' opportunities already in existence. It is the alertness of entrepreneurs that count not their ability to envision and bring into existence 'new combinations'. According to Kirzner's analysis, markets will always tend toward perfect coordination and equilibrium except when external forces intervene in the market process.

Fundamentally, Kirzner's analysis implies that there are finite numbers of opportunities in the market under a set of conditions. Since no one creates opportunites, entrepreneurs have to rely on exogeneous change to make market opportunities visible. Kirzner's concept of entrepeneurship has been challenged because it offers no endogenous explanation of entrepreneurial failure or disruptive change (Vaughn 1994). Kirzner's entrepreneurs can only discover and correct errors of other of overlooking profit opportunities but does not account for the possibility of errors in entrepreneurial perception. Kirzner's explanation also does not account for how entrepreneurs assemble resources (capital) to exploit opportunities (Foss and Klein 2005). By separating entrepreneurs from capital, focusing on past error of others and ignoring the temporal dimension of entrepreneurship, Kirzner fails to account for uncertainty in his explanation of entrepreneurship process. Moreover, some argue that opportunities are not only found but also created through enactment, social interactions and negotiations between social actors (Sarasvathy 2004a, 2004b; Steyaert and Katz 2004).

Most scholarly works aimed at understanding and explaining entrepreneurship from the viewpoint of economics have been largely based on one of these two giants – Schumpeter or Kirzner. Lachmann (1986) contributed to this debate by arguing for radical subjectivist approach based on a blend of ideas from Menger, Weber and Shackle while also moving away from the equilibrium-seeking premise that is foundational to Kirzner and to a lesser degree Schumpeter. Although Lachmann rejected equilibrium-seeking explanation that is fundamental to the Mises, Hayek and later Kirzner, he incorporated Mises notion of uncertainty and Hayek's concept of distributed knowledge.

The starting point of Lachmann's radical Austrian approach is that market is an economic process powered by entrepreneurial action and not just a space for exchange of goods and services. Chiles et al. (2007) introduced Lachmannian approach to entrepreneurship using Low and MacMillan (1988) key specification: purpose, theory, focus, levels, time and methods to provide a legitimate framework for addressing important theoretical questions about process of entrepreneurship and move away from the dominant neoclassical-oriented stance of entrepreneurship research. Chiles et al. (2007) argue that Lachmann provide new insights into entrepreneurial creation, a topic neglected by Schumpeter and Kirzner, and open up new possibilities on how we think about 'entrepreneurial exploitation as a continuous recombinative process (rather than an episodic one, as Schumpeter posited); and fills a gap in the literature regarding the causal connection between entrepreneurship and economic progress' (p. 473). Lachmann through his market process theory - how entrepreneurs use their creative imagination - and his capital theory - how entrepreneurs exploit opportunities through continuous combinations to produce goods and services- explain how entrepreneurial action at the individual and organisational level lead to economic progress.

Lachmann's approach extends subjectivism beyond individual's interpretation of the past to include expectation of the future by arguing that entrepreneurs form imaginative plans for the future based on their subjective knowledge and expectation of the past. In Lachmann's analysis, expectations are oriented towards an imagined but yet unformed future, a future that is unknown and knowable in the present. Because the future is unknown, entrepreneurs must imagine a range of possible futures to form a universal set from which choices are made. In this process, choice is not a simple, mechanical act but a creative act of imagination and belief. Creative imagination (Lachmann 1986) in this sense is different from Kirznerian discovery in which entrepreneurs uncovers opportunities already in existence and Schumpeterian innovation that denies the role of human subjectivity (Witt 1992), but predicated on a forward-thinking process of imagination and capacity to 'think outside the box'. The figurative 'box' in this context defines the limits of knowledge, practices and combinations rooted in the interpretation of the past (Chiles, Bluedorn and Gupta 2007). Some scholars have argued that scholarly research sometimes treat innovation as a 'black box' (Coriat and Weinstein 2002). Entrepreneurs in Lachmann's analysis have the capacity to transcend the limit of what is presently known through creative imagination and chart a path to a future yet unborn. This is in contrast to the concept of Kirzner's 'opportunity recognition', which assumes that opportunities are discovered but does not account for how they are created, that is pervasive in entrepreneurship literature.

Entrepreneurs create plans to guide action over time into the future but differences in expectations, knowledge and history will lead to different interpretations, create divergence of expectations leading different individuals to make different choices. Success or failure results from the intersections of plans with the market, therefore there is need for continuous revision of plans as new, endogenous, market-generated information based on entrepreneurs updated interpretation become available. This is consistent with Chiles et al (2007) who submit that the market process is the 'outward manifestation of an endless stream of information continuously converted into new knowledge and new expectations' (p. 475). How individual entrepreneurs interpret market information and organizes capital and other resources in the pursuit of the exploitation of invention or execution of plans is critical to success or failure. Lachmann recognises the central role of capital in the act of opportunity exploitation. Unlike Kirzner who argues that entrepreneurs do not need capital, Lachmann argues that:

> '*it is hard to see how entrepreneurs can exploit profit opportunities without having to invest their capital for at least a few years and thus running the risk of seeing the opportunity vanish before the capital is amortized*.' (Lachmann 1986, p. 66)

To use capital goods effectively in their plans, entrepreneurs' capital combinations must be preceded by understanding how different capital goods complement each other. Where expectations differ, entrepreneurs' plans that rely on capital controlled by others are unlikely to be successful. Any investment in such a plan may be wasted except entrepreneurs recombine capital from unsuccessful plans with other plans. Lachmann calls this *capital regrouping*. In line with this analysis market disequilibrium arises from different expectations. In a dynamic world, plans are constantly re-interpreted and clashes of interpretation will be the norm. Therefore, some plans will succeed where many plans will fail and evolve into new forms with associated capital continuously rearranged into *new combinations*. These combinations in Lachmann's analysis differ from Schumpeter's because Lachmann's combinations are based on imagined future driven by entrepreneurial imagination whereas Schumpeter assumes such knowledge is already available outside of the entrepreneur.

Lachmann's analysis provides a framework to explain Penrose (1995 [1959]) idea that imaginative entrepreneurs bundle and re-bundle resources as a new venture grows. Entrepreneurs are also known to exploit opportunities through resource combination (Garud and Nayyar 1994) and through other means such transfer of technology and knowledge resources. Lachmann's capital theory allows research to extend beyond the focus of a specific firm to a constellation of firms and other social actors whose resources have been co-opted into the process of innovation. At its core, Lachmann's Austrian approach (his market process and capital theories) rejects the idea of equilibrium as the end state or even the direction that economy tends but emphasises instead the continuous nature of entrepreneurship to create disequilibrium and maintain a continuous state of evolution. Unlike Schumpeter and Kirzner, Lachmann is not beholden to neoclassical economics nor is he wedded to equilibrium assumptions or equilibrium outcomes.

Lachmann's analysis is considered to be radical because he argues that most markets never really achieve equilibrium and may never move towards equilibrium state (Boehm et al., 2000). In this way, Lachmann's analysis is a radical breakaway from the neoclassical school of economics to which Kirzner's analysis is wedded. Lachmann's contribution does not in any way diminish the contributions of Schumpeter and Kirzner in showing that entrepreneurship is a disequilibrium process, rather what Lachmann does is to bring to the fore that entrepreneurship is continuous process that is always travelling in the direction of disequilibrium and not one of punctuated by periods of equilibrium as Schumpeterian analysis suggest or always tending towards equilibrium as Kirzner submits (Chiles, Bluedorn and Gupta 2007; Meyer, Gaba and Kenneth 2005).

By integrating knowledge gained from past experiences with future expectations through creative imagination, Lachmann set the stage for a market process theory in which entrepreneurs' divergent knowledge and expectations prevent plans from being coordinated. Although the market exists as a social space for exchange through which diffusion of innovation and knowledge coordination can occur, the market cannot facilitate diffusion and/or coordination of expectations (Lachmann 1986) because individuals can revise their plans based on temporal and spatial influence on their imaginative ability. More importantly, Lachmann's approach agrees with the belief that entrepreneurs use creative imagination and capital resources in the market process to create innovation. In this analysis, disequilibrium and change in market conditions it brings are treated seriously thereby providing a new way of researching and understanding entrepreneurship and entrepreneurial process. Chiles et al. (2007) argues that using Lachmann approach, it may be possible to start constructing an overarching theoretical framework for studying and understanding the dynamic process of entrepreneurship. This new theoretical framework will encompass disparate ideas including entrepreneur's capacity to imagine the future (McGrath 2010; McGrath and MacMillan 1995), continuous combination and recombination of resources (Lichtenstein and Brush 2001), engender perpetual disequilibrium (Stevenson and Harmeling 1990), and adaption to changing knowledge environment through thoughtful and deliberate deviation (Garud and Karnøe 2003).

2.10 Psychological Perspective of Entrepreneurship

The study of personality traits has been used to create a link between innate qualities and the likelihood of exhibiting entrepreneurial characteristics. In recent years, and with increasing body of evidence, reliance on personality traits has suffered what Chell (2000) referred to as a 'crisis of confidence' largely because this line of study has not succeeded in establishing clear causal link between personality and entrepreneurship.

To begin an examination of how the study of personality contributes to our understanding of entrepreneurship, it is important to understand what ‘personality’ is and how the trait construct helps us understand and explain personality types. The term, personality, describes the distinctive character of an individual - the type of person an individual is. A trait is unitary dimension of personality consisting of a number of components that can be generic or specific to an individual (Chell 2000). For psychologists, consistency in observable behaviour allows psychologists to identify personality types (Furnham 1992). Once traits relating to a personality type have been identified, then psychologist can predict certain behaviours.

The question then arises, is there such a thing as entrepreneurial personality and if it exists, what are the trait(s) that constitute this personality? Gartner (1998) argues that entrepreneurship is about doing and not about being, therefore researchers should focus on the dance (the act entrepreneurs engaged in) and not the dancer (the entrepreneur). Researching the act of entrepreneurship does not and should not vitiate the case for examining what insights about the entrepreneurship can be gleaned from psychological investigation of the entrepreneurial process. One may even ask, is it possible to separate the dancer from the dance since the dancer and the dance are implicated in a socio-cultural engagement through which the dancer relates to the audience and the environment? Chell (1985) address this question in arguing that behaviour is not a function of personality alone but a product of personality, situations and their interaction.

The approach of using psychology to study entrepreneurial behaviour rests on the premise that behaviour is a function of personality and collections of traits define personality. Therefore if it is possible to establish a causal link between traits and behavior, it should be possible to predict entrepreneurial behaviour by identifying those traits that make individuals more likely to be entrepreneurs. In an algebraic sense, this explanatory framework rests on treating personality as the independent variable and behaviour the dependent variable in the analysis. There are several approaches in the literature on trait related to entrepreneurship but the big three are need for achievement, internal locus of control and risk-taking propensity.

McClelland (1961) suggests that achievement motivation is the key to entrepreneurship. Individuals with a need to achieve have innate drive to excel, learn required know-how, plan and execute plans to succeed and realise goals. McClelland argue that individuals with high need to achieve are different from the rest of the population. People with high need for achievement take responsibility for finding solutions to problems so they are more likely to be entrepreneurs. However, the predictive power of McClelland's thesis has been questioned and contradicted by research. Although Johnson (1990) found a positive relationship between achievement motivation and entrepreneurship in 20 out of 23 studies reviewed, he cautioned about the multitude of measures attempting to measure the same construct and expressed concerns about heterogeneity in the population used in these studies. In a different study, Sagie and Elizur (1999) found only two of the measures used to represent need for achievement to be positively correlated to entrepreneurial orientations. They submit that ambiguities about need for achievement may be due to the different constructs used in measuring the trait.

Brockhaus (1982) argues that McClelland did not establish an empirical relationship between need for achievement and the decision to own and manage new business. The reason why individuals start their own business is a mixture of 'push' and 'pull' factors that may or may not be correlated with need for achievement (Chell 2000). Even if high need for achievement can be demonstrated to be prevalent and repeatable among entrepreneurs, it is unclear how it relates to business performance. Begley and Boyd (1987) found weak relationship between psychological characteristics of founders and non-founders and business performance. Lee and Tsang (2001) investigated the extent to which need for achievement is associated with venture growth among 168 Chinese entrepreneurs in small and medium-sized businesses. They found positive relationships between personality traits and venture growth but concluded that entrepreneurial industrial and managerial experience is a dominant factor affecting venture growth, and not some innate trait(s). These studies raise the question whether findings linking personality traits to entrepreneurship can be replicated across different socio-cultural contexts. In view of the importance of experience, Lee and Tsang therefore suggested that to shift attention to entrepreneurial skills away from entrepreneurial traits.

Rotter (1966) developed the idea of 'locus of control' (LoC) as part of social learning theory of personality. People who have 'internal LOC' are those who believe they have control over their destinies while those who have 'external LOC' believe external factors shape events in their lives. Rotter (1966) speculated that need for achievement and internal LoC should be positively correlated, that is, high achievers should also have high internal LoC. However Hull et al. (1980) could not establish any relationship between internal LoC and entrepreneurial action. Also, Brockhaus and Nord (1979) found that it was not possible to discriminate between entrepreneurs and managers using internal LoC. Mueller and Thomas (2001) tested LoC across cultures and found stronger support for LoC in countries with individual cultures, prompting them to conclude that LoC is learned. In the study of 168 Chinese entrepreneurs, entrepreneurs in large firms with higher growth rate exhibit higher internal LoC and concluded that there is overall weak support for entrepreneurial traits. These two studies from Mueller and Thomas (2000) and Lee and Tsang (2001) point to entrepreneurship as a culturally embedded phenomenon.

Given the evidence, should LoC be considered an entrepreneurial trait? Entrepreneurs frequently operate in an environment of turbulence, with in complete information and against forces writ large within macro-economic environment. To deal with these challenges, entrepreneurs create strategies, using their experience and other resources, to attempt to move the odds in their favour. Therefore an individual's view of internal LoC will be tempered by experience and past history of success or failure.

Entrepreneurship is an inherently uncertain process but locus of control provides some sense of certainty and comfort in accepting new challenges. LoC may allow individuals to persuade themselves that they have the requisite skills, abilities and resources to control events and achieve desired outcomes. LoC provides entrepreneurs with the illusion that they can influence events that are inherently random in nature (De Carolis, Litzky and Eddleston 2009). Believing that they can control events better than others and more adept at dealing with associated challenges, entrepreneurs are likely to view hazards in a more favourable light. Illusion of control can affect problem recognition ability and likely to lead to escalation of commitment to failed venture (Keil et al. 2000; Simon, Houghton and Aquino 2000).

In the context of entrepreneurship, risk taking implies pursuing an idea without assurance of a successful outcome. In the literature, risk taking is one of the key features of entrepreneurship. Brockhaus (1980) argues that successful entrepreneurship is related to risk taking and successful entrepreneurs are moderate risk takers while Timmons (1985) submit that entrepreneurs take calculated. However Chell, Haworth and Brearley (1991) suggest that the evidence is inconclusive that entrepreneurs are risk takers just as Hull, Bosley and Udell (1980) could not find any evidence to support the assertion that entrepreneurs have higher risk taking propensity. Although Timmons (1985) submit that entrepreneurs take calculated risks, Janney and Dess (2006) argue that ascribing greater risk-taking to the entrepreneur is conceptually mistaken.

Entrepreneurs' risk propensity influences how individuals assess or perceive risks (Brockhaus 1980; Busenitz 1999). If an individual has a high risk propensity, he or she is likely to assess risky situations lightly and accepts risks more readily than others. Kahneman and Tversky (1979), in their prospect theory, posit that people exhibit risk avoidance behaviour by seeking to minimise losses if there have been prior gains. Losses following prior gains heighten risk perception and induce people to seek to minimise losses by exhibiting risk avoidance behaviour. On the other hand, higher risk propensity leads to lower risk perception and increased likelihood of risk taking. Sutkin and Weingart (1995) however could not establish a correlation between risk propensity and risk taking although they found that risk perception play a mediating role in the way people assess and deal with risk. If the link between risk propensity and risk taking is tenuous at best, does how individuals entrepreneurs think have a bearing of entrepreneurial decision making?

Cognitive biases refer to how entrepreneurs think, reason, assess risk and make decisions. Some research has investigated how cognitive biases make some entrepreneurs more successful than others (Markman and Baron 2003). De Carolis and Saparito (2006) argue that cognitive biases may explain why some entrepreneurs are more effective in the deployment of social capital in the creation of new ventures than others. Shane and Venkataraman (2000) submit that entrepreneurship is the nexus of lucrative opportunities and enterprising individuals which supports social cognitive theory assertion that social environment play a significant role in shaping individual’s cognition and behaviour (Bandura 1986). Cognitive biases affect individual perceptions and interpretation of experiences. This is the foundation of the argument that entrepreneurs experience and interpret situations differently making it possible for them to recognise and create new ventures (Busenitz and Barney 1997; Simon, Houghton and Aquino 2000).

Different scholars have offered different explanations of entrepreneurial behaviour but there is no agreement on what constitute a set of traits of entrepreneurial personality profile. There is limited support linking achievement motivation and entrepreneurship. There is also mixed results linking internal LOC and risk propensity to entrepreneurship. Stevenson and Sahlman (1989) criticise personality trait approaches because character traits are not universal and have failed to produce evidence to support existence of personality traits common to and shared by groups of successful and unsuccessful entrepreneurs in explaining entrepreneurial behaviour.

In this section, need for achievement, locus of control and risk propensity have been explored as personality traits that can be used to explain entrepreneurial behaviour. There are other entrepreneurial traits in the literature such as entrepreneurial orientation, tolerance of ambiguity, entrepreneurial self-efficacy, social competence and intuition among others to explain entrepreneurship, which have not been discussed here but they all suffer from lack of universal application and reliability. In conclusion, it can be argued, in agreement with Mueller and Thomas (2000) and Lee and Tsang (2001), that investigation of entrepreneurial skills is likely to be a more fruitful arena of research compared to study of entrepreneurial traits.

2.11 Sociological Perspective of Entrepreneurship and Innovation

Entrepreneurship cannot be adequately understood outside its socio-cultural context (Altinay, Wang and Aquino 2011; Thornton 1999; Thornton, Ribeiro-Soriano and Urbano 2011). Sociology as a science of human behavior and development of organizations and institutions can provide useful insights about how human beings coordinate action in the pursuit of innovation. In researching the happenings and actions at the nexus of innovation and entrepreneurship, it is important to explore the tension between material conditions and socio-cultural influences that not only influence but shape the outcome of entrepreneurship process.

Weber (2003 [1904]) shows that Protestantism was conducive to the development of personal attributes which encouraged business activity and capital accumulation, establishing a strong link between personal and social group qualities and external factors that made it possible for Protestants to be more successful than Catholics in accumulating capital. In seeing capital accumulation and pursuit of gain as virtues, these attributes, in combination with moral worth of work and dignity of the individual, became the pillars of the church and the society. Encouragement of frugality, thrift and capital accumulation propelled expansion of capitalism. Weber's analysis shows that entrepreneurship is likely to be boosted where the social structure, culture and network structures are supportive.

Swedberg (1998) argues that Weber's economic sociology identifies two contrasting societies: a static society in which wealth creation emanates from rent and a dynamic society where wealth is created through profit and capital accumulation. In the latter society, opportunity (chance) is exploited with the goal of profit making. In societies where individuals are free to pursue capital accumulation and profit maximization, "the main actor here is not the typical merchant (as in traditional commercial capitalism) or the political-economic operator (as in the political capitalism), but the modern enterprise led by an entrepreneur ('the moving spirit'), and oriented to the exploitation of market opportunities" (Swedberg 1998 p13). Swedberg refer to capitalism in a society where entrepreneurs pursue their dreams as traditional capitalism.

It is important to note, in Weber's own words, the centrality of the entrepreneur to the development of free market capitalism. In defining the entrepreneur as a 'moving spirit', Weber acknowledges the importance of entrepreneur, as a central part in the interlocking wheel of relations and activities, of exercising his freedoms for exploiting market opportunities. This 'moving spirit' drives entrepreneurs to make choices among alternatives, seek new combinations and pursue market opportunities. As Swedberg (2000) argues, social science in general and Weber in particular have important contributions to offer in understanding of entrepreneurship.

In analysing the different threads that runs through sociological analysis of entrepreneurship, Ruef and Lounsbury (2007) identified four perspectives which are contextual, behavioural, constructivist and ecological. *Contextual perspective* stresses the role of material and cultural environment in the orientation of the individual towards entrepreneurship. The *behavioural perspective* examines the structure and process of entrepreneurship at the individual level. The *constructivist perspective* is focused on the implication of entrepreneurship at the macro level including organisational start up, industry, community and society at large while the *ecological perspective* seeks to analyse direct impact of material and cultural environment on economic and institutional development. A common thread through the different perspectives is the importance of group and collective action. Although some of these perspectives focus on the individual or micro level, sociological perspectives generally assume that entrepreneurial formation emerge out of interaction between individuals, situational and cultural factors (Shapero and Sokol 1982) and based in collective action. A number of sociological studies of innovation and entrepreneurship stress the role of individual, cultural and structural factors as facilitators or barriers to entrepreneurship (Burt 1992; Granovetter 1973; von Hippel 1994).

2.11.1 Social Capital and Embeddedness

In this section, the literature will be explored to explain how social capital and embeddedness develop and used in facilitating social action including pursuit of innovation. Social capital inheres in an individual’s set of relations and the network to which he or she belongs. The social network refers to the number of informal and formal ties of an individual in a network. Bourdieu and Wacquant (1992) define social capital as “the sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition" (p. 119). Social networks are not naturally occurring features of social life but rather they are products of active construction and engagements by social actors using a variety of instrumental strategies (Portes 1998).

De Carolis, Litzky and Eddleston (2009) identify two broad types of social in the literature: bonding social capital and bridging social capital. Bonding social capital uses groups as the unit of analysis and focuses on the connections within groups that enhance self-enforcing values and behaviours. On the other hand, bridging social capital explains how individual successes relate to the contacts and connections made possible through social capital. Entrepreneurs use bridging social capital in the creation of new ventures or development of new products or services. Nahapiet and Ghoshal (1998), in recognition of the multidimensional nature of social capital, discuss the structural (overall pattern of connections between actors) and cognitive dimensions of social capital. Relational capital, a dimension of social capital concerns an individual's personal relationships developed through interactions and connections with other members of same network. Relational capital in this sense is a form of bridging social capital.

An entrepreneur's position within social network hierarchy and the strength of links to other social actors are important for that entrepreneur's social capital (Lin 2001). Social capital is created through social relations embedded in social networks with ability to facilitate collaboration and cooperation in the pursuit of mutual benefits (De Carolis Litzky and Eddleston 2009). Members of social networks gain mutual knowledge, social status or recognition and access to information that can help in developing new businesses. Networks have been shown to help in firm growth, provide legitimacy and mitigate liability of newness (Aldrich and Fiol 1994; Zimmerman and Zeitz 2002), connect entrepreneurs to opportunities (Ellis 2000), support innovation and reduce risk (Lipparini and Sobrero 1994). The asset that inheres in social relations within a network can also help new ventures creation and innovation development (Adler and Kwon 2002; Tsai and Ghoshal 1998). Therefore, our understanding of entrepreneurship is enriched by our knowledge about how social capital helps the process of being enterprising.

According to Lin (2001), social capital facilitates flow of information and help social actors overcome market imperfections, reduce transaction cost, help influence agents who occupy critical decision making roles, enhance social credentials and credibility. Social capital also reinforces identity and helps those who possess it to enjoy higher recognitions. Burt (1992) argues that by bridging 'structural holes' across networks, actors reach otherwise inaccessible information and other sources of important capital in pursuit of strategic goals. Burt's approach establishes a linkage between social positions and embeddedness of resources. Social capital advantages bestowed on entrepreneurs can weaken the impact of competition, 'creating entrepreneurial opportunities for certain players and not for others' (Burt 1992 p. 57).

Information flow and influence are two direct benefits that flow from bridging form of social capital (De Carolis, Litzky and Eddleston 2009). Information flow is critical to identifying and development of opportunities but the timing, relevance and quality of information flow can all be enhanced by social capital. Individuals can also accumulate favours and obligations from other members of their social network that can be called upon and leveraged to achieve desired ends at a later date.

Social interactions tend to take place among individuals with similar lifestyles who think alike and share similar socioeconomic characteristics (De Carolis, Litzky and Eddleston 2009; Lin 2001). Where members of the same network share common language and vocabulary, information exchange and learning is enhanced. This is in line with interpersonal attraction theory (Byrne 1971) which argues that individuals are attracted to others with similar beliefs and in so doing reinforce commonly shares set of attitudes and behaviours. Social information processing theory suggests that co-workers within organisations influence individual's attitude and behaviour through the information they provide about an object, event or situation (Salancik and Pfeffer 1978). All of these are powerful indications that networks are effective at facilitating information and knowledge sharing because knowledge creation requires exchange and combination of pieces of information enhanced by shared vocabulary (Bolandi and Tenkasi 1995). Although information flow within a network can enhance innovation opportunities, negative information can also spread through a network stopping innovation in its track.

Heterophilous interactions demand greater investment between and among interacting partners because different parties have different access to and command over available resources. The power distribution and relations between the parties forces individuals to assess the willingness of counter parties to engage in exchange and limit who can access and use the social capital that inheres in these relationships. The literature on social capital and its consequences for social action is overwhelmingly positive (Portes 1998). Most of the literature on social capital recognises its nonmonetary form as an important source of power and its positive consequences for empowering social action. In Bourdieu's analysis, social capital is treated as an instrumental concept that accrues to an individual who participates in groups or other forms of sociality with the intention to create and/or access social capital. Two important inferences flow from Bourdieu's analysis, which are that individuals can have access to resources under the control of others through social relationships, and that the amount and quality of resources that can be accessed is central to how effective social capital can act as lubricant in instantiating social action (Anderson and Jack 2002).

Transactions involving social capital are usually characterised by unspecified obligation, uncertain time horizon and possible failure of reciprocal expectation (Portes 1985). Resources obtained through social capital have some characteristics of a gift from the view of the recipient and some expectation of reciprocity or payback in some form though undeclared remains in the background. Therefore, access to social capital can in some contexts relate to the degree of trust between parties and the belief that the receiving party will meet expectation of party or parties that are the source of social capital.

2.12 Role of Trust in Entrepreneurial Process

Johnston and Selsky (2006) examination of trust in Japanese economic and social life show that trust is a paradox than facilitates and underpins economic and social relationships under certain condition but also has a 'darker' side in other situations. Trust facilitates but can also hinder social relations and can therefore be considered a paradox.

How appropriate is it to view trust as a paradox? Clegg (2002) provides some useful answer in the way he describes two categories of paradox: 'materializing' paradox in which paradox is inherently bound to the nature of phenomenon of interest and 'representing' paradox where paradox is a means through which a phenomenon is represented. The first category is what Eisenhardt (2000) define as 'simultaneous existence of two inconsistent states' (p. 703) while the second category is what Ford and Backoff (1988) describe as the bringing of oppositional tendencies into proximity through reflection or interaction. Eisenhardt's definition describes a duality while Ford and Backoff explanation embodies human attempt at reconciling opposing or even contradictory tendencies. Both approaches reveal the tension, ambiguities, even contradictions in social systems and how social agents construct and sustain them as paradoxes (Lewis 2000; Johnston and Selsky 2006; Poole and van de Ven 1989).

The treatment of trust is of particular interest as it relates to social relation and decision making which is an important part of innovation process (Welter and Smallbone 2006). A number of scholars have made the argument that trust is strongly related to risk (Bhide and Stevenson 1992; Das and Teng 2004) since trust relies on expectation of future event or performance which in the present can only be uncertain. Opinions vary on the relationship between trust and risk. Boon and Holmes (1991) submit that trust is needed only under conditions of risk and uncertainty echoing Currall and Judge (1995) who describe trust as 'reliance on another person under a condition of risk' (p. 151). Trust is often used to explain a variety of context bound social actions and decisions involving risk taking but how trust facilitates social actions remain an unfolding academic interest.

Different types and categories of trust are discussed in the academic literature including subjective trust, goodwill trust, competence trust, relational trust and behavioural trust among others. Subjective trust relates to the assessment of probability that an individual whom we have chosen to trust (trustee) will perform as expected (Gambetta 1988). In trusting another person, an individual (trustor) engages in cooperative behaviour based on the confidence that there is a high probability that the trustee will perform to expectation. Das and Teng (2004) submit that implicit in the acceptance of subjective trust is the association with risk as soon as we see subjective risk in terms of probabilities. Economists see perceived risk as calculated probabilities under condition of uncertainty but perceived risk and subjective trust can also be seen as two sides of the same coin. When people engage in calculative behaviour, they are forced into situations that calls for trust but they may not always estimate probabilities associated with their decisions consciously but the processing may take place subconsciously (Das and Teng 2004).

Goodwill and competence are two sources of subjective trust. Das and Teng (1996) suggest that risk in inter-firm situations can be in two forms: relational risk and performance risk. In relational risk situations, interacting partners are not fully committed to the relationship and there is a risk that either party may not perform to expectation. On the other hand, when performance risk is an issue, the probability and consequences of not achieving the goals in a relationship are considered even when the parties have good intentions and make the effort to succeed. Relational risk flow from conscious intention of one of the parties not honour obligations and live up to expectation while performance risk stems from certain constraints like inauspicious environment or inadequate capabilities of the trustee.

Goodwill trust develops when the trustor believes that the trustee has good intentions and willing to act in trustor's interest (Das and Teng 1996). Contrasting this with relational risk in which one of the parties act in bad faith or with the intention not to perform as expected, we can say goodwill trust and relational risk are mirror images. Since factors affecting performance risk are beyond the parties' willingness and intention, a perception of goodwill cannot of itself lower the level of performance risk.

Competence trust arises from the trustor's belief that the trustee has the required skills and abilities to carry out necessary actions and achieve the desired outcome (Gabarro 1978). Competence in this sense refers to the trustee's skills, capability, technical qualifications and expertise (Mayer, Davis and Schoormann 1995) to meet expectations and performance targets of the trustee. Das and Teng (2004) identified lack of competence as the most important factor affecting performance risk. To trust is to rely on the expected action of the trustee over which the trustor has no control (Currall and Judge 1995). In technical innovation construction, technology entrepreneurs must elicit competence trust in other stakeholders to have confidence in their ability to deliver technical artefacts that can meet expected needs. While social capital can facilitate access to critical decision makers and tacit knowledge that can be critical in problem framing, it is insufficient to give confidence to either VCs to support innovation construction with funding or end-users who ultimately decide whether technical artefact is suitable for their need. On the other hand, if critical stakeholders have confidence in the ability and know-how of the entrepreneur to deliver technology that may meets the challenge of the present, they are likely to be more supportive. This support is not without its own risk since a technology-entrepreneur may still fail to deliver but trust based on perceived competence of the entrepreneur may be sufficient to create the social space to engage in innovation construction (Anderson, Steinerte and Russell 2010).

Hardwick, Anderson and Cruickshank (2013) submit that parties in a joint, social process of entrepreneurship will not undertake opportunistic behaviour if there is trust between the parties. Trust has been shown to help reduce transaction cost, bargaining, the need for monitoring and uncertainty associated with joint action (Anderson and Jack 2002). One can argue that trust widens the social space for entrepreneurship and technical innovation construction. To trust is to expose oneself to a degree of risk and vulnerability but trust can and does change over time; waxing and waning (Anderson, Steinerte and Russell, 2010). Through communication and transmission of information, parties are able to build and improve confidence, enhance predictability and may even engender blind trust (Heimer 2001).

Behavioural trust arises from having subjective trust in another individual; it is a condition that encourages risk taking because it influences how people perceive risk. From earlier discussion, we know that when the trustor displays subjective trust, there is an assessment of probability, consciously or unconsciously, along with an expectation that the trustee will behave as expected. In general, people prefer certainty over uncertainty. If the perception of failure is low, people are likely to be more willing to undertake risky venture. The perception that risk of failure is low nudges people to be more willing to take risk. Therefore, we can say that subjective trust is about the perception of risk while behavioural trust relates to risk taking. When there is abundance of goodwill, level of perceived relational risk is low and perception of competence is enhanced which can in turn lead to low level of perceived performance risk (Das and Teng 2004). This shows that behavioural trust is a combination of certain levels of relational risk and performance risk. Trust develops between individuals depending on social relations or the institutional contexts in which they operate, especially when connected by strong ties (Jack, Dodd and Anderson 2004). Our understanding of trust and the institutional context in which it develops have implications for entrepreneurial action since investing in networks and creating social capital, it is possible for entrepreneurs to use their position and relationships to accumulate goodwill that can in turn help reduced perceived relational risk, enhance their perceived competence with stakeholders and attenuate worries about performance risk or ability to deliver what is promised. In this way, social capital helps enhance trust between parties and help lubricate the technical innovation process.

2.13 Time-based View of Entrepreneurship and Innovation

So far in this chapter, entrepreneurship and innovation have been presented as a social phenomenon. While discussions to date acknowledges the social character of innovation and recognises the contextual influences, how innovation and entrepreneurship change over time has not been given sufficient attention. Discourse on entrepreneurship treats the concept as 'processual', 'relational' or 'processional-relational'. The relational view of entrepreneurship encompasses studies of entrepreneurship based on social embeddedness and network relations that has been discussed earlier in this chapter. In the concluding section of this chapter, a different but complementary view of entrepreneurship will be presented that will form the basis of the conceptual framework for this study.

Entrepreneurs extract cues from the different contextual settings, create a set of interpretations and act in concert with others to bring into existence constructs of mental and material representations over time. Scholars have recognised that entrepreneurship occurs within a larger context – a constellation of events, circumstances, happenstance, settings, economic and regulatory environments (Chell 1985; Gartner 1985).

Consequently, an increasing number of studies have adopted ‘processual’ approaches to studying entrepreneurship (Chell 1985; Downing 2005; Jack and Anderson 2002).

In his seminal work, Pettigrew (1997) put process is at the centre of his analysis adopting Van de Ven’s definition of process as ‘a sequence of events that describes how things change over time’ (Van de Ven 1992 p. 338). The fundamental assumption behind processual thinking is that social reality is dynamic, constantly unfolding and context bound where things change because of perpetual human actions in the process of becoming. Since reality is dynamic and constantly evolving, Pettigrew (1997) argues that researchers have to attempt to ‘catch this reality in flight’ (p.133).

To engage in processual thinking and analysis, Pettigrew argues that researchers have to liberate themselves from language that restricts the ability to see an unfolding process of becoming, emergence, transformation and change through time. Any language that captures the dynamic, doings and happenings within a process, have to be grounded in action thereby putting agency at the location of social action. Action is one of the key drivers of agency. This study takes the view that we can really explore the inter-relatedness between action and process when we expand the scope of analysis to capture the sets of relations between actions, context, history of participating individuals and the insight they bring to the process of becoming. It is in our recognition of the burden of the past that we can see how cumulative effects of individual history and experience become salient in the process of technical innovation construction. While time and history are critical building blocks of processual analysis, the goal of processual analysis should be to search for patterns in a process, find the underlying mechanism shaping observed pattern of actions and explore conscious intentions of key stakeholders.

Processual analysis allows a researcher to account for and explain the what, why and how of entrepreneurship are linked to the context, process and outcomes of a social process. Pettigrew argues that the starting point for analysis of a phenomenon that changes over time is to examine the content of change because context and process are inextricably bound to the content of strategy formulation. Pettigrew (1987) uses content, context and process as three dimensions of a framework to study strategic change, which is the outcome. Processual approach is suitable in the study of entrepreneurship since entrepreneurship creates change and alters the conditions under which social actors carry out previously routine, taken-for-granted and familiar tasks. For a study of technological innovation such as this, a processual view allows the researcher to explore the simultaneous social transactions and the transformation of an idea in the process of becoming. The ability that this type of analysis offers in linking processes to context and outcomes makes it an interesting alternative for looking at a context-sensitive phenomenon like entrepreneurship.

Social processes are embedded in and have a dialectic relationship with the context they are situated in. Looking at entrepreneurship and innovation using processual analysis allows us to account for critical incidents, process subtleties and complexities, ripples and perturbations from human actions across temporal and across spatial boundaries, and the responses they generate from others and the environment. Through processual analysis, the researcher can study context bound phenomena, reveal temporal interconnectedness linking the flow of events and action over time. This approach also allows the researcher to examine human agency in relation to their environment and treat time (past and present) as a bridge for understanding important transitions. This type of analysis afford the researcher an opportunity to link different levels of analysis that are contextually relevant, and explore how the perceptions, learning and recall of social actors feed their subjective interpretations of the environment. Researchers can also examine how antecedents shape the present and influence the future, revealing how structure and context are implicated in the production and instantiation of social action.

Through processual view of entrepreneurship, an analysis consistent with this view can help researchers excavate underlying features of the innovation construction process that may not be directly observable but implied in the beliefs and understandings that actors bring to the field of practice. This approach provides a path through which researchers can trace the flow of events, associated changes and progress through time.

2.14 Conclusion

This chapter presented different perspectives on innovation in the literature and argues that simple categorisation does not address the complexity and highly contextualised nature of innovation. The strengths and weaknesses of different models innovation have also been discussed especially in relation to how little they inform about the nature and process of innovation by entrepreneurs and small businesses.

Innovation in general and technical innovation as a sub-class is presented as a deeply social process in which trajectory of emergence and development is highly dependent on context. Although both are socially embedded and contextual processes, innovation and entrepreneurship have been shown to be time bound and future-orientated but anchored to the present with tentacles to the past. The time dimension brings a complication that can best be addressed by taking a processual view of innovation construction.

In this chapter, a strong case has been made for the evolutionary view of technology as a better representation of the changes in the dominant thinking about technology frames and what the implications are for innovation construction. Consistent with evolutionary slant of this study, the research adopts a processual perspective blended with sense-making in trying to understand the happenings and interactions as an idea is transformed into a technological artefact.

In the next chapter, an exploration of the different social theories that are relevant to this research will be presented. The chapter will explore how individuals and groups construction of meaning is informed by these social theories and with what implications for the innovation construction. The chapter will conclude with the argument of why sense-making is the most suitable lens for studying technology innovation construction in the UK oil and gas industry. The discussion of relevant social theories that started in this chapter will be concluded in the next, laying the foundation for the development and presentation of the conceptual framework for this research in chapter four.

Chapter 3

3.0 Introduction

This chapter will explore different social theories relevant to this study and explain how these theories help us understand how social agents engage in meaningful exchanges. These social theories have been selected because they help us examine how social actors construct meanings in their engagements with each other and the world. In the course of this exploration, the chapter explores how the process of meaning construction informs our understanding of innovation construction. In the previous chapter, innovation was presented as a social phenomenon that emerges from social interactions. In this chapter we examine the antecedents to these interactions, how individuals construct meaning alone and in concert with others and the implications for innovation construction.

Entrepreneurs create innovation by extracting and interpreting cues from the environment, envision a future and manifest their mental representations. In the creation of innovation, entrepreneurs have to impose interpretations on cues drawn from chaotic and unrelated set of information. To be effective, entrepreneurs have to be good communicators to successfully translate their understanding of ambiguous situations, help others achieve meaning and secure their understanding and support for innovation (Verganti 2008). To be an effective communicator, entrepreneurs must also be good at translating subtle meanings into shared understanding and have the capacity to make sense of things. This is consistent with Krippendorff (1989) who argues that design is about making sense of things. Consistent with the argument that meaning is critical to innovation construction (Verganti and Öberg 2013), this chapter begins with an exploration of meaning construction and why it matters in the innovation construction process.

Important social theories like Giddens' Structuration Theory (ST) and Bourdieu's habitus and theory of practice are discussed to show how they inform our understanding of entrepreneurial process and practice. While ST makes a valuable contribution to our understanding of how to structure and agency inter-relate, empower or constrain innovation, it will be argued that ST on its own does not allow us to see the full happenings in the innovation process. Using ST, it is easy to reify structural constraints inhibiting agency or give undue prominence to heroic actions of individuals who succeed in the entrepreneurial process. It will be argued that ST can easily fool the researcher into mistaking aspects of a phenomenon for the whole and relegating subtle but important factors to the background. Although Bourdieu's habitus provides a means of understanding how objective structures of society get internalised and reproduced in action by social agents, it is argued in this chapter that it is helpful but insufficient to explain the choices actors make in relation to innovation.

While ST and Habitus provide some explanatory power of how and why people do what they do, it will be argued that the provenance of innovation is tied to our mode of being. Since innovation is about newness, it is argued in this chapter that to understand innovation emergence and its construction, we need to understand antecedents to the moment social actors recognise the need for innovation. Adopting Heidegger's explanation about our modes of being, this chapter argues that what we make of and tools for coping with the world depending on how we are disposed to the world. This disposition shapes our understanding and circumscribes the boundaries of what we consider to be possible. Without our interactions with the world and the necessary understanding that flows therefrom, social actors will be incapable of seeing the urgency for doing something different or the need for innovation.

Consistent with the theme of conceptualising innovation as a social phenomenon, technical innovation is examined in the light of Heideggerian perspective of different modes of being and implications for its mode of emergence. Using Heidegger as a guide, we examine ways of relating to the world that can either enhance or inhibit innovation. Since technical innovation artefacts are used by human beings to achieve certain ends, the ends to which we put technical innovation cannot be divorced completely from the process of its emergence. This fundamental understanding of how material objects are disclosed to us and our understanding of their roles in our day-to-day activities, including our place in the world, is central to what we apprehend and are capable of imagining. Therefore, our ways of being-in-the-world delimits our capacity for problem solving and scope of imagination that mediates innovation construction.

Finally, an exploration of how social actors make sense of ambiguous and uncertain situations to which entrepreneurship and innovation are inextricably bound is explored through the lens of sense-making. Sense-making helps us structure available cues, impose order on an otherwise chaotic universe of data, information and symbols so that we can meaningfully deploy our interpretation of extracted cues in encounters and engagements-with-the-world as we pursue our imagination. In a certain mode of being, we recognise a breakdown in the use of a tools or equipment. This understanding can only translate into entrepreneurial opportunity if we can create a shared understanding around the recognised 'breakdown' and develop a convincing solution narrative that other stakeholders deem credible. This is how social actors demonstrate practical knowledge of the world and reflect an aspect of practice that is not fully captured in either Bourdieu's or Giddens' social theories.

In conclusion, this chapter presents conceptual tools that will be used as critical building blocks in the construction of a theoretical framework that will underpin an analysis of technology entrepreneurship and development of a theory of technical innovation construction that is socially embedded, contextually situated but applicable to a different temporal-spatial centres of innovation.

3.1 Meaning and Social Action

Innovation is about change, the transformation of ideas and creation of new combinations from existing resources into new forms therefore; it is characterised by newness. In order for social actors to do this individually and collectively, they must make sense of often ambiguous situations which requires them to construct personal meanings that must be meshed to construct shared understanding. In the innovation construction process, different understandings of a problem have to be re-arranged and re-formed to coalesce into a coherent form that stakeholders can identify with, support and accept as a basis for action. To achieve meaningful rearrangement, social actors impose their schematic projections on material objects to make sense of situations (Streeck 1996) and create new forms.

It is human nature to seek to make meaning of their surroundings (Baumeister and Vohs 2002); meaning helps human actors adapt, coordinate with others and leave their imprints on the sand of time. Schreurs, Bakker and Schaufeli (2009) define meaning-making as the 'ability to integrate challenging or ambiguous situations into a framework of personal meaning' (p. 509). This suggests that meaning-making is intensely personal but it is also the case that it will be impossible to have coordinated social action if actors cannot align their meanings of the same situation to agree on a set of actions. Schreurs, Bakker and Schaufeli (2009) explore different types of meanings, and argue that different forms of meanings have a common, underlying feature which is that social life cannot be separated from the process of meaning-making. Making meaning allows social agents to draw on existing stocks of knowledge and connect the task at hand with the end that is sought. Meaning-making also allows individuals to understand the contents of change (Webber and Manning 2001), make sense of situations and envision a path to a desired future even when dealing with incomplete information (Weick 1995). Therefore meaning-making is closely tied to the process of sense-making.

Meaning is dynamic, constructed on an ongoing basis (Wrzesniewski, Dutton and Debebe 2003) and requires continuous engagement of social actors. Schreurs, Bakker and Schaufeli (2009) posit that meaning-making is a process of interpretation and reflection, drawing a distinction between meaning-making and sense-making. To Schreurs, Bakker and Schaufeli (2009), sense-making allows social actors to engage with and place into some order an ongoing stream of events and experiences to facilitate action. Therefore, sense-making helps human beings impose order on confusing situations using different schemata to achieve comprehension. On the other hand, meaning-making is co-generated through representations and social agreement (Verganti and Öberg 2013). This interpretation is consistent with Schreurs, Bakker and Schaufeli (2009) who submit that meaning-making occurs after sense-making has taken place.

The meanings that agents bring to the innovation site are informed by their experiences, cultural and socio-economic factors. While meaning-making may start at a personal level, our understanding of circumstances is challenged and sometimes altered when we engaged in coordinated social action. In technological innovation construction process, actors brings multiple interpretations, and by extension, multiple meanings to the innovation site but what emerges as innovation is a negotiated outcome from contested multiple meanings and interpretations.

In the next section, this chapter presents an exploration of the interplay between structure, agency and the context in which social actors engage with each other and negotiate to produce innovation. This exploration will be undertaken in the context of what we can infer from application of Gidden's structuration theory and Bourdieu's habitus. The role of context and how its ties structural features and habitus together in the innovation process will be explored.

3.1.1 Entrepreneurship, Risks and Decision-Making

The concept of risk is bound with innovation because its outcome is always uncertain. There are different types of risk associated with innovation including, innovation risk, business risk, market risk or agency risk among others. As a business proposition, technological innovation can be confounding, appear unstructured, difficult to control and lacking a clear path to exit. These factors make it difficult for techno-entrepreneurs to secure finance for technical innovation development. There could be occasions when a technical innovation project can appear to look like a 'research project', pursued by technology developers as a form of scientific enquiry unworthy of financial support and difficult to justify on commercial grounds using proven metrics. It is also impossible to predict in advance, the duration of new product development, therefore it is not uncommon that projects overshoot initial cost expectations (Reid 2002). All of this introduces elements of risks into the innovation construction process.

The key variable in entrepreneurial decision making is the significance of outcome. The theories of rational decision-making and rule-based decision making treat outcomes as the primary product of the decision making process. Individuals or group of individuals participate in the decision making process to shape decision outcomes. How people make sense of the variables plays a significant role in decision making because it allows participants to establish meaning, reduce uncertainty and ambiguity, prior to making decisions (Weick 1995). Studies have shown that decisions are often loosely linked to the information gathered prior to decision making (Shapira 1995). March and Sevón (1984) submit that meaning is not only a precondition for decision making but that meaning is also shaped by decision making. In order words, participants develop shared meaning as they explore an issue and proceed towards decision making (March 1994). This finding has significant implication for any investigation of innovation model that is socially situated and seek to account for the influence and role of different social factors that mediates innovation construction.

At its heart, decision making is a process of choice in which participants develop and share their interpretations of events, experiences and vision of the future. To make a decision is to choose between competing alternatives, seeking to influence the future. It is therefore important that we focus on the interpretations that inform decision making as much as we focus on the decisions made in order to gain insight into the intertwined connections between meaning and decision making.

The theories of rational choice and rule-based choice assumes that there is a relationship between decisions and the premises that informed them, that action is consistent with the premises and that premises are antecedents to the action. Consistent with explanation based on sense-making, March (1999) submits that action comes first and individuals retrospectively seek to make premises consistent with actions or decisions taken. Another complication arising from the co-evolution of meaning and decision making is that decision outcomes do not tell us very much about the process associated with how decisions are reached. The link between information collected and its use in decision making is weak (Feldman and March 1981). This is because, individuals and organisations, retrospectively construct stories and narratives to create a bridge between actions and consequences, identities and behaviour.

Based on these research findings, one could argue that the process of choice is an elaborate myth designed to facilitate desired change. The availability of choice gives comfort to participants that an intelligent choice has been made, one that recognises concerns of relevant people, explore deep reasoning and predicated on a thorough analysis of alternatives. Decision making systems can therefore be seen as symbols that individuals in socially relevant roles use as props to reinforce the myth that the decision reflects the set of choices and consequences explored during the decision making process.

As explained above, meaning and decision making co-evolve. This co-evolution complicates our understanding of the decision making process. Because the process of innovation and entrepreneurship cannot be separated from decision making of individual actors engaged in the process, innovation investigation has to be treated as a complex set of socially linked processes that can be studied through the experiences and understandings of the actors. This complication stems from the simultaneity of decision making and meaning construction. If the link between information and decision is weak, that suggests the process of decision making is fluid and subject to social influences. This is simultaneously an opportunity and a threat to innovation for technology entrepreneurs.

Later in this thesis, a case will be made that decisions actors make about innovation is best investigated by a methodological approach that is based on the principle of Vestehen, a deliberate search for understanding through the eyes and lived experiences of actors in the innovation construction. For the rest of this chapter, the thesis will focus on relevant social theories with explanatory power to increase our understanding about aspects of innovation construction.

3.2 Agency, Structure and Context

3.2.1 Giddens' Structuration Theory

Agency is about autonomy of action, the ability to act purposefully and deliberately in pursuit of an action or goal. One of the contentious issues in sociology is the relationship between agency and structure and how one is implicated in and influences by the other. An exploration of social theories on the relationship between structure and agency will be undertaken mainly through Structuration Theory (Giddens 1984) and Bourdieu (1977) theory of practice. These two social theories have been selected because they offer explanatory frameworks that improve our understanding of how actors engage with and enact their environment. This study recognises the role of social structure and influence of individual's experiences in the creation of innovation but contend that neither of the theories is sufficient to unravel the interplay of social forces that drive innovation.

Giddens contends that human actors often act against existing structure using inherited meanings and symbols to make their actions socially meaningful. To respond to and act in concert with others, human actors rely on intersubjectivity, which is the capacity of an individual to harmonise and comply with interpretations of reality that is socially meaningful to others. On the other hand Bourdieu (1997) in the theory of practice argues for a perspective of agency that is spatial and transferable across social fields. The environment in Boudieu's theory is both enabling and constraining thereby endowing the field with generative power.

Studies of innovation typically either take the agency perspective, centring on the actions of the individual, or adopt a structural approach with an emphasis on how the attributes of organised pattern of social relationships and institutions (social structure) enable or constrain adoption (Jones, Edwards and Beckinsale 2000). However, technology as a product of innovation process is a product of human action that is endowed with structural properties (Orlikowski 2002) and deployed by human agents in social spaces and through social interactions to achieve productive ends (Orlikowski 1992). This view presents human actors as potential agents of change as they interact with technology and engage in different endeavours of social and economic production. Through the actions and decisions of human agents, technology gets used in certain ways that embeds it within the social structure. Therefore, it is logical to argue that innovation in concept and practice is a social process with agential and structural features.

3.2.2 Effect of Social Structure on Innovation

In sociology two methodologies have been developed for dealing with structure and agency. Approaches focusing on structures and adopting an objective stance are labelled *macro* into which we include 'grand theories' such as Functionalism and Marxism. Giddens argues that these approaches give pre-eminence to social structure but are weak on explicating the role of action (Currie, Galliers and Galliers 1999). On the other hand, subjective approaches such as Symbolic Interactionism, Hermeneutics and Phenomenology are labelled as *micro* and have agency and human actions as their focus, explaining how individuals influence society and in turn are influenced by society. There is a sense in which social actors reproduce structural features but it is also true that the environment is external to the individual and has certain influences on the limit of what is possible. It is in response to this macro-micro dichotomy that Giddens developed structuration theory. The concept of structuration involves thinking about objectivity and subjectivity as mutually constitutive of the social structure (Parker 2000). The causal linkage between social structure and human action is what Giddens (1984) refers to as the 'duality of structure'.

Structuration theory attempts to combine functionalists' preoccupation with social structures with concerns that micro theorists have about human actions. Giddens (1984) argues that the interplay between structure and agency allow actors to produce and reproduce social structure. He identified *signification* (the generation of meaning), *legitimation* (rule and norms of what is appropriate or inappropriate) and *domination* (exercise of power over others) as aspects through which human actors internalise the social structure, reproduce and perpetuate it. It could be argued therefore that the social structure is a product of past practices of agents or internalised by social agents in the guise of phenomenological and hermeneutics inheritance (Stones 2005). For example, to be successful, a technology entrepreneur can develop ideas familiar to customers or expend considerable resources explaining how new combinations can serve productive ends within the rules of what customers deem plausible. In working with what is familiar to likely customers, the agent is reproducing structural features that have proved previously successful or using his understanding of these features to create a new combination that is compliant with what others will see as legitimate and credible solution.

A structure is stable as long as the positions within the structure and associated embedded resources remain unchanged. According to Lin (2001), the social structure has the following elements:

i. Different positions within the structure possess different amounts and types of valued resources;
ii. There is a hierarchy of authorities controlling access to available resources;
iii. There are commonly shared rules and procedures governing the use of available resources;
iv. Individuals occupying entrusted positions act according to prevailing rules and procedures.

Giddens (1984) submits that structure and agency are a duality, existing side-by-side, each co-creating the other. The structure consists of the organisation of social relations created by and between individuals and groups, and the relationships between the different elements of the social system. The structure is externalised in everyday conduct, actions and decisions by individuals and groups in social interactions thereby objectivising the structure, shaping available opportunities and limiting choices. Although the structure is not immutable, it is difficult for individuals to alter. Human agency on the other hand refers to the unlimited nature of human action; to be the cause rather than the effect of social forces. If social structure is difficult to bend to human will, how do social actors use structural features to achieve productive ends? Agency appears in the literature in different forms ranging from intentionality (Bandura 2001) to capacity to act (Ahearn 2001). Following Giddens (1984), scholars now acknowledge freedom and constraint in their analysis of agency. How is it that individuals on their own can shape the course of the future through personal causality is a question worth investigating. Is it even possible that individuals have such range and potency of power to instantiate action as our understanding of agency would have us believe?

Through the explanatory framework of structuration theory (ST) we develop some understanding of how agents first form structures and how these social creations develop structural properties through repeated human actions with power to constrain action over time. Through their knowledge of the structure, agents are able to modify, rearrange structural features or create circumstances that may render aspects of structure impotent to their preferred course of action. Therefore, one can argue that ST shows how structure and agency exist side-by-side and in dynamic interactions. It is this dynamic interaction that helps us understand how agents create socially meaningful forms, recognise the limits of what is possible under prevailing social rules, and how agents influence each other that makes ST an attractive conceptual framework for understanding the link between action and structure across time and space of innovation construction process.

ST has been used in diverse areas of organisational research because of its ability to help us understand and explain complex social interactions (DeSanctis and Poole 1994; Orlikowski 1992, 2000; Pozzebon and Pinsonneault 2005). According to ST, contextual factors constrain or enable exploitation of opportunities in a dialectic relationship in which entrepreneurial action creates change in contextual conditions and surroundings that in turn constrain or enable the limits of possibilities. Since structural norms tend to make human agents want to repeat successful behaviours from past experience, there must be certain triggers for structural change if human agents are to contemplate adopting new radical innovation. ST is a useful approach to study technical innovation process because it allows researchers to link action and structure with different temporal stages of the innovation process. Using ST as a conceptual lens allows the researcher to examine the entrepreneurial process and the interlocking relationships between individuals, social action and prevailing structural conditions.

The deployment of technology is context-specific, shaped by social and economic forces beyond managerial intentions because human actors often have to respond to their environments. In adapting to these forces, technical innovation becomes a means to an end in accommodating resistance to managerial intentions. The character and utility of any technology evolution depend on how and why it is used by human actors within organisation and to what end. Therefore, for any technology to be structurally embedded, shared meaning around its use must develop within an organisation or social group and socially constructed. In the construction of shared meaning around any technology, layers of interactions and multiple points of decision-making by human agents take place in determining how value and performance are recorded, interpreted, evaluated and communicated. It is by delving into these complex layers of interactions and vortex-of-change-in-the-making that we can gain useful insights into the innovation construction process.

Agents are reflexive with capacity to routinely observe and understand what they do in the moment of action through self-awareness and sensitivity to the social context so that they can recalibrate their actions in response to structural obstacles and responses of fellow agents. The power of reflexivity allows human actors to routinely observe and understand what they are doing while they are doing it. Chiasson and Saunders (2005) argue that entrepreneurs learn through time, based on successful and unsuccessful experiences to develop a library of scripts; transplanting previously successful scripts into new contexts. Unsuccessful scripts can either be discarded based on market signals or kept away to be employed at a future date under suitable conditions. The structure owes its durability to the prevailing arrangement of positions, resources, rules and procedures configured in a particular arrangement to mediate social action. Based on the features of the structure listed by Lin (2001), human agency can alter the stability of the structure or at least shifts its centre of gravity by seeking new arrangements of its components: resources, rules and procedures. Through repeated use of successful scripts in the process of being entrepreneurial, entrepreneurs help reinforce situated practices and social structure. This process of learning and social engagement is also an opportunity to seek realignment or rearrangement of structural elements by matching and sometimes adapting scripts to contexts.

In developing new technology, entrepreneurs must evaluate and develop ideas, aggregating resources required for translating opportunity into a new product or service or create a new venture. In the process of evaluating and accumulating resources for bringing into existence a new product, service or venture, the entrepreneur operates within the social structure but also by his action of creating something new alters the structure. The traditional view of the entrepreneur filling market gaps is replaced by the view that the entrepreneur and the social system co-evolve (Sarason, Dean and Dillard 2006) emphasising the interdependence of context (structure) and actors (agents) and reflecting the entrepreneur's subjective interpretation of social reality. Much of the research work in entrepreneurship is about outcome, but the process of entrepreneurship is equally important. Although outcome is important, even in failures there are important lessons that can illuminate our understanding the process of entrepreneurship (Cannon and Edmondson 2005; Sitkin 1992). Similarly, the outcome or technological entrepreneurship is technical innovation product or artefact but the process of emergence has economic ramifications not only about success or failure of a product but also about our understanding of drivers of technical innovation process itself.

Different types of knowledge may be needed to create innovation. ST distinguishes between discursive and practical knowledge: discursive knowledge refers to what human actors can articulate while practical knowledge refers to tacit knowledge that people cannot articulate but draw upon in making decisions or choices (Stones 2005). The difference between discursive and practical knowledge is an important factor in how entrepreneurs develop technology. For a new technology to be of interest to end-users it must not only meet expressed needs gained from discursive knowledge but must also capture many of the needs and features that are part of practical knowledge that often cannot be articulated by end users. This is a source of uncertainty for an entrepreneur to which he must engage, but also an opportunity. To be able to create a narrative that will help create a shared understanding of a problem in need of technical solution through technology, the entrepreneur must be able to access and translate practical (tacit) knowledge into discursive knowledge that can then form the basis of a problem solving framework. For an entrepreneur trying to introduce new technology into the oil industry, he/she must create shared meaning with end-users that forces a re-examination of existing ways of doing things and recognises the need for change. Even if the need for change is recognised, when and how potential end-users start to believe in the power or transforming capacity of new technology to achieve change and desired end is often contested.

Structuration theory is not without its limitations. Pozzenbon and Pinsonneault (2005) argue that Giddens ST operates too much at a high, conceptual level of abstraction making it difficult to apply as a methodological research tool. Archer (1996) raises a fundamental question about ST in arguing that structure and agency are phases with power to influence outcome over different time intervals: human actions effecting change over a short term while the structure endures over a longer time horizon. She even questioned whether inquiry into the reproduction of social structure is a worthy subject of interest rather arguing that asking 'why some form of social reproduction succeed and endures while others do not is a more interesting question. Although structuration theory advances our understanding by making a distinction between practical and discursive knowledge, the theory does not present us with a well developed account of how discursive consciousness produces social change. Even though rules and resources are central to Giddens' structuration theory, the rules that operate in society and the resources available to agents are themselves products of social action.

3.2.2 Linking Structuration Theory, Habitus and Entrepreneurial Game

Bourdieu used the concept of 'habitus' to capture and explain how the society becomes embedded in individuals forming lasting dispositions and guiding human capacity to act, feel and choose. Bourdieu concerned himself with a method of inquiry and concepts that can help us understand how the objective structures of society like rules, norms, social roles and social institutions influence subjective behaviour. In Bourdieu's view social behaviour or what he called '***practice***' aggregates to produce the reality that we know as society. It is another way of dealing with what Giddens (1984) referred to as the duality of structure and agency. At its core, Bourdieu's reflexive sociology has as its aim how objective social factors affect intentions and limits of action of social actors (Fries 2009).

Bourdieu's relational theory is premised on a social ontology that the social world is a collection of interconnecting multidimensional spaces that is connected yet differentiated into distinctive 'field' or socio-cultural arenas of interaction and struggles (Schatzki 2002). Each field has its norms, rules and logic. The capital or cultural resources that are effective and transformative in one field may be completely ineffectual in another. Human actors transit between fields as they interact with, re-create and unreflexively reinforce the structural features they confront whilst simultaneously transforming structures elements through creativity and rearrangement of available resources. The cultural resources available to social actors to manipulate and instantiate action within these fields are socially conditioned and encoded with particular cultural meanings (Macey 2000).

Bourdieu describes habitus as a 'set of basic, deeply interiorized master-patterns' (Bourdieu 1967) which embodies cognitive schemata that guides behaviours based on beliefs about the nature of social reality. Behavioural dispositions consist of beliefs, values and attitudes to become internalised aspects of the social structure through socialisation. The habitus is a set of dispositions that in ingrained in an individual and induces one to behave in a particular way under certain conditions, in certain contexts. These dispositions (pattern of speech, bodily gestures and comportment) are repetitive and compliant with the structured nature of social reality. The habitus defines how a person ***is*** in the world and informs how an individual thinks, his beliefs, behaviours and the way the individual relates to the social world. The habitus attempts to reconcile the Cartersian dichotomy that separates the mind from the body by seeking to reconcile, if only at the epistemological level, the body, culture and social structure by treating them as dialogical, dynamically interacting concepts.

Habitus can be transported across multiple fields through adaptation and accommodation of context-specific conditions, carrying within it forms of capital used in reproducing fields and shaping social practice. The habitus not only helps to bridge the analytical divide between individual and society but also it is a means of transiting between the interrelating multidimensional spaces that constitute social reality (Sterne 2003). Individuals engage continuously with the society, shaping society and they are in turn shaped by society, therefore, Bourdieu's dialogical understanding and explanation of the relationship between individual and society is very insightful.

Habitus is an enigmatic concept that is elusive and slippery to properly define but sufficiently elastic to be employed in describing all sorts of circumstances and context bound actions. Maton (2008) argues that the contested nature of habitus is because not only is it intended to transcend a series of dichotomies that structure our way of thinking about the social world but also a means of analysing the workings of the social world through empirical investigations. Therefore habitus is not only central to Bourdieu's theory of practice but also key to understanding most of his substantive analysis of the social world. Human actors often act as if they are agents free to make decisions and choices but contradictorily usually base their choices and decisions on the predictable character, behaviours, attitudes and acceptance of others.

Social practices are characterised by regularities even though these practices are guided and driven by unwritten rules. This is what Maton (2008) calls 'an experiential and a sociological conundrum': how to reconcile how behaviour is regulated without direct obedience to rules (Bourdieu 1994), that habitus is designed to resolve.

Habitus is a property of actors (individuals, groups or institutions) comprising of 'structured and structuring structure' (Bourdieu 1994 p. 170). It is a structure that is systematically ordered and not a random collection of generative dispositions producing propensities and practices. It is 'structured' by the past and present circumstances including family background, education, cultural exposures and other experiences. It is also 'structuring' because it shapes our ongoing engagement and interactions with the social world in the present, thereby shaping future practices. The dispositions habitus produces last over time (durable) and can be used in a variety of circumstances (transposable) to create social action. The habitus is structured by past and present conditions but through its generative properties sustain practices, beliefs and perception in the present and shape the beliefs, perceptions and actions about the future.

It is important to realise that Bourdieu's habitus does not see human actors as robots pre-programmed to behave in a certain way because of their upbringing and experiences, stripped of individual and collective initiatives, rather Bourdieu submits that there is 'an unconscious relationship' (Bourdieu 1993 p.76) between a habitus and a field. Bourdieu (1986) argues that practice results from the relations between one dispositions (habitus) and position in a field (capital), which is the social arena of contest (field). To understand Bourdieu's theory of practice and effectively deploy it in studying and explaining social phenomena, one needs to appreciate the relationship between the three thinking tools of habitus, field and capital. It is the relationship between the physical and social spaces social actors occupy that produces practices. Simply put, the habitus encompasses one's history, way of feeling, thinking, how being comports itself in the world including how we interject the past into the present and see the future. Human actors continually engage with and seek to change the world but without control of all the forces at play.

In an ontological sense, our present view of and relations with the world is defined by our past. At any point in time, social actors have multiple choices and alternative paths to the future but our dispositions shape not only the choices we make but also the future we can perceive. Human actors do not and cannot see likely paths to a future that is not informed in part by their habitus. Experiences from the past help shape vision of the future and limit the range of options available in the present looking into the future. The choices made in the present delimits possible future options since a choice implies alternatives rejected, or possible future paths deemed unacceptable or unrewarding. Although durable and transposable, the structures of habitus are not immutable or ossified in time and space. The contextual landscape in which the field of struggle is situated is dynamic and ever changing. As individuals, groups or institutions interact with the changing contextual landscapes, the habitus co-evolve, empowering ability to adapt, altering the course of the future and creating new possibilities for actors to contemplate and articulate. Understanding how a field evolve along with situated actors their habitus within the field helps to understand the dynamics of practices (Bourdieu 1990, 1991).

The habitus links the past, present and future by bringing together the individual and the social, subjective and objective, structure and agency under the umbrella of a coherent analytical framework. The habitus brings together the objective 'outer' world and the subjective 'inner' world by showing how the subjective internalises the social world which in turn becomes embodied in the conduct of social agents influencing interactions and practice. In bringing together the objective social structure and subjective personal experiences through habitus, Bourdieu seeks to transcend the dichotomy of the individual and the social world and provides a mechanism for understanding subjective pathways through which actors make meaning by focusing on the underlying principles generating practices (Bourdieu 1993). Habitus functions as an explanatory tool to understand practice in the way it helps to explore the relationship between relational structures of habitus and field as mutually constituting and co-evolving.

How does the concept of habitus enrich research into entrepreneurship? One can argue that habitus provides an epistemological account of the social world that is not bounded by the dichotomy of structure and agency, but explains the nature of how structure and agency interact. More importantly, habitus provides us with a lens with which we can re-examine the world and our taken for granted assumptions about its inner workings and dynamics. By stressing the relational mode of thought, habitus allows us to delineate new boundaries of social interactions and actions, explore new meanings and transform our understanding of the co-evolution of individual actions and social practice.

As Maton (2008) argues, habitus allow researchers to retain analytical integrity of structure and agency whilst being able to relate them to each other. In other words, habitus has the power to transform our understanding of the social world and the researcher. Habitus is not without limitations or weaknesses. It is too elastic and slippery that can be applied to almost any situation if the researcher is not discerning (Davey 2009). Notwithstanding these limitations, it is a powerful conceptual tool for examining transformation and innovation; exploring what entrepreneurship is and what entrepreneurs do taking into account the contextual landscapes in which technical innovation construction (the game).

3.3 Context as dynamic and emergent phenomena

In reviewing Giddens' ST and Bourdieu's habitus, context is a recurring and ever abiding presence. Context is implicated in the social structure of Giddens and also manifestly implicated in the way agents deploy habitus to suit particular circumstances. A critical question to ask is why is it important to contextualise entrepreneurship? How does contextualising entrepreneurship increase our understanding of the phenomena and associated processes? In management research, context refers to circumstances or conditions external to but can enable or constraint a phenomenon; the settings or circumstances in which an event occurs (Welter 2011). Capelli and Sherer (1991) present context as surroundings associated with a phenomenon while Johns (2006) sees context as situational opportunities and constraints that affect behaviour. These different dimensions and descriptions of context suggest that it is varied and multidimensional. Context is important because it has the power to empower and constrain individual action; allow individuals to develop opportunities but also delimits the boundary of what is possible and acceptable within a socio-economic and cultural context. Welter (2011) argues that individuals may experience context as an asset or a liability, therefore submitting that 'context is important for understanding when, how and why entrepreneurship happens and who becomes involved' (p.166).

Low and Macmillan (1988) argue that economic behaviour can be better understood when contextual factors are taken into consideration. Contextual factors such as social (Granovetter 1985), spatial (Katz and Steyaert 2004) or institutional (Polanyi 1957) can also be critical in understanding economic behaviour and entrepreneurial action. In recognition of contextual factors, Gartner (1995) argues for considering the role of context in entrepreneurship research to counter the bias that arises from underestimating influence of external factors and overestimating role of internal factors in making judgement about the behaviour of others. Considering the spatial dimension, Baumol (1990) recognises that rules for entrepreneurship changes depending on location.

Whettern (1989) recognises this multidimensional aspect of context by introducing the 'who', 'where' and 'when' dimensions of context. Although who is an entrepreneur is an interesting theoretical question, the ‘who’ in relation to context helps us understand the impact of context on entrepreneurs and entrepreneurship. ‘Where’ in relation to context can refer to business, social and/or institutional context. In the literature, business context refers to how industry and market conditions impacts on entrepreneurship. Social context on the other hand includes the effect of networks, household and family members while spatial context refers to physical business location and support infrastructures, characteristics of local and regional communities. Institutional context often refers to culture (societal attitudes and norms), political and economic system (policy, support measures, legal and regulatory framework).

Recognising that context also cuts across levels of analysis allows researchers to pay attention to different levels of analysis; to the direct and indirect influences of context on entrepreneurship as a phenomenon. For example, Welter (2011) shows how institutional and social contexts determine gender roles within families and help explain why female entrepreneurs start in specific, low-income industries in Uzbekistan.

The social network approach is the most common application of context in entrepreneurship research since it is a source of capital, information, future clients, potential customers, and different types of support. Researchers have explored the different dimensions of context in entrepreneurship research such as social (Davidsson and Honig 2003; Drakopoulou-Dodd and Anderson 2007; Fletcher 2006), societal and spatial contexts (Welter, Trettin and Neumann 2008), and demonstrated they are intertwined and implicated in the phenomenon of entrepreneurship.

Although formal institutions are creations of human actors, they are embodiments of political and economic rules which create or restrict opportunities for entrepreneurship. In the same way, informal institutions including rules, norms and attitude of a society influences what is deemed as entrepreneurial opportunities as well access to resources and how opportunities can be exploited. These rules, norms and attitudes can manifest in the way society ascribe value to entrepreneurship or the social approval or disapproval of outcomes of entrepreneurship process. Research on formal institutions shows how changes in regulatory framework (Davidsson, Hunter and Klofsten 2006; Klapper, Lewin and Delgado 2009), technology and political forces (Shane 2003) can influence occurrence of new opportunities. Research into informal institutions have focused on understanding entrepreneurship as a socialised process influenced by society but that also changes society, demonstrating the recursive link between entrepreneurship and its contexts. This treatment of entrepreneurship as a social change allow researchers to move beyond purview of heroic entrepreneurs (Ogbor 2000) to embrace a wider community of social actors who engages in entrepreneurship bounded by socio-spatial-economic and cultural boundaries of their locations.

Context, as previously argued, has empowering and constraining influences. A lot of the work in the academic literature focus on deepening our understanding of how context shapes individual actions and influence outcomes of entrepreneurial actions. Most of the research papers focus on positive aspects of context. However, context has a darker side that can inhibit and stifle entrepreneurial action. Welter (2011) argues that spatial proximity can contribute to 'over-embeddedness' where embedded ties can be used as a controlling mechanism. In the same way, individuals can use the links between spatial and social contexts, which normally help to develop trust between parties, to create 'closed' local networks that preclude outside participation and prevent change.

It is clear that context is dynamic and constantly unfolding along with human action and choices. Without doubt, it has capacity to enable or constrain action depending on how individuals engage with the context. Through habitus, individuals can reach into the past to find generative actions suitable to particular fields or transpose previously successful scripts to a new context. Therefore, one could argue that context informs habitus, shaping dispositions of individuals, and it is the milieu of structure and agency.

3.4 Knowing and Reflection in Action

In the previous sections, an exploration of social theories in explaining innovation has been presented. In this section, a brief overview of the technical dimension is undertaken to make the point that social and technical factors are inseparable if we are to properly understand innovation. To do this, a brief summary of the Technical Rationality model is presented as the most appropriate model for exploring the issues of interest in this research. Why the Technical Rationality model of instrumental problem solving instead of any other explanatory framework in the context of innovation construction? At its heart, a technical innovation process is about problem solving using scientific knowledge and practices. However, in opposition to simply applying means to an end, the arguments explored to date in this thesis show that individuals including engineers come to the innovation space with different habitus and alternative constructions of problems and solutions. The underlying theories and disciplines of engineering can only be applied to a particular problem after there is a social agreement of the nature of a problem. The ends that are possible to pursue are also constrained by the rules and norms of what is deemed socially acceptable, legitimate and grounded in prior experience.

Schön (1983) presents an exposition of the dominant epistemology of practice that is based on the Technical Rationality model of instrumental problem solving through the application of scientific theory and practice. Schön argues that systematic knowledge base forming the foundation of professional practice is predicated on 'specialized, firmly bounded, scientific, and standardized' (p. 23) types knowledge. Professionals are assumed to apply very general principles and standardized knowledge to concrete, real-life problems. Schön identifies three components of professional knowledge, which are:

1. An *underlying discipline* or *basic science* component upon which the practice rests or from which it is developed.
2. An *applied science* or "*engineering*" component from which many of the day-to-day diagnostics procedures and problem-solutions are derived.
3. A *skill and attitudinal* component that concerns the actual performance of services to the client, using the underlying basic and applied knowledge.

Implied in the list of components is a hierarchy in the level of knowledge moving from basic science to applied science that in turn yields diagnostic and problem-solving techniques that are applied to deliver services. Given what we know about innovation, this same hierarchy of knowledge and application applies to innovation construction. According to Shils (1978) knowledge is only acceptable if it rested on empirical evidence, rigorously criticized and rationally analyzed. According to the Technical Rationality model, research is separate from practice and only connected through defined exchange mechanisms. In other words, knowledge from pure science is different from knowledge derived from practice, from the application of scientific principles. But what is wrong with this view of professional knowledge? The answer to this lies in the history of philosophy. Technical rationality is an offshoot of the Positivist epistemology of practice.

This rather neat delineation of and graduation between knowledge levels and dependencies is far from the day-to-day experience of practitioners. Since the Reformation, human progress has been inextricably and relentlessly linked to the pursuit of scientific research and accumulation of knowledge. Professional practice has developed as a way of applying scientific knowledge to addressing human problems and adapting nature to human needs thereby charting the course of human progress. To the Positivists, empirical science was the only source of positive knowledge and all disagreements about the world can be resolved by reference to observable facts. Propositions that are neither analytical nor empirically testable are deemed to be meaningless. These assertions fail to recognise that human observation is biased and conditioned by experience since human actors are never disinterested observers of the empirical world. Over time, as science developed referring to scientists, Schön (1983) submits that 'They began to see laws of nature not as facts inherent in nature but as constructs created to explain observed phenomena' (p.33) based on current understandings leading to the hypothetico-deductive system of scientific investigation. Science has moved into an era of using experiments to choose between competing hypotheses of explaining observable world.

The Technical Rationality model of instrumental problem solving differs from hypothetico-deductive model of research investigation because practical knowledge cannot be reduced to a form of descriptive knowledge or to analytical schemas to be resolved through logic and mathematics. In recognition of this dilemma, Positivists solve the puzzle of practical knowledge by construing practice as 'knowledge of the relations of means to ends' (Schön 1983 p. 33) reducing practice to simple instrumental concept. If the desired end is known then a problem can be reduced to an instrumental question of which means is best suited to achieving desired ends. Although this approach has dominated professional practice until this day, it must be borne in mind that ends are not independent of social actors including scientists and engineers but contingent on context, understanding and sense-making. Actual practice is laden with complexity, uncertainty, incomplete information, uniqueness and do not conform to the model of Technical Rationality that sees professional practice simply as a process of problem solving. The focus of Technical Rationality on problem solving ignores problem setting since problems are constructed from the available materials of situations human actors deem puzzling, troubling and uncertain.

This short but important detour is to demonstrate that the application of scientific principles and knowledge in solving day-to-day problems for engineers is both technical and simultaneously social. While scientific principles may be universal, the choice of how to solve a problem and picking the most suitable tool depends on the individual and collective experiences of social actors involved in the selection. To innovate, social actors apply basic and applied knowledge to meet contingent needs of the present and accommodate the nature world.

To summarise Schön's (1983) contribution to this analysis, it is important to take on board the key concepts in his thesis which are:

a. A significant proportion of knowledge that underpins action and social life is tacit, implicit but visibly demonstrated only through our patterns of action. Most of the time social actors routinely act and do without thinking about the action in which they are engaged.
b. Knowing-in-action is a type of corporeal, embodied type of knowledge that human actors call upon to carry out routine activities and engage in day-to-day social life.
c. Reflection-in-action describes the state of being in which social actors consciously and deliberately evaluate options and make changes to plans in the flow of action to accommodate contextual surroundings and social features. Knowing-in-action allows human beings to call upon their bank of experience to deal with unfamiliar situations. Although an advantage in handling uncertainty, knowing-in-action can

draw human actors away from thinking and critically re-examining their taken-for-granted assumptions.

d. Dealing with uncertainty is foundational to what makes an individual a reflective practitioner. Knowing and reflection in action allows human actors to expand their cognitive horizons, accept new ideas, take and experiment with risks and deal with unfamiliar situations. Through the use of experience and stock of knowledge, human beings can call upon a library of scripts to deal with challenges and problems of the moment. The reflexive practitioner, who practices knowing and reflection in action, is able to sidestep the trap of experience, recognise new situations, and avoid a dulling of his or her creative abilities.

This leads nicely to how social actors recognise the need to innovate. What in the environment act as triggers to seek new arrangements and combinations? In the next section, we draw on Heidegger's explanation to gain new insights about innovation.

3.5 Technology Artefact as 'Ready-to-Hand' Equipment

In various ways and at various points in preceding pages, innovation has been presented as a social product that is socially constructed. In this section, the concept of innovation will be explored using Heideggerian's perspective of different modes of being and what insights we can gain from such exploration. Borrowing from Heidegger's *Being and Time* (1963) a case will be made to show that technical innovation is a product of human understandings and how we relates to the world in which we find ourselves.

According to Heiddeger (1963), we first encounter worldly objects as available, ready-to-hand rather than entities or things with meaningful objects with causal relationship in our day-to-day engagement with the world. These ready-to-hand objects manifests as 'things of use' and can be deployed in everyday activities. Ready-to-hand equipment is pressed into use unreflexively, without thought. The context and purpose of ready-to-hand equipment is largely learnt through social engagement with other agents in a particular socio-economic and cultural context. In the occurrent or present-at-hand mode of being, objects show up in our consciousness because they have inherent properties with latent potential and capable of exercising causality in our engagement with the world (Chia and Holt 2006; Nayak and Chia 2011).

To understand technology as 'ready-to-hand' equipment, it is first important to summarise some of the key ideas from Heidegger's *Being and Time* that underpins this argument. The understanding of Heidegger's ideas and how they inform this investigation about innovation construction is summarised as follows:

- Human beings are bound up in the world not because of the way we think but because we engage with the world in different modes. Therefore the way we think about the world depends on the answers that we sought, an approach that led Heidegger to make the distinction between ontological questions (ways or mode of being) and ontic questions (properties of being).
- Human beings understand the world to which they interact as a practical holistic context and this understanding allows human beings to make sense of the world
- Making sense of the world requires people to understand and make connections (projecting onto possibilities) that are intelligible to themselves and others, therefore meaning at individual and social level is central to social action.
- The breadth and scope of imagination of social actors is constrained by what others can understand and accept based on social rules, norms and prevailing practices. In other words, what can be projected as possible is normatively constrained and legitimated.
- Understanding the world requires us to understand the structure of the world and the way entities relate to each other to form a complex structure of relations and inter-dependencies. It is within these structure and interdependencies that human actors move between different modes of being.

In *Being and Time*, Heidegger shines a light on our unreflective understanding of the world by pointing our attention to different ways we see and apprehend the world (Dreyfus 1990). According to Heidegger, the first sense of the world we should be aware of is to see the totality of entities that can be present-at-hand or what he refers to as seeing in the ‘ontic-categorial’ sense. In the ‘ontic-categorical’ sense, we are concerned about a universal set of all that is possible independent of whether we understand them or not. In the second sense, human actors are concerned with and become aware of the various categories that make entities what they are. Through our awareness of different categories of things and objects, we structure our understanding of these entities and their place in the world. This is what Heidegger refers to as the ‘ontological-categorical’ sense of the world. In the ‘ontological-categorical’ sense, we classify entities into groups based on their meeting certain necessary conditions and possessing certain properties. The third sense of the world is what Heidegger calls ‘ontic-existentiell’, a mode describing how human beings live as engaged, practical beings in different contexts. In the ‘ontic-existentiell’ world, human understandings and actions are constrained by norms and practices. Finally, the fourth sense of the world is the sense through which we make sense of complex relationships between entities and their order in the ontological framework of the world.

Why are these ways of seeing the world important in our engagement with and understanding of our place in the world? It is because the way we see the world structures what we see, what we think and what we can imagine as possible. Our understanding of the world we live in and our interpretation of that world thereof are important resources we call upon when confronted with situations for which there are no readily available recipes for resolution or action. As human beings, the more extensive our understanding of the constituents of universal set of present-at-hand entities, the greater the range of entities we can co-opt or seek to re-arrange when we try to create new combinations or improve existing situations.

To understand the world, we need to be practically engaged with the world and know how entities inter-relate or hang together. To be practically engaged with the world, it is not enough for human beings to simply exist in the world, it is equally important that human beings can change their environment, exhibit agency within the rules and norms of what is possible and intelligible. Human beings make sense of the world by bringing together understanding of the structure of the world and how entities in the world relate to each other. Context is and always will be an abiding presence in human understanding of the world. Heidegger argues that in our demonstration of understanding the world, human beings exhibit practical orientation toward the world in a way that presupposes that the world is minimally understood as a whole. In other words, human beings understand how entities relate to each other including the rules and norms operating within a prevailing system of intelligibility. We understand the world as an interrelated set of entities to which we relate and help constitute through our interpretation of and engagement with it. The understanding that we demonstrate is therefore inextricably bound to a context.

Generally, people make sense of the world through their understanding of the prevailing rules, norms and practices by ongoing self-interpretation. The interpretation of what is intelligible in certain contexts and roles allow people to engage in enactment. In this way, self-interpretation becomes a driver for agency although context, norms and range of practices delimit what is possible.

So how are these entities disclosed to human actors to which they engage in the world? Social agents operate in a meaningfully structured space of intelligibility which in turn influences the way they relate to entities – available or occurrent. When human beings are disposed to a thing or situation, it means they are 'attuned' to the thing or situation, engage in self-interpretation (understanding) of the thing or situation and know how it can be pressed into use in socially permissible ways. Entities in the world to which human actors inter-relate and engage can either be ready-to-hand (available) or present-at-hand (occurrent). When a piece of equipment is classified as available, its place within the context of other equipment is delineated and the use to which it can be put within prevailing system of meaning is fully understood. When in the *available* mode, human actors use equipment in pursuit of goals and ends unreflectively, without examination. To be *available* is to belong in the realm of the known within a particular socio-cultural context.

Human beings engage with the world using available equipment or entities in day-to-day engagement. There are occasions when what is deemed 'available' equipment fails to serve the purpose to which it is put or intended. It is in these situations of unmet expectations that 'available' equipment reveal their inherent '*occurrent'* qualities.

Equipment is classified as *occurrent* by virtue of their properties rather than how they are used in relation to other objects or entities. Since we engage with *occurrent* equipment based on their inherent properties rather than how they are used in particular contexts, our understanding of the world and range of possibilities for change opened to us increases if we see things, objects, and entities as *occurrent*. Once we see the world as a space of intelligibility in which equipment can exist in either '*available*' or '*occurrent*' mode depending on context and circumstances, the logic of our understanding and the meanings that flow such disposition lead us to accept that the use and purpose to which we put entities are co-constructed. The understanding that entities can be seen as '*available*' or '*occurrent*' depending on context open us up to the acceptance that the process of arranging entities to achieve new, previously unavailable tasks, goals and ends (another way of looking at innovation) is fluid, dynamic and socially constructed.

The norms that govern what we can do are available to everyone, therefore our space of intelligibility is social in character and content. Conforming to the world allows actors to make decisions without the need to explain in the knowledge that other parties understand our actions. Heidegger contends that being-in-the-world implies skilful demonstration of practical coping techniques by social actors. In the pervasive presence of the 'one', the social other to whom an individual relates, how do individuals retain their individuality and still exhibit agency? In line with Heidegger, our response to this question is that social actors retain the ability to use their understanding and interpretations to 'project' particular interpretations or situations based on the generalised understanding of what is permissible. It is in the understandings and interpretations that individuals create space for something new based on what-can-be or have ability-to-be. It is through this understanding that individuals exhibit agency (Heidegger 1963).

Entrepreneurs engage in innovative act, enact situations differently from previously accepted way of doing things, and act as agents of change. If one is to extend Heidegger's argument, one could argue that entrepreneurs need to engage with and relate to the world in a way that demonstrates that they understand things, objects and entities for what they truly are. That is material objects should be seen as *available* or *occurrent* depending on circumstances. With this understanding, entrepreneurs see the ‘occurrent’ character of objects and entities and can project different possibilities by exploiting the potential combinations of entities, matched to particular contexts, to serve needs and purposes. It is not sufficient that entrepreneurs have cognitive mastery of the process and can articulate what ends to pursue, it is equally important that entrepreneurs can rearrange and exploit *occurrent* character of resources and materials to achieve new ends in a manner that is not completely unfamiliar to others and respectful of prevailing rules, norms, procedures and practices in the socio-cultural context.

Human beings use technology to serve certain ends, therefore, to the degree that human actors use technology to achieve pre-determined or expected outcomes, technology can be seen as *available* or ‘ready-at-hand’ equipment. This conceptualisation of technology is pragmatic and functional but also limiting. Technical innovation develops in response to a need but its path and effectiveness cannot be pre-determined from the outset. The risk of failure is always lurking in the vicinity of any technical innovation. Technology entrepreneurs engage with a range of actors to develop technical innovation to meet defined need or solve a problem or address unacceptable performance. If we accept the definition of a problem as unacceptable gap in performance (Weick 1995), then we can argue that a problem to which a technical innovation response is required is a demonstration of a failure of ‘ready-to-hand’ equipment. It is into this space of intelligibility that entrepreneurs can operate and co-create a socio-technical solution along with others by rearranging available objects, things and entities into a new order to deliver expected performance while respecting prevailing norms and practices.

Although any technical innovation can be seen as ‘ready-at-hand’ equipment within the context of its use, looking at the process of technical innovation allow us to see ‘available’ and ‘occurrent’ entities as starting point for technical innovation product. The occurrent character of entities and objects presents entrepreneurs with a vast canvass over which a number of possibilities can be explored and viable concepts developed for exploitation whilst respecting prevailing rules and norms of intelligibility in a particular context. Since true innovation involves deploying resources in new ways or rearranging resources in ways previously unknown within a particular context, it can be argued that all innovations in the early phase rely on some ‘occurrent’ character of entities, objects and things because of their inherent properties. The process of technical innovation construction allows entrepreneurs and other social actors to 'mould' these occurrent characters of entities, objects and things into a product that is capable of resolving identified performance gaps. What emerges as technical innovation that can bridge identified performance gap is a socio-technical product deployed to achieve an end, and if successful, attain the status of ready-at-hand equipment whose place is now delineated, the types of uses to which it can be put is now known, its purpose is now clear and available to be used without reflection.

It has been argued that innovation is social in character and the need for innovation is recognised from a change in the way human actors are engaged with the world and how material objects are disclosed to us. When the use to which actors put equipment breaks down, and a need for innovation is recognised, there is no clear path to how innovation should develop. The transition from recognising a need for innovation to production of technological artefact can be tortuous, unpredictable filled with pitfall and dogged by incomplete information. To move from the moment of recognition to creating a platform of shared understanding around which joint action can be developed requires skills and coordinated social action. In this next section we explore how sense-making help us understand how different actors develop shared meaning from fuzzy situations.

3.6 Entrepreneurial Agency and Sense-making

Sense-making occurs when individuals or groups transform circumstances into meaningful situations that can be comprehended and shared with others in words or other forms of communication thereby providing a foundation for social action (Weick and Sutcliffe 2005). The process of sense-making allows individuals to jointly develop shared meaning and create the social space for coordinated social action. Technology is endowed with potential for multiple interpretations influenced and shaped by social factors and organisational context of action (Weick 1995). The variation of and multiplicity in meanings associated with technology-in-use is also be true for how people frame the need for, construct acceptable technical solution, and ultimately decide whether or not a technology artefact is worthy of consideration and trial.

In this research, sense-making is presented as a conceptual tool that helps bring together the different elements that make up the innovation construction process. Weick (1995 p.17) outline the main elements of sense-making as:

1. Grounded in identity construction.
2. Retrospective: that is, it allows us to understand meaningfully lived experiences and "capture the reality that people can know what they are doing only after they have done it".
3. Enactive of the environment: social actors in part produce the environment into which they are immersed. We take sensory cues as data or inputs from which we generate information that fit our concept of situation
4. Social: our understanding of ongoing events is created in the presence of others or our decisions made in the knowledge that outcomes will be influenced by others.
5. Ongoing: people are always in the middle of things, therefore sense-making is forever ongoing in a continuous flow of time.
6. Focused on and by extracted cues: strongly influenced of context, human beings notice and interpret cues to make sense of the environment. By corollary, cues we do not notice have no significance in our understanding and construction or reality.
7. Driven by plausibility rather than accuracy.

Sense-making explains how we create the basis for meaningful action out of interactions with social others and the environments and in the process cognitively integrates multiple interpretations into existing schema with a common frame of reference. Innovation by definition embodies change with promise of progress but pregnant with ambiguity and uncertainties. Therefore, when users reject any technical innovation, it may not be necessarily be due a culture of risk averseness but it could be due to perceiving change and its consequences through different lenses compared to frame of reference the technology developer(s) is/are employing.

As Weick (1995) explains, sense-making is retrospective where human actors seek plausibility rather than accuracy. Because sense-making is grounded in identity construction, and our identity is created and sustained in relation to and in conjunction with others, then sense-making is a social process. These features of sense-making makes it an ideal theoretical tool to examine the nature of social interactions and process of technical innovation emergence because technical innovation is pregnant with ambiguity and uncertainty, holds multiple meanings and interpretations for different actors as has been previously argued. Before users can accept any technical innovation they would have accepted the inadequacy of existing tools or equipment and the need for change. However, before users' commitment to change can be secured, individuals and groups must develop a shared meaning, understanding and expectation of what the innovation entails based on a common frame of reference.

As an alternative explanation, sense-making allows us to understand how we create the basis for meaningful action out of interactions, act in concert with social others and calibrate our responses to the environments while cognitively integrating our understanding into an existing schema. Innovation embodies change with promise of progress but it is inherently risky with an uncertain outcome. When users reject any technical innovation, it may not be necessarily be due a culture of risk averseness but it could be due to perceiving change and its consequences through different lenses compared to technology developers. Sense-making allows us to explore how social actors engage in the innovation process, coordinate multiple interpretations and create the basis for social action. Through this theoretical lens, we are able to peep into the underlying processes of decision-making and social information exchange that would otherwise have been opaque to critical analysis needed to understand the drivers of this social process. In making choices, the desire to reduce discomfort associated with multiple alternatives forces people to choose familiar solutions they are comfortable with while accentuating the negative potentials of unfamiliar alternatives. Through the process of sense-making, social actors can create shared understanding, attenuate the impact of bad experiences from the past, change negative perceptions about innovation among end users and collectively implement change (Balogun et al. 2005).

From a definitional point of view, a problem is a discrepancy or gap between what exists or deemed unacceptable and what is expected or desired that needs to be bridged.

Alternatively, a problem is a gap, a difference or disparity between the way things are and the way they ought to be (Weick 1995, 2004). Problems are characterised by the existence of gaps that are difficult to fill but must be filled because bridging the gap is expected to lead to desired consequences. Since what constitutes a problem depends on the difference between current conditions and a desired future state, what is seen as a problem will depend on who defines it and the prism through which he is looking at the world. Therefore as Weick (1995) argues, problems are conceptual constructs reflecting current understanding of realities and prevailing preferences. A problem, whether invented or constructed, is only meaningful to the collective if it the context and constrain defining the problem respect how it can be solved. In other word, problem framing is a subset of sense-making.

In creating and selecting options to consider as potential solutions, human actors try to avoid cognitive dissonance by relying on heuristics (Sandri 2009; Tetlock and Skitka 1989) or adopting previously effective solutions from similar but not identical circumstances. The desire to reduce discomfort associated with their choices forces people to choose familiar solutions they are comfortable with while accentuating the negative potentials of unfamiliar alternatives. This is a challenge for any technology entrepreneurs because any solution advocated must overcome the residual influence of what others are familiar with from the past. In the sense-making process, entrepreneurs must reduce the amplification of bad experiences from the past while increasing the comfort levels others have towards any new solution.

Sense-making asserts that one sees what one expects to see, therefore the cues we recognise are not unfiltered but deceptively presented to us as environmental inputs for decision making based on what we know, familiar and comfortable with (O'Leary and Chia 2007). Because human beings are presented with overwhelming amount of information at any time, we consciously or subconsciously choose what cues to notice. The cues an individual accepts are integrated into our schema and those ignored do not exist for practical decision making. As human beings we strive to avoid cognitive dissonance by ensuring that the cues we accept are those that fit into our assumptions and frame of meanings. The cues we use are sources of ideas and help us tie disparate and seeming unrelated elements together cognitively. Context affects both cues we extract from the environment and how we interpret the cues. Therefore, when we reconstruct the past, the flow of events is always different from the way it is remembered (Bartlett 1932). This is why sense-making is not infallible because it can lead to incorrect understanding and misrepresentation. Human actors can lessen the chance of incorrect understanding by disclosing and sharing with others, the cues informing their understanding and the basis of their interpretation.

An acceptance of technical innovation implies an acceptance of the need for change or inadequacy of existing tools and equipment. Before users' commitment to such change can be secured, individuals and groups must develop a shared meaning, understanding and expectation of what the innovation entails based on a common frame of reference. Sense-making allow us to peep into the underlying process of decision-making and social information exchange than would otherwise have been opaque to critical analysis.

The decision to accept or reject technological innovation can be construed as a socialised decision. Individuals within organisations carry two simultaneous identities, as individuals and members of a group (Weick 1995). Human actors create meaning by fusing the past with the present because sense-making is retrospective. Several antecedents precede an action but the stimulus to which we attribute the meaning it holds for us is central to our understanding and subsequent action. Since the stimulus we choose is influenced by context, therefore the meaning of an action cannot be separated from its context.

The self is created and defined in relation to the presence of others, therefore, decisions human beings make are not made in isolation but under the influence of what others might think because we all constantly try to shape the way others see us. This may explain the common complaint from entrepreneurs that end users are too comfortable in making group decisions thereby slowing the pace of technical innovation construction. Recognition of how the presence and influence of others looms large in the thinking of decision makers can help entrepreneurs develop appropriate tactical responses fitting to different contextual situations.

Sense-making argues that people in part, consciously or subconsciously, enact part of the environment they respond to. Resistance to an action may be a manifestation of divergence or misalignment of interest, therefore consciously or otherwise, organisational decisions are made in the presence of and with the knowledge of others, what they might accept as part of the contextual factors in the background. It is therefore safe to argue that decisions are never acts of individual agency but products of social engagements and are socially legitimated. If using sense-making as a conceptual lens, it is important to pay attention to discourse and conversations because these are media through which social contact is enacted.

Innovation of any sort has different meanings for different individuals because people because of different histories and social roles in the innovation process that impose or demand different expectations of the individuals. Consequently, individuals in different roles are bound to have different motivations and interests. In the technical innovation process, individuals make different assumptions about the need, application and suitability of any technical innovation. Proponents of sense-making argue that one sees what one expects to see, therefore the cues we recognise are not unfiltered but deceptively presented to us as environmental inputs for decision making based on what we know, and are familiar and comfortable with. While accepted cues are integrated into our schema, rejected cues, for all practical purposes, do not exist. To avoid cognitive dissonance, we accept cues that fit into our assumptions and frame of meanings (Mark 1998; Weick and Sutcliffe 2005; Weick 1995). In making decisions about technology, social actors seek many cues but often rely on familiar cues for information ordering, complexity reduction, analysis and decision making. Therefore, to engage and persuade others to accept and support a technical innovation, entrepreneurs must seek ways to enter into the social worlds of end users and decision makers and seek to influence the set of cues upon which they construct their meaning and base their decisions.

We face ambiguity when the flow of information supports different interpretations simultaneously with potential to constrain or enable action depending on which interpretation is chosen. While some ambiguities can be resolved through social construction of alternative constructs or narrative for sense-making, others can only be resolved through scanning for additional information to minimise uncertainty (Weick 1995). Funtowics and Ravetz (1990) describe uncertainty as a situation of inadequate information and could take the form of inexactness, unreliability or ignorance. Uncertainty is not just the absence of knowledge because uncertainty can exist even in circumstances when there is a lot of available information. Circumstances may arise in which additional information or access to new knowledge increase uncertainty as new information help uncover new uncertainties or show current or previously held understanding to be limited or simply wrong. With additional information, residual uncertainty can be transformed into risks allowing actors use of familiar decision making tools or heuristics or previously successful scripts. Huber and Daft (1987) contend that when managers are confronted with ambiguity or confusion, they use language to share perceptions among each other and create meaning through discussions, experimentation and joint interpretation. This is an example of how actors can use active language to create new understanding and reality (Pettigrew 1997). This study submits that technical innovation construction employs similar problem solving framework.

With insufficient information and attendant ambiguity, it is quite possible for entrepreneurs to mistake a problem (performance gap) that calls for additional information to establish common understanding and problem framing as a situation that can be resolved by a technical innovation. In these types of situations, innovation could easily be deemed unsuitable by end-users because they have yet to fully process cues and agree on the best way of dealing with emerging and ill-defined problems. In an extreme case, entrepreneurs could develop a technology for a problem users either do not recognise or considered the performance gap sufficiently worthy of a search for a new solution. The idea of 'creative destruction' and how new products or technology displaces existing ones implies that there must be the right time and supporting environment for new technology or product to emerge. In a broader sense, Schumpeter's creative destruction is a good example of human agency using inherent occurrent qualities of entities to create new combinations and potentially change practices.

The process of sense-making allows individuals to jointly develop shared meaning and create the social space for coordinated social action. To understand the contextual environment and how timing might affect entrepreneurial opportunities, we need to understand the dynamic forces at play in the process. Timing is important because it helps entrepreneurs understand when to transition from exploration to exploitation (Choi, Levensque and Shepherd 2008). Although the contention is not that timing is an unimportant factor in the technical innovation process, rather the argument is that recognising when there is sufficient information around which a common frame of meaning and sense-making can be built is equally very important.

3.7 Conclusion

In this chapter an exploration of the relevance of different social theories and how well they inform our understanding of who we are as social agents and why we act in the way we do. The understanding of how socio-cultural and economic contexts influence social action and choices agents make is critical to understanding possible paths of innovation emergence and construction. Social theories such as ST and Habitus have been shown to offer useful insights into the interactions and dynamic between agents and social structure. It has been shown that elements of the social structure are not immune to change, but require dexterity and social awareness to transform seemingly inhibiting elements of social structure into enabling agents of change and transformation in the innovation process.

It has been shown that social reality and human agency are interwoven and intimately bound together with each shaping the other in the process of becoming. Bourdieu's habitus allows us to explore how the past come to be internalised and shape the present in our interaction with other social agents. Both ST and habitus are limited in helping us gain deep insight into the origin of innovation construction because they do not explicate how individual reality is constructed nor explain adequately how and when individual reality changes in the process of meaning-making. Heidegger idea of modes of being and how we engage with the world has been presented as a conceptual bridge to help close the gap in our understanding. By understanding how our modes of being influence what we recognise and to what use we put objects and entities we come into contact with, a platform has been created from which we can investigate how and when innovation becomes important to individuals and groups. Using a sense-making perspective, we see how that awareness is constructed in retrospect and used to manage uncertain and ambiguous situations.

The focus of this thesis is to shine light on the process of technical innovation construction and how particular discursive practices combine with contextual factors to help produce meaning (Creed, Scully and Austin 2002; Heracleous 2006b), and in so doing, lead to production of technical artefacts. The foundation presented in this chapter will be used in the next chapter to develop the conceptual framework for this study.

Chapter 4

Conceptual Lens of Theoretical Framework of Research

4.0 Introduction

Discussion in the preceding chapters has established the foundation to the claim that innovation is not only a social product but emerges from an assemblage of interpretations around which a set of actors have created a coherent framework for action. In place of the linear view of innovation, the process view of entrepreneurship has been shown to be more representative of the actions and interactions that mediate innovation construction. The language of change, action and novelty indicates an orientation towards something in flux and changing with time. We can construe innovation emergence and construction as a process through which entrepreneurs act across spatial-temporal boundaries, creating and extracting value from different classes of assets and resources, bringing the past into the present and creating a bridge to the future through mental representations. In this vortex of change, entrepreneurs link the universal to the specific by selecting appropriate interpretations to match prevailing circumstances and suitable contextual conditions.

Argument has already been presented in support of the contention that entrepreneurship is socially constructed where social interactions shape, mediate and facilitate social action. Innovation is an outcome of such interactions, through which new forms emerge, combining resources to create artefact that offer new utility or enable new capabilities hitherto unavailable (O'Connor and McDermott 2004). Although newness and new capabilities are important characteristics of innovation, usefulness of technology artefacts and risks associated with innovation are just as important to end users (Oh, Anderson and Cruickshank 2012).

In this chapter, a conceptual framework is developed grounded in social constructionism but borrowing from a number of social theories discussed in chapter three to create the scaffolding for exploring the social forces driving innovation construction. The conceptual framework acknowledges the limitation of a number of social theories taken individually to explain the social processes involved in innovation construction. However, by combining some of these social theories and addressing some of their individual limitations, a conceptual framework is developed that traces the genesis of innovation to how human actors engage with the world and its subsequently development through a complex human-to-human and human-to-context relationships at the innovation site. The innovation site in this study is conceptualised as a site where material objects are not encumbered by the meanings invested in them through routine practices and unreflexive, day-to-day engagement with the world.

4.1 Social Construction of Reality

The 'social construction of reality' is a term first used by Berger and Luckmann (1966) to describe the shared processes and socially negotiated set of understandings that underpin social life. Social construction argues that individuals and groups in their social relationships create mental representations and concepts that become habituated in individuals and subsequently reproduced in social actions thereby becoming institutionalised. Berger and Luckmann (1966) argue that the beliefs, concepts and knowledge that individuals and groups have of social reality are embedded in institutions, therefore the reality that social actors operate under is socially constructed.

Interpersonal understanding – our ability to locate the meaning behind other peoples' actions and words – is central to social interactions and relations. Language is an important component of social reality because it is the medium through which individual or shared knowledge is communicated and located within a socially recognised system of meanings. Gergen (1999) encourages us to see and treat interpersonal understanding as the interplay between the individual and social practice. This is a more expansive and elastic approach that encompasses the eclectic range of practices and actions social actors engage in and consistent with Bourdieu (1997) logic of practice. This approach locates meanings firmly in the realm of social interactions and practices suggesting that meaning is a social product which becomes recognised and actionable when socially legitimated (Schmidt 2006) and meaningful when acknowledge by others.

Social constructionism helps us understand the nature of social interactions that underpin social life including entrepreneurship and its capacity for economic and social transformation (Lindgren and Packendorff 2009; Chell 2000; Fletcher 2006). This view raises the issue of whether we can understand these complex processes and sub-processes by adopting an objectivist's stance and making use of quantitative techniques. Lindgren and Packendroff (2009) argue that investigation of entrepreneurship through scientific, statistical methodologies assume a dualist world where entrepreneurs, opportunities and technologies are seen as independent of each other. However, these statistical methodologies are designed to establish causal relationships thereby reducing complex social interactional processes like entrepreneurship to statistical correlations which seem inadequate to enrich our understanding of the complex web of relationships that drives innovation and entrepreneurship.

Steyaert (1997) argues that research into entrepreneurship should be aimed at understanding the social interaction processes, the emergence and manifestations of social relations by asking questions of 'how' and 'why'. The 'how' questions allow us to explore the processes and social mechanisms that underpin social phenomenon while the 'why' questions allow us peep into the intersubjective world of social actors engaged in the phenomenon of interest. As previously argues from a social constructionist's view, technology is socially constructed and only meaningful insofar as people are ready to endow it with meaning (Fletcher 2006), acquiring purpose by virtue of its referential relations to its surroundings and how human actors deploy it as ready-to-hand equipment (Heidegger 1963). In adopting a social constructionist perspective, this study subscribes to the view that the actors engaged in technical innovation construction create the reality they perceive and operate within. Therefore, if the reality actors operate under is socially constructed, then this stance has ontological and epistemological implications for this or similar studies.

Through social construction, we can see and examine the links between individual constructions of sense-making to the environmental and contextual factors while paying attention on the situatedness of particular practices (Fletcher 2006). We have already established that entrepreneurial opportunity crystallises over time as the entrepreneur refines, reconstructs and transforms ideas and cues into tangible artefact with the help of, along with, in conjunction with and in the presence of others. Therefore, we can argue that even if an idea starts in an individual's mind, the process of transformation is relational because what finally emerges as an entrepreneurial opportunity is a culmination of multiple conversations drawing on relational experiences and other social interactions. Therefore, it is only by excavating the web of social interactions, network of meanings and understandings of process participants in the innovation construction process that we gain a richer understanding of what constitute a 'market gap' and why some technical innovation succeed where others fail.

Cunliffe (2008) argues that social reality is inseparable from human actors and context because social actors and social reality are interwoven and intimately bound with each shaping the other in the process of becoming. In adopting social constructionism for this study the researcher is assuming that we can understand how actors construct their reality by adopting a critical stance towards taken-for-granted assumptions about phenomena of interest. Some of the assumptions inherent in this approach include an acceptance that knowledge is a social product constructed through social processes, acknowledge the role of social interactions in exercising agency, and accept language and communication as critical to understanding how social actors enact entrepreneurship and innovation.

Social constructionism allows us to study how particular discursive practices combined with contextual factors to help entrepreneurs and their audiences produce shared meaning (Creed, Scully and Austin 2002; Heracleous 2006a). Our understanding of inter-subjectivity leads us inevitably to conclude that human actors interact and generate meanings through social interactions (Cunliffe 2008). This understanding necessarily commits the researcher to accept that there is no fixed social reality but rather, social reality is dynamic, constantly in flux, with multiple meanings depending on context of actions and prior experiences of social actors interacting at any given moment.

By implication, this ontological stance leads one to perceive everyday life as a product of social interactions and engagement with the world as social actors strive for and create socially shared meanings. In discussing the concept of inter-subjectivity, Cunliffe (2008) argues that we should accept inter-subjectivity as 'the presence of others in myself or of myself in others' so that we can see 'reality as social and relational rather than individual and cognitive' (p. 129). Our acceptance and acknowledgement of the role and influence of others in our everyday life and decision making forces us to examine how we speak and act constantly within a complex web of relationships that bring the past into the present in the active presence of social *others* (Bakhtin 1981). In taking such a social constructionist's stance the researcher admits to himself or herself that human actions and decisions are never made alone but that we are always acting as a representative of some form of a collective, consciously or by implication.

Social constructionism embraces pluralism of research methodology and takes account of the mediating role of social interactions in creating reality and meanings while giving equal weight to different constructions of meanings. This versatility makes it suitable for studying and understanding complex social relationships and provides a window into the inter-subjective web of meanings between social actors. In rejecting attempts to explain social phenomenon by searching for cause and effect relationships, and acknowledging that knowledge is tied to the subjective and inter-subjective interpretations of individuals, social constructionism remains true to the hermeneutic tradition of seeking understanding behind social action (Lingren and Packendorff 2009). This understanding commends us to place human interactions and interpretations at the centre of social reality where language is not an objective mediator of intentions but a negotiated medium of communication and transmission of interpretations.

Individuals interpret their environment and share these interpretations with others within the norms of what is socially acceptable and legitimate to create and develop entrepreneurial opportunities. Through social engagements, individuals create and re-create the reality they perceive and have to contend with in constant state of becoming. This ontology acknowledges the power of agency to create new realities without denying limiting effect of prevailing reality created by multiple of agents at a social site. This ontological position helps the researcher to appreciate what knowledge about entrepreneurship is accessible, examine how that knowledge is produced and decide what methodological tools are most appropriate for studying the phenomenon. It is in studying the unfolding processes and sub-processes of entrepreneurship that we can develop an improved understanding of change and transformational process of becoming (Fletcher 2006; Lingren and Packendorff 2009; Drakopoulou Dodd and Anderson 2007) by asking 'how' and 'why'.

In the process of becoming and within technical innovation construction, individuals shape the entrepreneurship process and are in turn shaped by the process (Downing 2005). The entrepreneur as a social agent transforms ideas through social interactions and engagements through the embedded networks of relations and social structures (Jack and Anderson 2002), relying on and making use of weak and strong ties in the network (Granovetter 1985) through a process in which innovation becomes an outcome. This approach portrays the entrepreneur as part of a network of agents engaged in entrepreneurial action and allows researchers to study entrepreneurship as a process through which we can integrate the past into the present and chart possible paths to the future (Brush, Greene and Hart 2001; Gergen 2003). By seeking understanding rather than 'explanation, description and interpretation rather than prediction' (Lindgren and Packendroff 2009, p. 32), social constructionism allows us to accommodate multiple meanings about social processes.

Lingren and Packendorff (2009) argue that entrepreneurship should be studied as open-ended series of events used by people to create or develop things together while paying attention to the transformational sub-processes (emerging, becoming and changing of the self) developed in relationship to unfolding entrepreneurial reality. In using the social constructionism approach to studying entrepreneurship and innovation, twin phenomena deemed to be socially constructed, the researcher is invited to engage in dialogic interactions with alternative constructions of reality. Therefore, social constructionism is most suited to understanding social interactions and complexity of social actions. It is also why it has been adopted in this research.

4.2 Social Theory and Theoretical Framework

4.2.1 Verstehen, Social Action and Interpretive Understanding

Social action is any action that is meaningful and directed while taking actions and reactions of others into account (Craib 1997; Hughes, Sharrock and Martin 2003; Schneider 2006). This conceptualisation suggests that human actors vary their behaviour and tune their action to take into cognisance the social context while reciprocating the actions of others. The concept of social action, understood and analysed in this way, allows us to gauge and analyse the fit between human behaviour, socio-cultural and economic contexts (Schneider 2006). If social actors calibrate their responses to social engagements based on expectations and reactions of others, then researchers can investigate how and why social actions manifest, including how individuals and groups adapt to and enact change.

Weber (1968 [1921]) describes different types of action: *affective action* which is emotional and spontaneous, *traditional action* which is designed to repeat previously successful and socially acceptable actions in similar situations, *rational action* which is based on value judgement but does not consider consequences and means of achieving goals, and *instrumental action* which is planned and enacted after evaluation. In Weber's sociology, these different types of actions are studied by trying to understand social action and its meaning through the eyes and interpretations of social actors using the method of *Verstehen*. This method allows researchers to place him or herself in position of social actors being studied in order to understand the motive and social driver of action (Craib 1997; Ritzer 2008). The method of *Verstehen* allows researchers to seek 'understanding' of how human actors make sense of the social world (Patton 2002).

Weber's analysis of the development of capitalism and the influence of Protestant ethic is a demonstration of the power of the method of *Verstehen* in providing deep insights into the relationship between social factors and social actions along with the underlying motives. Weber's analysis demonstrates how individual and group beliefs help create social reality. Marx and Engels (2011 [1844]) identify historical materialism, unremitting pursuit of profit and accumulation of capital as the driver for expansion of capitalism, while Weber argues that Protestants' pursuit of profit as a means to a higher calling underpin development of capitalism. According to Weber, Protestants' ethic based on thrift, hard work, devotion to duty, avoidance of waste among other things as an expression of devotion to God provide the right context for the growth of capitalism (Weber 2003 [1904]). Weber's analysis did not establish direct causal relationship between Protestants' work ethic and expansion of modern capitalism but offered a plausible explanation of how capitalism developed as a modern day economic phenomenon. Weber's sociology presents researchers with a methodological approach that creates a link between the context and social action, placing at its core the desire and curiosity to understand the meaning social actors attach to their actions and how these actors induce reciprocal actions from others.

The contextual nature of entrepreneurship and innovation has been well argued in previous sections. Stakeholders in the innovation construction process come to the innovation site shaped by different experiences and motivated by different goals. However innovation is a product of shared understanding and coordinated social action, therefore a method that uses some of the techniques of *Verstehen* will be most suitable in studying technological innovation construction process. In the next section, some of the social theories that can illuminate our understanding of the different influences on technical innovation construction and its enactment through entrepreneurship will be explored.

4.2.2 Social Structure, Agency and Social Action

Entrepreneurship is a social undertaking bounded by the rules of social interaction and ought to be studied within the context of social systems (Sarason, Dean and Dillard 2006). Structuration theory (Giddens 1984) suggests that social structures can simultaneously constrain and enable human actors, including entrepreneurs, who are engaged in social action. For entrepreneurs who are engaged in the entrepreneurial process, opportunities are not waiting to be discovered but emerge as the entrepreneur reflects on their social experiences, conceptualises and processes signals or information received in the course of engagements with the social environment thereby allowing the entrepreneur to discover and create opportunities (Chell 2000; Klein 2010).

Giddens' ST is predicated on the premise that people are knowledgeable, self-aware of the world they live in and use that knowledge to their advantage. Although rules and resources over time constrain people to act in an ordered and repeatable ways, individuals retain the capacity to draw upon rules and resources at their disposal in enacting social action. Consequently, by complying with prevailing social rules, actors reinforce structure but there is scope for social actors to assert agency although their actions is not under conditions totally within their control.

Study of the technological innovation process centres on how entrepreneurs create meanings, communicate with stakeholders, create new interpretations from existing configuration of objects and practices based on socially recognised sets of relationships, rules and procedures (Sarason, Dean and Dillard 2006). In this research, the traditional view of the entrepreneur filling market gaps is replaced by the view that the entrepreneur and the social system co-evolve and co-constitute new opportunities according to ST (Chell 2005). ST helps to conceptualise entrepreneurial ventures as a recursive processes in which the entrepreneur interfaces with potential sources of opportunity, accepting and rejecting opportunities based on objective and subjective criteria of success while engaging in the venturing process. ST presents a theoretical framework that links the entrepreneur and opportunity, theorizes the interdependence of context (structure) and actor (agent) across time and space (Sarason, Dean and Dillard 2006) by portraying the entrepreneur and opportunity as a *duality* that is interdependent and co-constituted; one does not exist without the other. An agent has the ability to intervene and influence the properties of the structure of the social system because he has causal powers such as power to influence, power of reflexivity, to persuade others and the power to make a difference. The power of reflexivity – the capacity of humans to routinely observe and understand what they do while they are doing it – allow agents to operate despite the constraining influence of social rules because they are aware of some of the consequences of their actions.

In the previous chapter, some of the limitations of ST as a conceptual lens for studying entrepreneurship and innovation construction have been explored. However, Chiasson and Saunders (2005) provide a more elastic conceptualisation of entrepreneurs' engagement with opportunities using the concept of scripts'. Although enabled and constrained by structural conditions, entrepreneurs can acknowledge structural hurdles but competently manipulate and shape conditions to gain unique market advantage using 'scripts'. Entrepreneurs learn through time and experience to develop a library of scripts that can re-enacted when required, modified, or created from scratch to suit new contexts. Entrepreneurs develop strategies and tactical manoeuvres to exploit opportunities using scripts in tactical ploys to gain strategic advantage. What emerges as a new product or venture is not just to fill market gap but represents a culmination of a process reflecting the entrepreneur's subjective interpretation of social reality and his interaction with the social context and others. Through repeated use of successful scripts in the process of new venture creation or product development, entrepreneurs help reinforce existing business and social structure.

4.2.3 Habitus and Field in Entrepreneurial Enquiry

Although 'scripts' as conceptualised by Chiasson and Saunders (2005) is a useful conceptual tool in studying entrepreneurship, scripts can be unsuccessful because they have been applied in the wrong contextual setting or applied without taking due cognisance of change in the contextual environment (Hardy 2008). The matching previously successful scripts to new contexts or arenas of social action require skills and deep understanding of the social context. ST provides limited explanation of how actors select the fit between script and context to successfully enact entrepreneurial opportunities. Bourdieu (1997) makes a case for using the concept of habitus to analysing the fit between context and use of appropriate tactical or strategic tools in enacting social action.

Habitus as a conceptual tool is elastic and have been used across many research disciplines, endowing it with almost universal quality which raises questions of meaning, usefulness and representation (Maton 2008). Notwithstanding the limitation of elasticity of use, habitus is a powerful concept with inherent capacity for analysing a wide ranging set of social phenomena and conditions including the fit between social action and the context of action. As a set of dispositions, perceptions, thoughts, repeatable actions and practices acquired in the course of life, habitus enables the individual to develop generative capacity for social action (Bourdieu 1997).

Habitus is structured by an individual's past and influences social action in the present. It is structuring because it shapes how individuals engage with the world, what they see, the choices they make and the future they can envision. Through habitus we see how the past shape the choices of actors in the present, empowering or immobilising depending on circumstances. Innovation is about problem solving but what constitutes the problem is socially determined and constituted by past and present circumstances. Therefore, the definition of a problem or performance gap is moderated by habitus of the individuals. The use of a script follows from a social agreement of what problem needs to be solved or an acknowledgement that the script is legitimate. The script becomes a bridge through which social actors connect the present to a possible, yet-to-be-fully-defined future. In this work, a connection is advanced that allows us to fuse elements of Structuration Theory and Habitus into a conceptual ladder for seeing beyond immediate limitations of either theories in the investigation of innovation and the choices actors make.

Agents develop dispositions that are durable (lasting over extended period of time) and transposable (can be deployed in a number of circumstances) over time (Bourdieu 1997). The habitus evolves continuously as human agents interact with others, make decisions or reflect on alternative paths not taken in the course of social action. Our decisions shape our path, understanding, experiences of the world and the evolution of our habitus. According to Bourdieu, in order to understand practices, we must understand the field within which social agents operate and the habitus of the social agents engaged in the practices of interest (Bourdieu 1990). The habitus allows an individual to bring elements of the past and present together into an arrangement from which he could envision future possibilities, providing a link between individuals and the social system in which they are embedded. Although every individual is uniquely shaped by social forces, all operate under and have to conform to socially determined patterns or expectations. Through habitus the individual internalises the external, objective world, codifies it and contributes to reinforcement of the structure through repeated practices in line with social expectations and norms.

The relationship between an individual physical location and the social space where agency is exhibited, or what Maton (2008 p.52) calls 'ontological complicity', is what create practices. Practices are products of habitus but habitus does not singularly constitute practice. When taking decisions, an individual is faced with a range of options shaped by the context (Schatzki 2002), but the options which appear meaningful is shaped by individuals' dispositions reflecting the sum total of individual history. While Gidden's ST talks about agents' power of reflexivity and use of resources to enact social action, Bourdieu emphasises the primary role of habitus in the identification and enactment of social action. Rather than see human beings as automatons making decision according to social rules, Bourdieu argues that individuals employ strategic positioning to maximise gains within a social space. The theory of practice is an exposition of how individuals shape and constitute socially effective strategy in the course of practice acting as a link between the material and social world. The interconnections and relatedness embedded in these relationships have capacity to constrain and enable whilst also helping to constitute social practice simultaneously.

Every social field of practice is a competitive arena where social agents deploy various strategic devices to maximise gains from available opportunities. The field in Bourdieu's social analysis is a social space in which the object of research is located in its socio-historical context with relational links to other social agents, therefore it provides a template for studying social order (Thomson 2008). A social space operates on the basis of social rules, socially and culturally accepted beliefs which endows each field its distinctive logic of practice (Bourdieu 1997). Over time, agents learn the unwritten rules of the game through experience and develop a “feel for the game” or “practical understanding” to allow them navigate the contours of a field's competitive landscape. Every social field is a field of struggle in which agents compete but no singular agent has a global view of the complete range of possibilities and associated rewards, rather agency flows from particular perspective or individual way of seeing the world shaped by habitus. This indicates that habitus is a situated concept that allows the practical nature of practices to be explored, explicated and understood.

One needs to understand capital in all its forms to be able to account for the structure of the social world and how social agents interact with and operate in the world (Bourdieu 1986). In Bourdieu's sociology, capital can be in different forms – economic (money and assets), cultural (forms of knowledge, education, taste, aesthetics, language), social (affiliations, networks, family, cultural heritage), symbolic (things which stand for other forms of capital and can be exchanged for other forms of capital). These different forms of capital offer different advantages depending on prevailing field conditions. Acquisition of a form of capital suited to a field gives individual distinct advantages within the boundaries of the field. The derivative advantage(s) from capital-field fit can be used to accumulate other forms of capital and gain competitive advantage in the game (Moore 2008). Ability to convert one form of capital to another in line with socially accepted rules and expectations is a skill that social actors learn as part of the rules of the game, their socialisation and embeddedness.

The field structures the habitus while habitus presents individuals with a set of dispositions and a framework for cognitively constructing the world through re-enactment of practices. The habitus mediates what meaning individuals recognise, the horizon of possibilities, choices individuals make and our comprehension of our role in the world. Although the habitus is durable and transposable under different material and social conditions, it is not immutable. It has inherent capacity to change and be transformed as a result of interactions between social actors and their environment.

Although individuals are shaped by social conditions and habitus, there is room for change created from perturbations in the social field through social actions. Change occurs in the social structure when there is a mismatch between habitus and the field of action. Mismatch occurs between dispositions, embodied in the agents and social conditions when dispositions outlast conditions that generated it (Hardy 2008). Mismatch can also occur when habitus is transposed to an unsuitable context or field of practice. The field serves a regulatory function by ensuring that out-of-sync dispositions and practices are not and cannot be rewarded in the competitive arena. When there is no longer any correspondence between habitus and the field; practices arising from habitus become out of sync with the field and incapable of attracting market or social reward. When there is a change in any field, a gap is created between opportunities generated due to change and the habitus or dispositions (attitudes, practices, etc.) of social actors required to recognise, develop and exploit opportunities. Therefore, it is logical to argue that a change in either the field or habitus requires reciprocal change in the other in order to maintain or restore socially rewarding practice.

Until now this chapter has explored how reality is socially constructed and makes a case for social constructionism as the most suitable ontology for unravelling the complex web of relationships that underpins and mediate the innovation construction process. To study such a complex social process, it has been argued that a methodology that is predicated on *Verstehen* is required. Discussion has also explored how we can accommodate social structure in the study of innovation without granting it excessive determinism. By creating a conceptual link between habitus and how social actors use scripts to inform problem definition, this work seeks to explore one of the critical issues in this research, an attempt to understand why the rate of technical innovation acceptance is slow in the UK oil and gas industry. The research approach adopted in this study provides a framework for studying the nature and workings of social interactions in the innovation process and by extension help address the research problem.

To understand practices, it is necessary to understand the social conditions that create and prefigure available choices, how habitus of social agents evolve with the environment, and ability of agents to adapt their habitus to the demand of a dynamic social landscape. Practices are conditioned by cognitive understanding and expectations from pursuing a certain course of action based on history, culture and habitus. Individuals learn over time from what position in the field they can maximise rewards of agency with resources available to them. Social agents move into positions within a field where there is a good fit between habitus and field conditions to maximise gain from strategic deployment of their dispositions. The match between habitus and field is critical to the success of agency but the process of habitus-field matching is invisible to social actors (Thomson 2008). Successful agents need to know the rules of the game, intuitively know the limits of what is possible and recognise when there is a fit between their habitus and field in which they operate. Successful entrepreneurs also need to know what resources are required to maximise gain from different positions within a field, and the boundaries of what is possible and achievable. This is type of knowledge of the field that Schatzki (2002) refers to as practical understanding.

Schatzki's practical understanding or what makes sense to a person to do differ from Bourdieu's habitus in that practical understanding allows human actors execute actions that practical intelligibility identifies as worthy. To Schatzki (2002), rules have similar connotations as Giddens conceptualises rules and resources because they function as constraining and enabling devices and a manifestation of the power relations bound to a context. In Schatzki's view, rules are explicit formulations, principles, precepts, instructions that not only encourage or discourage human action but also set out reward and sanctions trade-offs associated with social action. At the social site, Schatzki (2002) submits that social life is a 'mesh' of practices, arranged in a way to provide regularity, stability and interdependence, linked to human activities. Practices and order are presented as interwoven, co-determined, co-determining and interdependently evolving entities. Using practical understanding, social actors transform life at the social site through the creation of new orders and practices through agency. Through agency, arrangements of entities and order-practice mesh at the social site can be rearranged to create new combinations and technical innovation.

Bourdieu's theory of practice has been criticised for adopting an excessively objectivist stance towards to structural conditions and analysis of social practice (Jenkins 1992; Sewell 1992). Some of the criticism of Bourdieu's theory of practice notwithstanding, the relationship between habitus, field and capital has been adopted as a theoretical tool in this study because unlike many structural theories, Bourdieu's theory of practice attempts to provide an explication of the mechanism through which social practices are linked to structural and objective conditions.

The arguments presented in this section show how social theories with an array of conceptual tools can be combined in a toolbox that researchers can use to examine social action, entrepreneurship and innovation construction process. Social action has been presented as directed, embedded in social relationships and enabled by particular arrangement of entities at the social site. Giddens' ST argues that people reflexively engage in actions, analyse opportunities they can cognitively comprehend within the confines defined by structural constraints. Bourdieu's analytical tool relating habitus, field and different forms of capital is also an appropriate tool for analysing process of entrepreneurship and its outcomes. Schatzki (2002) shows how the orders of arrangements and practices at the social site may prefigure action and future possibilities even as he demonstrated that the power of structure to constrain is not immutable. Schatzki's explication of the process of change makes the case for success or failure as the outcome of pressing the right combination of practices and resources into action suited to the context through social actors' use of practical understanding. In this study, the process of technology development is assumed to occur at a social site consisting of arrangement of materials and practices. The object of research is to study the process of technology emergence as entrepreneurs reflexively employ their habitus across the field of practice using different forms of capital.

4.3 Conceptual Framework of Technical Innovation Construction

A theoretical framework provides the 'structure' or 'scaffolding' (Merriam 1998 p.45) around which a study is erected reflecting the experience a researcher brings to a study or his craft (Miles and Huberman 1994). The varied use to which a theoretical framework can be put is summed up in Anfara and Mertz (2006) definition of a theoretical framework as "any empirical or quasi-empirical theory of social and/or psychological processes, at a variety of levels (e.g., grand, mid-range, and explanatory), that can be applied to the understanding of phenomena" (p. xxvii). Every aspect of research ranging from the research questions to data collection and data analysis is theory laden based on a theoretical framework whether declared or implied, although theoretical framework underpinning observations may be visible or hidden (Anfara and Merz 2006). In this study, a conceptual framework combining a Heideggerian perspective, site ontology, habitus, sense-making and some elements of structuration theory will be developed for studying the process of technical innovation development in the UK Oil and Gas industry.

Moroz and Hindle (2011) ask 'what is both generic and distinct about entrepreneurship as a process?' This is a provocative and yet fundamental question. Any study predicated on a process view of entrepreneurship must explicate among other things what entrepreneurs do and how they do it. Entrepreneurship is about human actions that are situated and context bound. This understanding led Moroz and Hindle (2011) to argue that to understand 'how', there is a need to focus on the processes through which change is created and what emerges from the transformational process. Consequently, a processual view of entrepreneurship is adopted in this study because social actors see things differently at different times; meaning is constituted in historical time through experience (Schütz 1972). Heidegger (1963) argues that our understanding of who we are as Beings is implicit and largely taken for granted, but we engage with the world and comport to prevailing rules while operating in the available mode. However, occasion arises when existing ways of day-to-day living can no longer meet our needs, things breakdown because the things we are accustomed to using in routine ways can no longer fulfil the functions we expect or desire. These interruptions in everyday life act as triggers compelling us to re-examine available choices and reflect on alternative ways of achieving desirable means given available ends. Building from this perspective, this work argues that innovation occurs when humans are compelled to engage with the world critically because taken-for-granted assumptions are no longer sufficient to meet the challenges of everyday practical coping activities. The process of technical innovation constructions begins when human unreflexive engagements with the world break down and routine use of available tools and equipment can no longer meet our goals and needs of day-to-day existence. This is the ontological foundation for the conceptual framework that will guide the rest of this study.

Ready-to-hand is a mode of awareness in which human agent is fully engaged and immersed in the theatre or context of action. Heidegger relates the 'available' mode of engagement to what he calls 'dwelling', a necessary condition for existence (Chia and Holt 2006). In this mode, meaning in and of our engagements with the world arise from how entities are disclosed to us and deployed in everyday life; objects appear as tools or equipment to be used in carrying out familiar, everyday activities. In this mode, Chia and Holt (2006) argue that what is experienced by human actors in using tools and equipment disclosed to them is 'unobtrusive and unthought' (p. 641). In the available mode, tools are used to perform intended duties without need for human reflection, active engagement or critical thinking as human actors cope with practical challenges and demand of Being-in-the-world.

In the 'occurrent' or 'present-at-hand' mode, tools and equipment no longer meet the needs to which human actors use them for; there is a breakdown in the use of tools and equipment and they can no longer be used unobtrusively and without thinking or reflection. In this mode, Chia and Holt (2006) posit that 'thematic representation, deliberate intention and action take over from practical coping' (p. 641 – 42). In the occurrent mode, prior human experience is no longer sufficient to cope with the challenges of the moment, therefore, human actors becomes more reflective observers in making careful choices about how to apply means to desired ends. It is the failure in our everyday life that jolts human actors into critical examination of the problem of the moment and forces them to reflect on the best way of restoring 'normalcy' to an interrupted flow of action in everyday life. When our taken-for-granted assumptions no longer match social reality, there is a trigger event that forces human actors to re-examine assumptions of what we do, why, when and how we do things. The distinction between planned, intended activities in the 'available' mode and the bricolage of the 'occurrent' mode in which social actors adapt to circumstances show how practices are shaped by social actors.

Bourdieu's habitus is not just a blind social compliance but a mode of operating that emphasises the relational and dispositional character of social practice, so that social actions can be consistent and predictable thereby allowing social actors to cope with changing, dynamic circumstances within specific socio-cultural context. How individuals bring this subjective world into play to instantiate action and exercise human agency require refinement, skills and deep social awareness of the context. Bourdieu's habitus gives the impression that practices are formed from disposition and delineated by structural features of the arena of interaction but the theory does not present a complete explanation of how human agency shape social practices. The habitus encapsulates how we adapt to instantiate action but does not sufficiently explicate how our actions help produce social practices that can be empowering or crippling to social actors. As Lau (2004) argues 'how habitus 'works out' varies between individuals' (p. 373). As relationally constituted and empowered actors, habitus allows human agents to draw on their experiences from the past to deal with the present. The capacity to deploy lessons from the past in resolution of challenges of the present suggests that agents can act purposively to adapt without a grand strategy (Dreyfus 1990). Through acts of bricolage, agents can act to resolve immediate needs or seek relief from undesirable circumstances without the pursuit of a longer term strategic outcome as a goal. Agents act with a purpose when they seek to achieve a predetermined outcome, however, most of everyday actions are not designed to achieve strategic goals but rather as acts of adaptations designed to meet the need of everyday life. Dreyfus (1990) argues that practices do not arise out of rules and beliefs but emerge from and are sustained by inducting members into social groups to develop necessary social skills and become meaningfully active participants in the activities of the group.

The use to which we put ready-to-hand or available equipment is socially determined and inherited from the historical and social context we find ourselves (Heidegger 1963). Through social practice, rules and norms, individuals and groups are heavily invested in existing and socially legitimated ways of doing things. As beings in a meaningful world, we are disposed and attuned to things and our acts are meaningful only in relations to what is permissible in any given context. However, it is insufficient to know that social reality is context bound and constituted by social relations, it is equally important for the researcher to seek to understand how these relationships mediate action and account for social change. Although habitus allows individuals to bring their experiences and history into play during social interactions, how these traces of memory and history combine to create new combinations is a social process, and not very well understood with respect to innovation.

The conceptual framework adopted in this study argues that social agents arrive at a conceptual site (the innovation site) to attend to a socially constructed problem because of an interruption or breakdown in the means to which available equipment and tools can be put to achieve desired ends. The innovation site is akin to the 'clearing' (Heidegger 1963) or the social site (Schatzki 2002) where objects have latent potential. Since objects are stripped of their referential relations at the innovation site, it is possible for social actors (technology entrepreneurs), acting alone or in concert with others, to engage in rearranging material objects into new combinations (inventions). Objects at the innovation site are not encumbered by meanings invested in them in the available mode hence the latent capacity for innovation.

The creation of new combinations is a necessary stagepost along the path to create innovation. The second part of the process is to create the means of exploiting the invention from which economic rent can be extracted. While individuals and groups can use the features and freedom of the innovation site to re-examine existing combinations and seek new arrangements that attend to the problem of the moment, it is impossible to proceed without defining the problem and agreeing on tentative arrangements that can lead to possible solutions. Agency is not the same thing as free will at the innovation site because human transformative power and mental capacity for rearrangements is limited by contextual and socio-historical factors. Through agency, the mesh of practices and prevailing orders of arrangements are transformed. The power of structure to restrain or inhibit agency remains (Giddens 1984) but excluding possible ways to act is not synonymous with rendering change completely impossible (Schatzki 2002). Through timing and selection of suitable and appropriate scripts at the right location (Chiasson and Saunders 2005), it is possible to alter prevailing arrangements of order and practices to create new combinations. Structural features that constrain also have inherent power to facilitate action given the right context, selection of appropriate scripts, rearrangement of material entities and deployment of appropriate practices.

In this thesis, my conceptual starting point is that innovation occurs in a social space that is context bound but not fixed to a particular location. Entrepreneurs reconstruct the order-practice arrangements to generate higher valued artefacts from lower order assets through the transformation of weaknesses of prevailing material arrangements and practices into tangible and valuable business assets. The relationship between space, time and practices in combination with the social context is critical to our understanding of how we delineate the boundary of the socially constructed phenomenon under investigation. Space makes possible the particular while time allows us to experience and understand processual development and change (Anderson 2000). But space is a human construction, a description fitted to particular coordinates that must be acknowledged as being implicated in the process of social action but not reified. Space becomes determinate only through coordinated social action. This understanding of space in general and innovation space in particular as a descriptive device leads one to argue that 'the innovation site' is socially constructed and culturally specific concept for explaining the interplay between mental representations and their transformations into tangible artefacts.

It can be argued that the idea of innovation space is not entirely original but this conceptual framework foregrounds innovation in a social space where actors have expanded possibility to create new combinations without the strictures imposed on material objects by meanings based on everyday use of equipment and tools. Resources and power are distributed unevenly across the innovation space but entrepreneurs are able to exploit the inherently uneven distribution of resources at the innovation site as they act with and inter-relate to other social actors. Successful entrepreneurs recognise inherent features of the social space to empower, constrain and realign power gradients over time and across spatial locations. Using their understandings of social space, other social actors and material objects located therein, entrepreneurs recognise and create opportunities that can be transformed into new businesses, products or services through creative imagination and coordinated social action. Entrepreneurs can exact value from rearranging resources and exploiting latent opportunities through their remoulding of what is available at the innovation site based on good understanding of contextual factors and recognition of exploitable situations.

The creation, transformation and extraction of values at the innovation site occur through agency by rearranging and realigning entities in the social space to facilitate emergence of innovation. This view contrasts sharply with those who ascribe deterministic power to environmental and structural features to which the entrepreneur must adapt and submit (Gartner 1985). However, Anderson and Jack (1999) make a strong case to support the assertion that adaptability is the essence of entrepreneurship allowing entrepreneurs to cope with uncertainty. One could extend this argument by relying on Weick (1969) and posit that the environment in which social action occurs is the creation of human actors. This in essence is the central plank of social constructionism. To argue that the environment is socially constructed is not to deny that there are structural features in the environment that can impinge upon or impede entrepreneurial action but rather to acknowledge the power of human agency to transform some structural features from liabilities into assets in support of innovation given the appropriate contextual conditions. This understanding led Anderson (2000) to conclude that "if one can chart the relationship between the social construction and the entrepreneurial action one may begin to ascertain the underlying nature of the entrepreneurial process" (p. 104).

Our reality is constituted inter-subjectively through social and human-to-context interactions. In adopting a social constructionist stance, we gain understanding of everyday life using pre-existing plausibility structures. But socially meaningful forms of life are made real through language and by actors creating and sustaining this reality through compliance with prevailing rules and expectations using the language game. As Pettigrew (1997) argues social actors create new realities through active use of language. In creating new combinations, social agents must seek and establish interpersonal understanding which allows parties to locate the meaning behind the actions of others (Gergen 1999). Meaning emerges from coordinated social action. Actors in general and technology developers in particular seek to developed shared understanding and coordinate action with other stakeholders in the technical innovation construction process to create new technology artefacts.

Entrepreneurs subjectively interpret equivocal information and enact these interpretations by treating their enacted environments as if they are real (Gartner, Bird and Starr 1992; Weick 1969). These interpretations, informed by their habitus and in response to the contextual environment, present possibilities from which new business opportunities are ultimately created. These interactions between the entrepreneur and his environment, the relationship between the subjective and objective, the link between the particular and the universal, present the researcher with a conundrum: how is one to study the paradox of entrepreneurship and innovation as objective reality using the careful reconstruction and representation of the subjective, lived experience and interpretation of process participants? This dilemma presents ontological and epistemological challenges. The challenge was summed up by Anderson (2000) who submits that 'the problematic is that we may try to analyse a pre-interpreted environment, where the creation and recreation of meaning is exactly the very condition of what we seek to analyse' (p. 105). It is only when we have access to how social actors construct meanings from their engagements with the world, and the antecedents to these engagements that we can begin to explicate the process of entrepreneurship and innovation.

Heidegger's grounded his explanation of social action on a relationally based view of practical, involved action and human agency. Bourdieu's (1998) social analysis is also foregrounded in a framework that gives primacy to social relations as the driver for social practice. This relational thinking was extended by Schatzki (2002) using ***site ontology*** to provide a vivid description of the latent connections and relationships that constitute and empower social action at the social site including the limits of human agency. Schatzki (2002) argues that practices are more than what people do because the social site is a location where events, entities and meanings coexist in a dialectic relationship. Schatzki's (2002) explanation goes beyond the limits of habitus that Bourdieu uses in explaining recurrent practices to implicate material objects and location in the production of practices and human response to contextual challenges. In this research, site ontology is used as a bridge for linking the complex description of human-to-context engagements by Heidegger to social action and practices explicated by Bourdieu.

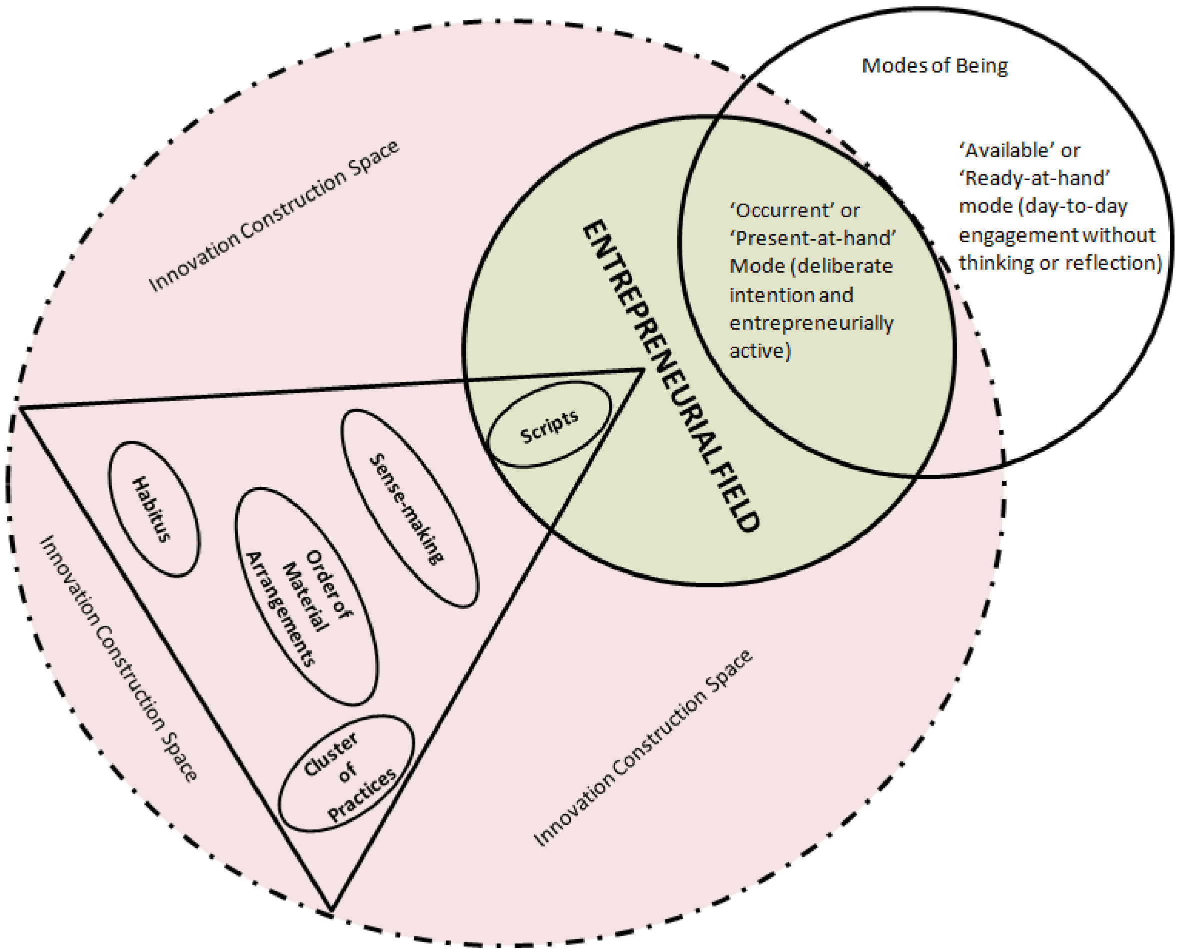

Figure 4-1: Schematic of conceptual framework of research

This conceptual framework presented in Figure 4-1 takes up the challenge posed by Anderson (2000) about the difficulties associated with accessing knowledge of the pre-interpreted environment by providing a lens through which meaning-making from multiple understandings is created. This conceptual lens will allow the researcher to probe into the interactions of multiple social actors in multiple roles with different perspectives and motivations to understand how they engage and coordinate action at the innovation site.

In line with understanding gained from Heidegger's mode of being, the theoretical framework of research starts with the understanding that innovation and its process of construction should be studied by starting from the moment the need for innovation is recognised. The need for innovation is recognised when there is a breakdown in the tools we use in everyday engagement with the world or available tools/equipment cannot meet the ends that we seek. This breakdown triggers an awakening from the slumber of ‘available’ mode and human actors enter into the occurrent mode.

Once the need for innovation is recognised, social actors starts to reflect on the elements of the situation and the problem at hand as they understand it. Individuals will have different understandings and interpretations of available information; there are probably going to be as many understandings and interpretations as the number of social actors confronted with the situation. Whatever the problem confronting human actors, all its elements cannot be new in its entirety, therefore even when some of the elements of the problem will be unfamiliar, social actors can see aspects of the problem as something they are familiar with. Armed with some understanding of the problem and the familiarity with aspects of the problem, social actors reach into the past for suitable scripts that can be deployed in the present.

The understanding that informs the selection of scripts and the matching of scripts to particular situations is influenced by the history, experience, beliefs, thinking patterns and how these actors see the world. In essence, the selection of scripts is influenced by their habitus.

However, the innovation construction space is competitive because multiple interpretations and understandings clash in the early stages of confronting a new problem. With partial understanding and incomplete information, social actors create order out of available information, multiple interpretations and understandings through sense-making to arrive at a coherent framework that can serve as a basis for coordinated social action and problem solving.

To maximise their advantage in the entrepreneurial and technical innovation construction game, process participants have to work with prevailing social norms and rules and within existing intelligibility structures. Entrepreneurs who have practical understanding of how the arrangements of materials and practices inter-relate within the field they are operating in use this knowledge to their own advantage. These socially aware, contextually sensitive and socially embedded technology entrepreneurs use their knowledge to create new combinations that are credible with end users and capable of meeting the needs of the moment.

This conceptual framework acts as a theoretical vantage point from where it is possible to look into the innovation construction space, observe how actors relate to context and social structure, manipulating elements of the structure, available material and practices, and relying on their habitus to create innovation. This conceptual framework shows how those who are socially aware and skilled in the game can be successful while others who are less knowledgeable about how material, order of arrangement and practices hang together can be less successful under the same contextual conditions.

4.3.1 Field and Entrepreneurial Research

Any study of process requires an understanding of the nature and effect of interactions between actors. Participants in the process of technology development (entrepreneurs, VCs and end-users like engineers and managers) have different histories, experiences and by extension different habitus. The perceptions and meanings these social actors attach to the choices they make are important dimensions of the subject of interest. Bourdieu's tool of habitus, field and capital are suitable conceptual tools to understand these interactions.

Field theory can be used in analysing the process of technological innovation construction, investigate why some are successful within the field while others fail, what forms of capital are needed by entrepreneurs to operate within the field and how are these forms of capital are valued by other actors (VCs, bank officials, engineers and managers). The contextual factors influencing the decisions and actions of social actors in the field of technical innovation in the oil industry also need to be explored along with other social and economic forces affecting the power structure and relations within the field. Field theory can be used by a researcher to show how relative position of individuals or groups within a field drive change (Mutch 2006) and it is suitable for investigating and understanding technical innovation construction process and sub-processes.

Entrepreneurs use scripts in different contexts to achieve strategic advantage and extract reward from market transactions. The process through which entrepreneurs engaged in technology development and establish a fit between script choice and social conditions with the arrangement of order and practices at the social site is not well understood. If as Schatzki (2002) suggests success or failure depend on the correct deployment of practices suited to the order arrangement at the social site, then it should be possible to investigate how the past converge with the present to shape the choices made by people engaged in the technology development process taking cognisance of enabling and constraining contextual factors.

The field determines the range of what is possible and by extension what social agents do under specific socio-economic and cultural conditions. Thomson (2008) provides some practical tips about how Bourdieu's field theory can be used in social research by analysing positions in the field in comparison to the power relations within the field, mapping out the objective structure of relations between positions of social agents/institutions competing within the field and, analysing how the habitus of social agents is conditioned by social and economic conditions within the field. This approach allows a researcher to establish a correspondence between social agents positions in a field, the power relations between actors and entrepreneurial outcomes

Using field theory in research is not without its own drawbacks. Thomson (2008) identifies a number of practical difficulties with the use of field theory including challenges of delineating the outer boundary of the field of interest. It is also important to avoid including too many elements within the boundaries of study and the researchers must be sensitive not to ascribe too much determinism to the overbearing power of the field.

This research will use Bourdieu's habitus as the foundation of a theoretical lens whilst incorporating the generation and use of scripts (Chaisson and Saunders 2005) in studying entrepreneurial action or engagement. This research will focus on how the habitus of entrepreneurs and other actors engaged in the process of technology emergence influence social action within the boundaries set by objective conditions to shape the trajectory of technology development and emergence. The use of 'scripts' will help to investigate how individuals with different degrees of familiarisation with the game of technology development identify and use previously successful scripts, formulate new scripts or adapt existing ones when confronted with variation on objective and contextual conditions.

4.3.2 Constructing the Innovation Site

Conceptually, the review has established that most human activities in everyday life revolve around unreflective actions in which social actors as Beings meaningfully engaged in the world, cope with everyday challenges using available tools and equipment without the need for reflection and critical thinking. Through habitus, human actors are able to call upon memory traces from the past to fit current circumstances provided the contextual landscape allows. In engaging with the moment and interpreting available cues through habitus, human actors have been shown to seek practical coping rather than strategic intent most of the time. We have also discussed that what is disclosed to meaningfully engaged actors are not always fit for purpose in meeting the needs of everyday life by which time human actors are jolted into action and move from 'available' into 'occurrent' mode of existence.

This configuration takes account of innovation as a social product that is validated and legitimated by a collective at different stages of its construction until emergence and subsequently through its evolution. Knowledge creation and accumulation is central to the process of innovation development but as Stacey (2001) argues, knowledge is a product of relational process between social actors rather than a static thing. Harbi and Anderson (2010) building on earlier work by (Nonaka and Konno 1998) show how information is transformed into knowledge in ***"ba"***, a conceptual space for social interaction and exchange. The Ba is a form of innovation site, a conceptual space where actors interact and create not just innovation, but this thesis argues, the conditions for innovation construction. Explicit or codified information does not belong within the *Ba* but intangible and tacit information resides within its conceptual space. Transformation of information into knowledge occurs within the "*ba*" through sharing and interactions. Small firms collaborate and share information through networks (Drakopoulou Dodd, Jack and Anderson 2002). The sharing and collaboration is central to the transformation of information into knowledge provides strategic and tactical advantages. The strategic advantage stems from helping overcome liability of newness and/or smallness while tactical advantage flow from its ability to use existing connections to facilitate sense-making between participants. Sharing becomes central to how information is used and value extracted (Patrick and Dotsika 2007). This collaboration is a reflection of the leanness of resources available to smaller firms and crystallises the scale of challenges technology entrepreneurs face to accrue resources for innovation construction.

Technology entrepreneurs and SMEs do not have vast resources to call upon. The resources that small firms control are sparse and limited (Chorev and Anderson 2006) but sharing provides a strategic bridge to overcome hurdles and breakout of the strategic limitations imposed by limited resources (Jack, Drakopolou Dodd and Anderson 2004). Social situatedness, network linkages and social capital that inhere in social relationships help to facilitate information acquisition and access to and creation of knowledge (Nahapiet and Ghoshal 1998). Innovation requires new knowledge to be created using available intellectual capital in combination with other resources to create new forms and achieve unique outcomes (Subramaniam and Youndt 2005). For information to be shared, especially tacit information, it has to be accessible to others engaged in the co-creation of innovation. Through problem framing, technological entrepreneurs are able to access tacit information and make it available to a social group to facilitate sense-making. Technical innovation creation requires combination of internal and external knowledge (Goh 2002; Tseng 2009) through sharing of tacit and explicit knowledge between individuals (Cohen and Levinthal 1990). This can only lead one to conclude that the social is central to how knowledge is created and shared in the complex process of technical innovation construction.

Site ontology provides a new perspective because it posits that social life unfolds as part of and co-evolves with the context. The 'site' in Schatzki's analysis is an arena of action or broader set of environment in which human actors do things and make things happen. The construal of a site as a type of context provide a broad canvass upon which human actors can engage in all sort of activities and transform mental representations into technical artefacts. At the social site, individuals are immersed within a wider social setting constituted by other human actors and entities where actions can be instantiated and practices sustained. The site in the context of this study evolves and gets transformed through time. I construe the site in the formation stage to what Heidegger called the 'clearing', a space of unthematic representation where material objects do not have fixed uses and meanings.

The 'innovation site' that is likened to a 'clearing' is conceived as an open place where entities including human actors show up prior to all determinateness or representation; entities including human acquire socially meaningful roles and establish referential relations to other 'available' objects at this site. The innovation site acts as a zone of social interactions and meaning-making. At the innovation site, melding and merger of meanings occur and new understandings are developed. In this social space, material objects can be pressed into new arrangements to create new meanings. Human actors bring with them to the innovation site their habitus, multiple understandings and meanings. Through social interactions, including use of active language, conscious rearrangements of material objects and practices, create moments of shared overlapping meanings and understandings from which innovation emerges. Schatzki (2005) describes the clearing as a horizon of possible intelligibility where a range of ends can be served through means suited to the context.

In the innovation space, human actors operate in the 'occurrent' mode fully engaged with the world they are immersed in but also acutely aware of the shortcomings and inadequacies of existing tools and equipment. According to Heidegger, in the occurrent mode, things presented to us do not suffer from the limitations of how we are familiar to using them but instead have inherent properties and can be arranged and combined with other entities in infinite combinations. This freedom to see things anew and link entities in new arrangements is the source of innovation of at the social site. Although actors come to the social site with their habitus, in the 'occurrent' mode they have heightened awareness of the infinite possibilities of the moment and through social interactions are fully engaged in making sense of the issue at hand. This suggests that entities can be arranged to achieve different ends as long as human actors retain the capacity to apply different interpretations and select different means to achieve socially meaningful ends. This is similar to Bourdieu's concept of field where people pursue certain ends drawing on available resources but guided by their dispositions that are in line with prevailing socio-economic and cultural conditions. Shatzki (2005) submits that 'all human coexistence inherently transpires as part of practice-arrangement meshes' (p. 474) implying that any social phenomenon can and should be seen as socially constructed. Schatzki's portrayal of the social site is a more integrated account of human actions, practices and prevailing material conditions because of the primacy it accords human agency. The innovation site is constituted by nexus of practices and material arrangements in which practices are simply seen as organised human activities thereby foregrounding reality at the innovation site as a social construction.

Site ontology does not deny the power of social structure but presents a theoretical tool for analysing the distribution and exercise of power to shape the present and envision the future between agency and structure. Practices are organised, open-ended manifold or collection of actions across spatial-temporal dimensions consisting of how things get done, prevailing rules of engagement and teleoaffective structures. The teleoaffective structures in Schatzki's exposition refer to the array of things deemed acceptable to be in sync with prevailing practices.

Human construct the social site when they bring together a 'mesh' of set of practices and certain material arrangements. Schatzki (2002) posits that practices at the social site can be determinate but can also be altered by rearrangement of practices and material objects. This exposition provides a central role for human agency without denying the power of the structure to constrain or inhibit human actions. This stance opens the possibility of human agents to exploit seemingly inhibiting features of the social structure in the pursuit of new ends through careful selection of practices and materials aligned with appropriate context.

Making sense of the breakdown in the use to which tools, equipment and resources can be put compel actors to develop shared understanding of the nature of the problem. As we have already discussed, a problem emerges when existing way of doings things no longer result in satisfactory outcomes or current tools and equipment can no longer meet the need of everyday life. To be in sync with prevailing practices is to seek to be authentic (Heidegger 1963) or avoid cognitive dissonance (Weick 1995). When actors are in sync with their environments, it is easier for them to recognise new solutions being proposed or newly envisioned path towards new understandings and innovation construction. Since material objects and other entities assume determinateness at the innovation site, entrepreneurs in concert with others have unique opportunities to frame the issue of interest thereby shaping what is of concern, develop a range of acceptable solutions and selection of socially agreeable option for innovation and problem solving.

4.3.3 Problem Framing at the Innovation Site

It will be incomplete to discuss the happenings and doings at the conceptual innovation site without touching on how actors bring together disparate constituents of a problem into a coherent whole around which joint social action can be pursued. The integration of different aspects of a problem takes place through the process of framing. Framing is an essential part of and a critical step in making sense of unstructured data, disparate information or messy situations. The specification of a design problem is built from various desires of customers and end users that are often vague about what they need. There are even circumstances when end-users may be incapable of articulating their needs either because of inexperience or lack of strategic visioning. In other words, critical elements required to define a problem are often distributed among different stakeholders as a combination of explicit and tacit information.

During the problem framing stage, incomplete requirements and wishes of stakeholders are transformed into design specifications but the transfer or mapping of vague desires onto technical specification is selective, nonlinear often negotiated and imperfect. This is why problem framing co-evolves with development of tentative solutions as human actors choose between competing needs and technical requirement priorities. Problem framing is a social and dynamic process consistent with the findings of Schön (1983) that practitioners know how to achieve required goals through framing to accommodate the tacit and experiential knowledge of practitioners.

Individuals deal with problem framing differently depending on their experiences. Cross (2004) argues that coordinated social action at the innovation site require a central issue of concern around which social actors can develop new meaning and understanding. In this study, it is argued that problem framing provides such a focus for concerted social action and a central part of innovation construction. As already argued, a problem signifies a gap in performance or inadequacy of existing means to achieve desired ends. Experts decompose problems into components, using prior experience, to improve understanding and develop tentative response to problematic situation. On the other hand, novices employ 'trial and error' for problem scoping which is more time consuming. The findings of Cross (2004) show that experts and novices alike are active participants in the act of problem framing.

In the study of engineering students, Atman et al. (1999) show that novices or new students spend disproportionate amount of time defining problems (problem scoping) using 'trial and error' techniques for generating and implementing tentative design steps – modification, evaluation and design iterations. On the other hand, expert designers aided by experience have the ability to mentally develop design concepts from available information through recognition of underlying principles and design of tentative solutions for discussion and generative action (Atman et al. 2007). Experts are able identify critical components of a problem more efficiently by avoiding wasting time on structuring peripheral features of the problem. Lawson (1997) found that experienced designers use generative more than deductive reasoning compared to novices when problem solving using solution conjectures rather than problem analysis. This approach allows designers to interact with end users, tap into explicit and tacit knowledge of other stakeholders and create a forum for dialogue in which participants can use active language in the process of generative action. Solution conjectures are construals suited to particular needs and circumstances around which all stakeholders could be mentally and dialogically engaged.

Problem setting is a feature of reflective practice (Schön 1983) in which human agents name the things to which they must attend and frame the context in and from which a solution ultimately emerges. The designer in concert with other stakeholders design the problem to be solved (*naming*) and identify the range of options to be explored in search of acceptable solution (*framing*), setting boundaries of investigation and imposing on an otherwise messy situation a coherence to guide subsequent decisions and actions (Schön 1988).

Dorst and Cross (2001) submit that problem and solution spaces co-evolve starting with an exploration of a problem space from which tentative solutions are developed. The implications of these tentative solutions are subsequently used to generate some form of design concepts that are then transferred and matched to the problem space to evaluate the implications for problem solving. This recursive process allows the designer and others intimately connected to the situation to develop a 'problem paradigm' or a way of seeing the design problem that subsequently structures the range of possible solutions.

Problem framing captures the processes of structuring and formulating the problem but as Cross (2004) argues expert designers are focussed on the solution and not the problem. The choices that are made to develop a solution are not preconfigured but governed by experience, context, deliberate human choices and social. Problem framing and emergent solutions (technology artefact) are socially constructed. This critical stage allows technology entrepreneurs and other stakeholders (end-users and financiers) to develop shared cognition of what issue to address, what is to be done and how meaningful action is to be achieved. The technology entrepreneur has to persuade others to support a shared interpretation of the problem and the path envisioned towards a solution. Stakeholders do not necessarily have to agree on every elements of the problem framing outcome, they only need to recognise parts of shared representation as meaningful with latent capability to produce acceptable solution. The series of interaction and human choices in the problem framing stage exemplifies the socially constructed character of not only problem framing but also innovation construction itself.

4.4 Conclusion

In this chapter, a conceptual framework has been presented to describe a process view of entrepreneurship while also making a case for social constructionism as the appropriate ontological stance for the research. The conceptual framework describes how technology entrepreneurs use library of scripts under different contextual conditions to create innovation. Innovation as a socially constructed phenomenon is presented as a product of human interactions generated from shared meanings arising from multiple interpretations, understandings and habitus of different stakeholders.

The provenance of innovation is located at the space-time nexus when human mode of engagement with the world shifts from the 'available' to the 'occurrent' mode (Heidegger, 1963). Once the need for innovation is recognised, social action moves along a trajectory that ultimately leads to the innovation site where multiple meanings and understandings can be meshed to create new meanings and articulate new arrangements of materials and practices leading to new combinations.

The conceptual framework acknowledges the constraining role of structural elements but the case has been made acknowledging human capacity for agency to transform structural features into assets under appropriate contextual conditions. This understanding presents a foundation for analysing innovation and technological entrepreneurship, which is the means through technology innovation occurs, as socially constructed and should be studied through the lived experiences of process participants.

In the next chapter, the rationale and justification for the chosen research methodology for this study is discussed. The fit between the ontological and epistemological approaches and research strategy including sample selection, data collection and data analysis is discussed. The chapter will show the fit between the conceptual framework and research methodology, including how the conceptual framework will be employed in the data analysis and subsequent theory development.

Chapter 5

Methods and Methodology

5.1 Introduction

Entrepreneurship and innovation are processual phenomena with temporal, spatial and contextual dimensions. To study and understand entrepreneurship, it is necessary to understand contextualised human behaviour and reasons and motivations behind social action. This is a study about innovation construction and entrepreneurship, two social phenomena that are situated, context bound with multiple meanings for different individuals depending on their positions within the social field and existing power relations.

This chapter presents the ontological and epistemological basis supporting this inquiry making a case for an ontology firmly situated at the site of innovation construction where arrangements are constituted by human actors using non-human entities and social practices. The case presented here is that human activities are inseparably bound to and part of the social site but context is central to understanding social phenomenon and its outcomes. If reality is co-created socially at the innovation site, then our knowledge of it must respect and take into account the contextual factors and multiple realities bounding all together at the social site. As a consequence, this chapter makes a compelling case for recognising knowledge as socially produced, collectively legitimated, sanctioned and reproduced. If one accepts this contention, then it is logical to argue that reality cannot be independent of human actors, relationships and the context of action but rather socially constructed. It is for this reason that this research is underpinned by social constructionist ontological and epistemological assumptions.

In the course of this study, the role of actors and linkages between the social site and entrepreneurship is explored using a number of social theories to construct a theoretical framework of research. The conceptual lens or framework brings together elements from different social theories including Giddens' structuration theory, Bourdieu's Habitus, Heidegger's explication of modes of Being, Schatzki's site ontology and Weick's sense-making to articulate a different way of looking at innovation and entrepreneurship. This theoretical framework is used as a guide for seeing the world without allowing it to suppress efforts to generate meaningful analysis from field work representative of the phenomena of interest.

In this chapter and throughout this study, entrepreneurship and technology development are treated as social activities that take place tied to a particular context and social site. Identity, meaning, social position and power relations are considered as defining parameters for social action. This chapter makes a case for understanding the influence of meaning actors ascribe to their actions, relative position with a field of practice and power relations created by particular arrangements and practices to reveal the underlying conditions driving entrepreneurial interactions and activities. Technology development like any process of human interactions requires entrepreneurs to match correct resource combination with contextual conditions to be effective.

This thesis argues that successes or failures of entrepreneurial endeavours depend on how individuals deploy resources – strategies, tactical manoeuvres, different forms of capital and skills – in relevant social encounters to meet market needs and extract market gains. Technology – a piece of software or hardware - emerges out of need and social interaction suggesting that technology development is deeply social (Orlikowski 2000). Technology is a product of human action that is endowed with and acquires structural properties through repeated use (Orlikowski 2000). Through the actions and decisions of human agents, technology gets used in certain ways that embeds it within the structure. Although the entrepreneur is central to the process of development and technology emergence, he is by no means singularly responsible for its emergence.

Technology is a multidimensional human creation with deep social and referential relations to temporal needs and context of use. The interactions that mediate the birth of new technology are processual with spatial and temporal dimensions involving multiple social actors. In the oil industry, new technology must overcome severe challenges to survive and small and medium enterprises struggle to push through new technology from conception to market acceptance. A research design based on a set of ontological and epistemological assumptions is set out in this chapter that is reflective of the underlying social process of technology emergence and development in the UK oil industry. The nature, process and effect of social interactions in the technology development and mediating process are the foci of this research.

5.2 Ontological Foundation for Entrepreneurial Enquiry

The nature of reality within which phenomena to be investigated are subsumed is often the starting point for any research. In the 17th and 18th century, philosophers came to be divided into two camps – empiricism and rationalism. The rationalists like Descartes, Spinoza and Leibniz argue that human beings can acquire knowledge about reality with the mind alone through pure reason. The empiricists such as Locke, Berkeley and Hume on other hand dispute the foundational basis of rationalism and argue that any knowledge of the world come from experience. But what property of reason makes it a preoccupation of philosophers and scholars alike? What aspect of unadulterated truth, if there is such a thing, can we apprehend through reason? What type of reason makes one accessible to the essence of reality?

Descartes (2008 [1637]) argues that observation is inferior to reason because human senses can be fooled or deceived. He argued that the only thing man can be certain of is his capacity to think, therefore reasoning is of a higher order form of apprehending reality than empirical observations. On the hand, Locke (1996 [1689]) argues that the human mind is like a blank slate (tabula rasa) at birth, therefore human beings reason about the world after observing it. In other words, Locke's argument is that all ideas and thoughts owe their origin to experience while Bacon (2008 [1620]) argues that knowledge of the world is based on induction in which accumulated observations of particulars allow us to develop empirically based generalities.

On the other hand, empiricists argue that experience and evidence from sensory perceptions are the sources of ideas (Locke 1996 [1689]), therefore any methodology laying claim to being scientific has to be methodologically empirical so that generated theories and associated hypotheses can be tested against observation in the natural world. To the empiricist, causality is grounded in past experience, repeated observations and association of events based on constant conjectures between experience and the real world (Potter 2000). This empiricist stance implies that all reasoning must start with observation, which means that we cannot think about the world until and we have observed the world. However, it has been shown that inductive reasoning based on observation alone cannot be a source of true knowledge because it takes a single contradictory observation to invalidate a theory no matter the number of supporting, confirmatory observations (Hume 1977 [1748]). As Lee and Lings (2008) put it, Hume's thesis suggests that 'causality was only human belief based on prior experiences' (p. 29).

Descartes was concerned about whether it is possible to know anything for certain since 'truth' and 'certainty' are two different things – certainty is located in the mind while the truth is about something external to the mind. To apprehend the truth, Descartes argued for dividing questions into manageable parts and also sets out a rule that one should not accept as truth anything about which one has the slightest doubt. Descartes believe that it is only when there is certainty can one get at the truth, therefore the pursuit of certainty is the pathway to the truth. Since the search for certainty is the goal, one has to set aside anything in which one has the slightest doubt through a rigorous and systematic process giving rise to what is now known as the 'Cartesian doubt'. Cartesian philosophy can be summed simply as thus, "there is a reality out there that cannot be perceived by the mind but can be accessed through pure reasoning". Descartes' guiding principle: '*cognito, ergo sum*' meaning I think therefore I am is the foundation of rationalism, a school of thought that holds that observed data is inferior to pure reason (Lee and Lings 2008).

We learn as we interact with the world in the active or passive mode. Our observations are not totally unmediated; we see and interpret the world simultaneously consciously or subconsciously. It can be argued that facts about reality are not presented to human actors unfiltered but rather we apprehend and develop meaning about the world through historical, cultural and psychological filters. In other words, our observations are theory laden (Feyerabend 1975; Kuhn 1962; Machamer 1973). Researchers engage in observation and interpretation simultaneously, therefore the claim to objectivity and neutrality of scientific knowledge claims ought to be challenged. The argument that we can gain objective knowledge of reality falls apart when set against an alternative proposition that our experience of the universe or reality at any time is partial and contingent.

On the other hand, rationalists argue that knowledge can only be acquired through pure reason independent of the senses because our senses are unreliable. This position of idealists is not without its flaws. Hume argues that we locate causality in repeated associations between observable events using the power of logic. Logic allows human actors to distinguish between sound reasoning and fallacies based on examination of consistent premises or warrants but it is indifferent to the content of a discourse (Potter 2000). However, if our understanding of phenomena is based on logical relatedness between observations, and logic is about the structure and not to the content of reasoning, then by implication rational claim of science is contestable. Kant (2007 [1781]) straddles the positions between empiricism and rationalism in acknowledging the role of experience while asserting that the mind filters, organises and interprets our experiences in unique ways to create knowledge of the world using innate structure of knowledge that allows human beings to organise the world they encounter intelligibly.

Towards the end of the nineteenth century, scientists rather than philosophers started to engage in the debate about reality and how we can know more about it. The members of the Vienna Circle believe that only science can lead to true knowledge. This school of thought, which is an offshoot of empiricism, came to be known as logical positivism. They argue that ideas are only meaningful if they can be empirically tested and that it is impossible to have knowledge of anything without direct observation. This school of thought even argued that social theories can be reduced to more fundamental sciences through a process of reductionism. Logical positivism died out in the 1960s and positivism developed in response to the extreme position and flaws in logical positivism argument. Positivism rests on the contention that all things are ultimately measurable and that social actions can be reduced to relationships between individuals and their actions. This position makes ‘social facts’ appear to exist independent of human actors (Durkheim 1982; Jones

1986) and socio-historical contextual factors, reifying social reality while ignoring the social and historical mediating role of human actors. The objectivity and neutrality that positivism proclaims is tainted because it ignores the role of the researcher who as an intermediary, observes and records data and thereby help in the constitution of social reality being studied and reported upon. The observer or the researcher carries within him traces of history, experiences and previous social conditions shaping ideas, what questions are intelligible to ask about the social world, what is seen as data and the way data should be interpreted (Gergen 1994, 1999).

In response to some of the flaws of logical positivism, anchored to the belief that meaning of propositions must rest on observable facts, Feigl (1949) proposed a logical empiricist philosophy of science, also known as scientific realism, and argues that it is possible to study processes that are not directly observable through theoretical explanations. Feigl was arguing for an approach that concedes and accepts that knowledge about a phenomenon can be gathered through indirect means therefore by extension recognising the role of assumptions, inferences and interpretation.

Realists believe that an external world exists independent of human representations such as thoughts and language through which we know the world. Therefore, realists contest that scientific discovery should aim at revealing the causal relationships between phenomena and observations; explaining the association between observations and phenomena under observation. Popper (2002 [1935]) however challenge the claim that theories could be proven through observations alone but instead argues that no theory can be conclusively proven solely based on observations. According to Popper, theories are only provisionally accepted until they can be contradicted or invalidated by new observations therefore scientists should aim to falsify theories with observations that contradict theoretical predictions. What is presented as the truth is therefore continuously contested knowledge and subject to change depending on advancement in knowledge.

To the realist, reality consists of objects with properties independent of the observer. Although realists differ from positivists about the role of direct observation and what can be measured, both schools of thought share a belief in an objective world with independent existence from human creation and activities. This study takes issue with realist assertion that there is an external world independent of human beliefs, where it is possible to make a distinction between the nature and essence of reality on the one hand and the interpretation and meaning people attach to their experiences on the other hand. Also, reality cannot be grounded on empiricists or logical empiricists' assumptions because observation is theory laden.

The arguments set out above puts the individual as the observer or the individual mind at the centre of knowledge acquisition process. Gergen (1994) argues that the privileged position of individual mind in Western philosophy fails to adequately explain how the mind apprehends reality without any influence or mediation from an external source. Empiricists' argument that the mind acquires knowledge of reality through experiences alone implies the existence of subjective and objective worlds without an adequate explanation of how one is related to the other, or a description of the bridge connecting these two worlds. To accept the position of individual mind capable of existing on its own is to accept a dualist ontology that internal consciousness exist separate from the material world without explicating how the mind and the material world are causally related.

If there is a subjective world and an objective world, how does the mind acquire knowledge of the objective world? Empiricists try to solve this riddle by conceptualising the 'mind as mirror' that reflects the world as it is (Gergen 1994). The 'world as it is' view makes no allowance for the capacity of individuals to observe and interpret information based on accumulated experience of history, culture and context. The empiricist contention, taken to its logical conclusion implies that we see the world devoid of any external influence, mediation, interpretation or filters. This stance fails to explain how socially complex ideas and institutions emerge, or how communities come to develop complex socially shared concepts.

To be able to study the world as it is requires that observations are reflected and reported accurately with no interpretation, completely unmediated through a filter conditioned by social, cultural, historical or psychological influences. The failure of rationalism and empiricism to explain how the mind is causally related to an external world implies that the mind cannot be relied upon to truly represent the world as it is to us, therefore the concept of accurate observation cannot, in this perspective, be philosophically justified.

This study takes a phenomenological view of social interactions and reality. Phenomenologists argue that reality consists of contents and meanings of human experiences enabling us to communicate and partake in social activities. Human beings are intentional beings who are always seeking ways to structure the world they inhabit, re-arranging objects with which their lives intersect and in the process create new reality (Bergland 2007). From a phenomenological viewpoint, all that exist in the world take form through our perception of them, including how we interpret these perceptions and the meanings they hold for us (Moran 2005).

To take a phenomenological stance is to reject a worldview built on the idea of reality being independent of human actions. Natural sciences study conscious human experience taking consciousness for granted and without seeking to understand or explicate how consciousness made contact with materials objects. Husserl (2001 [1913]) using a *retentional-protensional-horizonal-synthetic* framework (Cerbone 2006) shows that humans are co-creators in the reality they experience including how they structure and understand their everyday experiences. According to Husserl, human beings seek to understand the workings of the world by joining together elements of what has gone before a point in time (*retention*), what has just happened (*horizon of experience*) and what is expected to come (*protension*), into a fusion to attain intelligibility (*synthesis*). Time is fundamental to this sequence and structure of experience because moments of conscious experience are temporal, dynamic and constantly in flux. Our experiences are defined in a series on 'now' stitched together in a passage of time. Therefore, our comprehension of reality is always different because of this temporal fluidity, and the continuous and incessant flow of events in the 'now'.

Since human beings are never presented with complete content of reality but instead have access to slices of reality, what we call experience is a synthesis or stitching together of impressions (adumberations) to form a whole unit through 'noesis'. These experiences composed through 'noesis' only take full meaning when they are integrated into existing framework of meanings to develop a new and whole unit of meaning through a process known as ‘noema’ (Cerbone 2006; Walsh and Lehnert 1967).

Husserl’s phenomenology concerns itself with the essence or essential components of experience. Through a method of reductionism, Husserl argues that it is possible to detach and isolate experience from its context and still access the essence of the experience and by extension of reality (Schultz 1970). Husserl (2001 [1913]) argues that our awareness is one thing we can be certain as human beings; our awareness is always about something, the mind is always directed towards objects and directedness is a unique feature of the mind. ‘Intentionality’ refers to this ‘aboutness’ of mental contents. Husserl argues that there must be some kind of content in the mind, or intentional content through which reality can be perceived that is responsible for this ‘aboutness’ or ‘intentionality’. Therefore, through phenomenological reductionism, we can access the essence of things and get at the true nature of reality (Husserl 2001 [1913]). This approach and its accompanying methodology is the culmination of a philosophy tradition that sees human beings as subjects in a world full of objects.

The Cartesian tradition with its subject-object relation that has dominated philosophical discourse was challenged by Heidegger. This philosophy tradition has been preoccupied with the question of what we as human beings can know about reality and the world. Heidegger in challenging this long held and accepted tradition forces us to re-examine whether we need subjective experience to encounter things and maintain our place in the world. Rather than to be preoccupied with the question of what we can know about reality and the world, Heidegger re-directs our experiences and to search for what is the world out there is like. An exhortation to investigate and explicate how human actors proactively interact with and engage with the world, thereby shaping it and being shaped by the world.

Heidegger argues that experience cannot be separate from its context if it is to retain meaningful comprehension; true meaning of experience will be lost if subjected to phenomenological reduction (Heidegger 1982). While Husserl describes phenomenology in terms of intentionality and how a transcendent object (outside of the mind) is presented to consciousness, Heidegger sees consciousness and intentionality as inadequate basis for understanding reality and argues for an approach rooted in human modes of existence as the basis for understanding.

Heidegger's locates 'Being' as the primordial condition which allows everything to come into existence and in the process provide us with a phenomenological basis for understanding human mode of existence. In philosophy, 'Being' is a very broad concept that encompasses objective and subjective dimensions pertaining to reality and existence. Being encapsulates the essence of our existence, the primordial nature of that which makes us exist. In Heidegger's ontological architecture, 'Being' refers to that which makes it possible for us to make sense of things we encounter and relate to. Rather than beings separated from the world trying to find ways to access knowledge of the world, Heidegger places humans at the centre of action, embedded and immersed in the day-to-day coping with the world. Heidegger articulates this entrenchment in the world with his description of human beings as being-in-the-world (Steiner 1991), whose everyday coping with the world envelopes the wholeness of being. In the view of Heidegger, the way we live and conduct our affairs is encapsulated in our existence which is context bound, and in turn determines the limits of possibilities for knowledge acquisition and the locus of possible action. Since we have no control over the "thrown-ness", the social environment and culture into which we are born, we learn to socialise and become embedded in a social context of which we are a product and become a part.

Heidegger's analysis shows that awareness and consciousness are not central to the way people relate to things. He argues that in normal day-to-day, routine activities, we deploy objects to achieve certain ends without reflection because the things we are familiar with are transparent to us. In transparent coping mode, humans deploy tools and equipment without thinking or reflection. Heidegger calls this type of transparent everyday coping 'primordal understanding' and the entities we use without reflection as 'ready-to-hand' or 'available'. This is a departure from Husserl because in Heidegger's view, human beings use ready-to-hand equipment or tools to cope with everyday need without the mind being directed toward independent objects. This Heideggerian perspective does not deny that there is a place or role for consciously directed intention or contemplation, rather it argues that primarily human beings are coping beings already engaged with and implicated in the world and its reality thereof.

In addressing the ontological questions, Heidegger argues that human existence unfold through one of three forms or modes of beings – Dasein, the available or ready to hand, and occurrent or present at hand (Heidegger, 1963). The word *Dasein*, a German word which means existence as in man's everyday existence captures human ongoing activity against a background of shared understanding of being. Dasein can also mean 'being-there' to convey the understanding that human activity of practical, everyday coping go on continuously where things are encountered in a continuous flow of becoming. Therefore, Heidegger use of Dasein has dual meaning: to describe human general way of being but also used to describe a single human being which is an instance of a more general way of being. Consequently, Dasein can be used to describe shared situations but can also be used to refer to specific instances or situation of individual engagement with the world. By being-there, immersed in and at the centre of social action, humans as individuals or in groups continuously engage with the world while coping with and shaping reality.

Heidegger (1963) argues that our understanding of being is implicit and largely taken for granted (pre-ontology) but the goal of ontology is to reveal and articulate our understanding of Being (mode of existence) based on this pre-ontology. His distinction between *ontic* (properties of being) questions and *ontological* (ways or modes of being) questions makes it possible for us to understand the structures of social reality and our relationships to these structures which make it possible for us to be human. Our pre-ontological understanding of being arises out of our continuous engagement with entities that manifest to us and our response to them. This pre-understanding is situated, context bound and rooted in human day-to-day activities and not to be found in consciousness as Husserl argues. Heidegger disagrees with Husserl's reductionism (bracketing or separating experience from its context) in order to explicate the essence of the experience but rather his focus is on human activities and interactions with its environment. Husserl pure phenomenology through reductionism can only lead to a distortion of phenomena and reality because reductionism can only explicate a representation of the world and not the world as it is (Crowell 2005).

Objects are presented to us as either ready-to-hand or present-at-hand (Heidegger 1963). We first encounter worldly things as 'available' (ready-to-hand) rather than entities with meaningful, causal relationships in our day-to-day engagement with the world. Through everyday engagement with the world, we interact with entities that are familiar to us. These objects manifest as "things of use" or tools or equipment that are "ready-to-hand" that can be deployed in everyday, ongoing human activities to which we develop "practical orientation" or how things should be used. Ready-to-hand equipment is defined in everyday existence through their use in relation to the types of activities into which they are pressed, the context and purpose of use. In the 'occurrent' (present-at-hand) mode of being, objects show up in our consciousness because of their inherent properties with latent potential but can exercise causality in the 'available' mode if and when directed towards goals and other human activities (Chia and Holt 2006).

In the present-at-hand mode, objects are separated from their contexts of use and stripped of their referential relationships that give them meaning, and also constrain how they are used, in everyday life. Without these relationships between human beings, objects-in-use and context, it is impossible to develop 'self-understanding' through which we know what qualifies as and how to use ready-to-hand equipment. This understanding allows us to interact with objects that manifest to us, filters what shows up in our everyday dealings and the meaning they hold for us in a way that is completely woven into the fabric of our social reality, prevailing practices and environment of action.

The implication of the foregoing is that human understanding of being is demonstrated in the way we act rather than how we think. Our way of being is rooted in our engagement with the world and not in our thinking as the idealists or rationalists would argue. Our way of being is interwoven with the world we live in and cannot be understood outside the interlocking and overlapping set of relationships with the world in general and context of action in particular. Scientists study the world as a collection of entities but entities are presented to us with referential relationships with other objects and the context in which they are situated, therefore objects cannot be reduced to and understood through physical and causal properties alone (Buren 2005). Natural science treat substances as part of the fundamental building blocks of reality capable of existence in isolation as independent units of reality. However, substances manifest to human beings not as substances with inherent capability for self-supporting existence (Cerbone 2006) but as ready-to-hand objects endowed with meaning when deployed in ongoing everyday activities. The things we encounter are what they are because of the context in which our lives intersect with them and how they are used. The same objects or entities will either lose their significance or take on new meanings when the context of use changes. Therefore, social scientists must strive to understand the world as meaningfully constituted using a hermeneutic approach and seek to understand rather than explain social phenomenon.

Objects that manifest to us are not exclusively subjective because referential relations have normative dimensions that delimits of what is socially possible or acceptable and how they should be used (Gergen 1994; Heidegger 1963). The use to which we put ready-to-hand equipment is socially determined, and inherited from historically and socially situated agreement of how objects should be used and how they manifest themselves to us.

Heidegger argues that being-in-the-world means we are in the world in a particular way located in a 'there' – a meaningfully structured environment permitting us to exist, engage in meaningful acts, disposed of and 'attune' to things (Heidegger 1963). In Heidegger's contention this attunement to the world allow human beings to "project onto possibilities" and develop practical and purposeful involvement with entities in an organised and meaningful world rather than through cognitive grasp or experience of the world. In other words, understanding precedes action in the world; to act, we need to understand how things relate to each other and how things hang together in the world we live in and interact with. This form of understanding is different from idealist conception of our relationship with the world. One can therefore argue that understanding in a cognitive sense would be inadequate to fully comprehend the world because it strips objects of their referential relationships with context and location (Heidegger 1963). Rather, understanding according to Heidegger relates to how Dasein projects onto and press into possibilities actions opened up by individual interpretations of how things hang together, testing the range of what can-be (potential) or has ability-to-be (socially constrained) in relations to the world.

Heidegger's analysis departs from the Cartesian approach where individual mind grapples to make sense of an external world by asserting a conforming public self and then proceed to explicate how autonomous individuals stand out from the collective public self. Human beings are vaguely aware that that the world to which they relate is somewhat ungrounded which in turn creates anxiety (Dreyfus 1990). To escape from or attenuate these anxieties, we seek to conform to the expectations and prevailing norms of the public self. While conformance frees us from immediate anxiety and social disapproval, compliance detracts from what it is to be our true self, an individual with power of agency. In our deeply socialised existence, we differ from others but operate under an ever-present social pressure to conform to socially defined norms, expectations and practices (Heidegger 1963). Since the world we know and relate to is socially shared, same norms govern what we and others do. Heidegger argues that through 'disburdening' people absolve themselves of responsibility for their actions by conforming to socially accepted norms. Conformity provides the background and social space in which we make important decisions without inviting social sanctions or disapproval.

As human beings, we ground ourselves through our relationships with the world, our interpretation of our role in the world and the practices we enact. Heidegger contend that to conform to the public self is a choice that denies us the experience of what it means to be fully engaged with the world. Dasein always retains some space to be true to itself and engage in an open, expansive and reflective action to assert its authenticity. This approach compels us to see meanings as contingent, tentative constructs designed to deal with issues-of-the-moment or concerns-at-hand. Dasein is authentic when it embraces its true self, contingent arrangements of practices and material orders and open up to ambiguity embedded in unique and specific situations. These relationships, interpretations and arrangement of practices provide an inherent scope and capacity for change and adaptation. The foci of innovation and entrepreneurship can be located in human capacity to manipulate these arrangements and reorder seemingly permanent structural features into a different assemblage of constructs and constituents to create new order adapted to specific situations (Schatzki 2002). Although the power agency is not unconstrained, the prevailing structural restraints do not deny human agents the social window to be authentic and project onto possibilities different constructs from their imaginations imbued with traces of their experiences and habitus. By being authentic, an individual refuses to submit and conform to the interpretation of the collective. Instead, human actors occasionally stray from the oppressive structure, order and compliance with prescribed norms because these conditions stifle innovation and prevent Dasein from being authentic (Steiner 1995).

It is not possible to understand human mode of existence on the basis of individual existence independent of any relationship to other human beings. As human beings, we are what we are because we share our world with others; our essence is not dictated by who we are but by those we interact with and relate to (Dreyfus 1990; Heidegger 1963). Therefore, our reality is defined by the way our mode of existence is woven into the fabric of social reality in which we live and constituted by the interlocking and overlapping set of relationships with the world. Entrepreneurs operate within a network of social relations (Anderson, Dodd and Jack 2012; Korsgaard and Anderson 2011) pressing into possibilities a range of social actions limited by social conditions and others with which they relate, based on their practical understanding of what can be or have the potential to be. To study innovation, understand entrepreneurship and agency will require us to understand social relations between entrepreneurs, other stakeholders with whom they interact and arrangement of relationships in the context of action.

5.2.1 Positivism, Interpretivism and Entrepreneurial Enquiry

If reality is socially constituted and determined depending on context of action, how can we account for the undoubted rhetorical power of scientific knowledge? Scientific knowledge is not unfiltered representation of reality but rather produced from within a culture which conditions the emergence of its knowledge claims (Pickering 1992). This culture, Pickering (1995) argues is not homogeneous but with subtle variations consisting of various components.

Scientists see data as uninterrupted inscriptions (Hacking 1992) but this assertion is contestable because observation itself is theory laden. Data measured in scientific experiments emerge from a process of invention and human intervention using devices for measurement based on formulated hypotheses, identification and isolation of variables of interest. Data generated from experiments is interpreted based on known theories and where there is significant deviation between prediction and observations, then theory can be revised or replaced (Ackerman 1985). The theory and practice of science operate in the flow of continuous becoming although to the untrained eye, scientific practice would appear to be unchanging acting like a veil screening the underlying process of change and becoming from scrutiny (Pickering 2009). One can therefore argue that theory is not and can never be a true representation of the world but a product of human intervention in the course of scientific practice.

However, nature does not always bend to human dictates and when theory is insufficient to account for all that is observable about the natural world, scientists resort to adaptation of practices in the process of scientific experimentation. This process of interactions between objects and agency is messy and non-linear or what Pickering (1995, 2009) calls the 'dance of agency'. The product of scientific practice is presented as a representation of reality arising out an ordered process of experimentation but this is a heavily reconstructed picture bereft of the messiness inherent in and associated with empirical work. The varnished, perfected version strips the presentation of the contextual contingencies, the adaptations and accommodations to imperfections that if made known could alter the meaning and acceptance of the knowledge claims. The use of cognitive, demonstrative, methodological, normative or rhetorical reconstructions in scientific studies are based on certain assumptions of how the world operates and conveyed by a form of rhetorical presentation. Human intellect and choices interject in and transform the natural world in the course of scientific practices by locating and articulating how the natural world works in a web of relationships linking empirical activities to the material and social world (Gooding 1992).

Gooding (1992) shows successive accounts of scientific experimentations are replete with construction and reconstruction of action through progressive replacement of ambiguities with certainties. In demonstrating agency, scientists make choices about the direction of experimental enquiry, but through reconstruction, conceal the chaotic process of practice from where scientific knowledge emerges. Gooding asserts that theory is incomplete and insufficient to guide action contrary to the hypothetico-deductive model because the process through which scientists experiment and interact with the real world is fused with complexity and full of contradictory relationships between material practices and instrumental model.

Nonetheless, Popper (2002 [1935]) argues that research should be predicated on systematically developed, clearly defined and testable hypotheses. Deductive logic provides a way of making authoritative statements about what is not currently known based on what is already known, allowing researchers to draw logical conclusions about phenomenon of interest based of general events. Unlike empiricists, Popper (1989 [1963]) contests the belief that scientific theories are derived from observations, rather he asserts that scientific knowledge emerges from a process of *conjectures* and *refutations*. Empiricists argue that scientific knowledge develops from systematic and repeated observation process of induction, moving observations from the particulars toward generalization and theories. As Popper argues, there is no certainty that observations from past instances will resemble future observations of same phenomenon. Since any instance of future observation that contradicts past occurrences invalidates inductively derived theory, Popper (1963) therefore argues that induction cannot be a valid form of inference and scientific theories cannot be proven but can be refuted. Therefore, rather than seeking to prove scientific theories, Popper argues that scientific knowledge should be develop using a process of *conjectures and refutations*. The method of theory development using *conjectures and refutations* is what is known as hypothetico-deductive method or what is otherwise known as the covering law model of explanation.

The hypothetico-deductive model consists of two parts: hypothetico meaning 'based on hypotheses' and deductico which means through deductive logic (Lee and Lings 2008). Researchers using hypothetico-deductive method use models as small scale representations of systems they are interested in investigating. These models are used to establish and clarify relationships between variables, establish linkages between observed phenomenon and variables in the model, and widen explanation beyond the narrow confines of representative model. Supporters of hypothetico-deductive method argues that through this method, the researcher aims to prove specific, previously unknown aspects of a phenomenon using general observation of what is known through systematic investigation.

The process of hypothetico-deductive method of investigation as presented in Figure 5-1 depicts a series of human interventions at every stage. The trigger for research starts with human observations and the need to develop better understanding of observed phenomena although observation is neither value free nor uninfluenced by experience of the observer. The need for understanding, the very trigger for research as a result of observation is subject to interpretation. A critical step in the hypothetico-deductive method is the development of testable hypotheses. When the researcher is developing testable hypotheses, he is actively interpreting his experience and engaged in a process of manipulation, selection and construction. Variables that are deemed important to answering the research questions based on understanding and interpretation of researcher(s) are privileged. These human active interventions have significant influence on the set of hypotheses that can be developed, how they are to be operationalised, what can be tested, criteria for confirmation or refutation. The development of testable hypotheses reflects an active process of human intervention and construction disguised as an objective process.

The research method deployed in data gathering is matched to the investigation and deemed suitable for collecting data necessary to answer research questions. However, since the hypotheses to be tested to confirm or refute tentative relationships between variables or things reflect the imposition of researcher's understanding on how things may be related to one another, these tentative relationships are outcomes of an interpretive process and cannot be presented as neutral or capable of revealing some objective truths about phenomena independent of human construction.

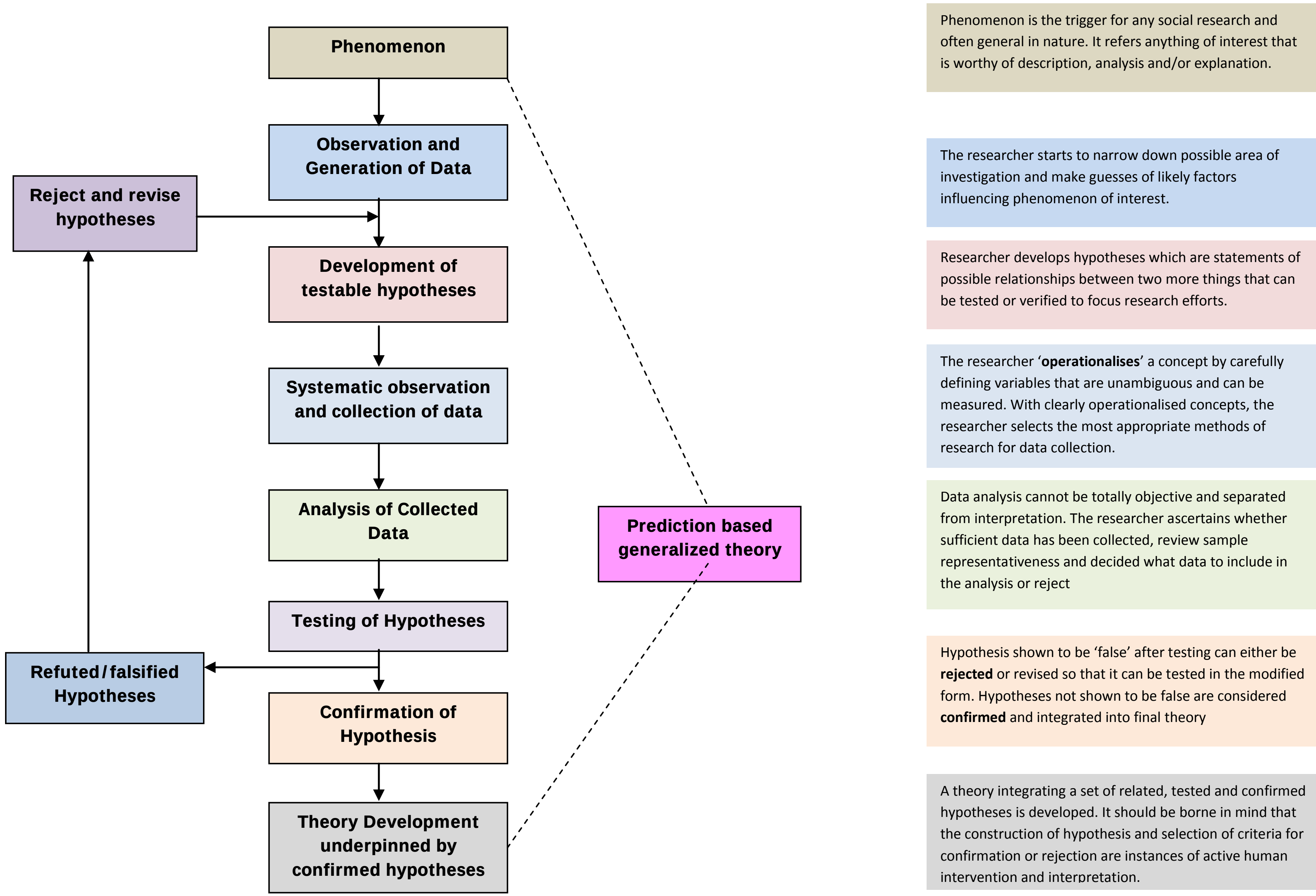

Figure 5-1: A schematic of the process of hypothetico-deductive method of investigation

Scientists develop models used in the course of experimentation based on conceptual understanding and normative expectations of how things should work. However, when experimental set up fails to work or material (non-living) entities do not conform to the expectations of human agency, scientists accommodate resistance of material object by trying other instrumental models. Gooding (1992) shows that scientists need tentative representation of possible outcomes (construals) to bring new phenomena into the domain of discourse and establish a fit between their cognitive creations and empirical observations. Over time, some of the construals repeatedly converge with material objects until they become embedded in and accepted as an integral part of reality of the phenomenon being investigated.

These methods developed by scientists to address contingent situations accommodate material agency and have the power to restrain or constrain human agency (Franklin 2008). It is the dance of agency and efforts designed to accommodate resisting non-human, material entities in scientific practice that Pickering (2009) called the *mangle of practice*. Pickering's argument about the mangle allows us to see the evolutionary progress of scientific practice developing temporally and spatially in response to coping and accommodating material resistance and agency. To be a scientist one needs to know how the mangle works but it is also in the interest of scientists to deny outsiders any insight into the inner workings of the mangle (Gergen 1999).

The process of scientific knowledge production is closed to those outside the community of scientists who lack knowledge of how these inscriptions devices work and how their measurements relate to aspects of reality. The general population has insufficient knowledge to question the validity of these measurements and the inferences scientists draw from their measurements deny non-experts the basis to question scientific claims and credibility. Lack of accessibility to the workings of scientific practice and the premise of claims emerging thereof cloak scientific knowledge with authority and credibility while simultaneously denying outsiders access to the inner workings of the 'black box' of knowledge generation (Latour 2005; Gergen 1999).

Scientific knowledge is produced from a relational process between objects, people and environment through a process of conscription (Latour and Woolgar 1986). According to Latour and Woogar (1986), scientists generate support for their positions and diminish contrarian arguments by relying on support of allies, prior texts, rhetorical devices (numerical numbers, tables, graphs, etc) and inscription devices (experimental tools and devices). Through co-opting and conscription, scientists produce knowledge claims. In scientific practice, rhetorical devices are accorded higher status in the practice of truth telling; evidence from inscription devices are presented as measurements of the world as it is, using power of rhetoric. The knowledge of reality that scientific method produce, far from being the unvarnished truth about an objective world, is a product of negotiated process designed to represent the world through the prism of particular interests. This is not to diminish scientific knowledge claims but to submit that scientific knowledge should have no greater claim to truth than other forms of knowledge.

If the knowledge claims produced through scientific methods are not beyond reproach, how are we to begin to understand knowledge creation? What are the mechanisms through which knowledge creation is initiated and sustained? In the next section, an exposition of social construction of knowledge is presented.

5.3 Social Construction of Knowledge

Reality, knowledge of the world and self is created through interaction, social exchange, temporal and spatial intersection of historically, culturally and socially related groups of people (Gergen 1994, 1999). This communal view challenges widely held, even reified, assumption in Western philosophy about the self and individual mind as the source of knowledge about what we take to be real. If our knowledge of the world is culturally, historically determined and socially certified, then the view that social science can explain social life using universally applicable law is unsustainable.

Kuhn (1962) argues that knowledge production in any discipline depends on socially certified practices and shared commitment to a paradigm. By extension, objectivity is only possible when humans are armed with rules of intelligibility that is set out and deemed acceptable by a paradigm. All researchers view the world through different prisms, lens or paradigms. These lenses or paradigms have strong influence on human observations, understandings and choices.

Kuhn (1962) argues that scientific progress occurs through epochs of normal science truncated by periods of scientific revolutions. According to Kuhn (1962), normal science is conducted according to a set of rules, standards and investigative practices which are accepted by those working in a particular field but are not universally accepted. During period of normal science, scientific problem solving occurs within the set of rules and techniques sanctioned and accepted by the community. Paradigms are collection of interrelating assumptions, beliefs, values and investigating techniques, analytical methods that are used and shared by members of a community. Paradigm shifts occur when facts and observations cannot fit into or explained by existing theories forcing scientists to seek new theories based on new sets of assumptions about the world in order to explain observations or re-interpret know facts.

The shifts in paradigms are results of scientific revolutions and emerging paradigms that are *incommensurable* with existing paradigms. When paradigm shift occurs, there is an effective break between emerging paradigms and prevailing and commonly accepted paradigms; the newly created paradigm does not share the same set of evaluation criteria with the one it is attempting to supplant. In contrast to Popper (2002 [1935]), Kuhn's argument suggests that what is 'true' or 'false' is only meaningful within the rules of evaluation sanctioned by the prevailing paradigm. Kuhn's explanation of scientific progress based on paradigm demonstrates the scope and limits for diversity in thinking about new problems or phenomenon.

Prevailing paradigm constrains what and how we think about the world, its constituents, their interactions and relationships (Lincoln and Guba 1985). Each paradigm is unique in the way it categorises and presents objects to us in interactions. To link back to Heidegger, because a paradigm constrains how the world is presented to us, it also fore-structures and delimits what we can envision as possible. Burell and Morgan (1979) explain the power of paradigm by bringing attention to how it shapes our foundational assumptions we use in constructing our frame of reference, our approach to theorising and selection of investigation methods.

This view is predicated on the assumption that any research needs a frame of reference and its underlying assumptions in defining research question, selecting research population and choosing a methodology. Our view of the social world and how we choose to investigate it depends on our assumptions about the world and cannot be value free or unconstrained by some fundamental theoretical assumptions. Therefore, one can argue that alternative research questions not asked are probably not less important; but they are simply invisible or deemed unworthy through the prism of filtering paradigm of the researcher. If prior commitment to a paradigm precedes knowledge creation, then it is impossible to separate any claim to truth from the paradigm that precede and informs practices in generating knowledge claims.

Linguistic exchange has been likened to a language game governed by socially defined and acceptable sets of rules. These rules allow people to interact, communicate with and understand each other and as a consequence integrate into prevailing social 'forms of life' and patterns of relationships between human and objects in the world they inhabit (Wittgenstein 2001 [1953]). If knowledge creation depends on a communally shared paradigm, and rhetoric or ability to persuade, depends on the use of language based on socially agreed rules, then what is produced as knowledge only reveals what is privileged to emerge based on socially agreed rules of conduct and discourse (Derrida 1978). Therefore, it is logical to challenge the capacity of philosophy to produce knowledge of the truth since philosophers describe the world through the medium of language. Since language privileges a description of a form of reality as against another, then knowledge of reality as described by a paradigm using the medium of language should and must have a limited reach.

Social scientists who are positivists rely largely on statistics to produce objective knowledge so that inaccuracies and ambiguities inherent in language use can be minimised. However, Iversen (2003) shows it is possible to reach vastly different conclusions using same data set when subjected to different statistical techniques and in the process paint different pictures of reality. This demonstrates that statistics, in the hands of suitably qualified researchers, should be construed as a language that can be used to construct different pictures of the real world, accentuating or suppressing different interests and aspects of reality.

A case has been made that knowledge is socially created, informed by a paradigm and rhetorically conveyed through the use of language. The argument of communally created knowledge and the mediating role of language challenges positivists claim that scientific method is the ultimate way to research and apprehend the real world. Everyday scenes have unseen, often taken-for-granted, background features through which reality is filtered and interpreted. For any group, the background features form a scheme for interpreting the world. Schultz (1970) argues that 'special motives' are required to make the socially taken-for-granted, life-as-usual of everyday scenes available to awareness, and make the invisible come into recognition. In the next section, an attempt is made to explore in greater detail how social actors use different tools offered by language to create social reality and with what implications for what can be known about reality and social phenomena.

5.3.1 Language and Construction of Social Reality

Sociality and socialisation require the formation of shared understanding but this shared reality is largely a product of commonly shared language. In our interactions, we create a pattern of actions from which we define what is socially acceptable, what constitutes a violation of acceptable practice and punishment for deviations. It is the tendency to establish order of repetitive and routinized actions that help human actors establish rules of social accounting and how to respond to others in social relationships (Bakhtin 1981).

Everyday life consists of taken-for-granted, familiar entities and unfamiliar, problematic issues that require effort to gain understanding. Human beings share everyday life with others and integrate problematic realities into their everyday life using pre-existing ‘plausibility structures’ and tools that have been socially proven to be effective at such task based on common sense knowledge and history (Berger and Luckmann 1996 p.24). In the ‘here and now’ of social interaction, two or more individuals exchange expressions and make their subjective world available to others through multiple and socially recognised schemes and symbols that give meanings to reciprocal action. The further individuals are removed from face-to-face interactions in everyday life, the more social interactions become anonymised but still retain traces of socially recognised framework of meaning to guide social action. Through the medium of language, subjective realities of individuals is objectified, made available to others and invested with the capacity to transcend immediate settings and locations of face-to-face interaction (Berger and Luckman 1966).

Although language originates from social, face-to-face interactions, it can be detached from settings of face-to-face interactions and has the power to communicate subjective meaning across spatial locations distributed between social groups. The power of language, sign or symbol to transcend geographical boundaries allows it to escape the shackles of the ‘here and now’ and immediate vicinity of its production. A sign is an objectivation, an outward manifestation and an index of subjective meaning (Potter 2000) but all objectivations can be transformed and deployed as signs to signify newly constructed meanings beyond the intention and location of original creation. Through language we recognise and fit into a relevance structure delineated by context. As human beings, we make use of our awareness of our relevance structures and that of others to pick and choose our actions and recognise the need for reciprocal actions in social interactions. The validity of knowledge is taken for granted until human beings are confronted with scenarios or circumstances where previously acceptable meanings become untenable and new knowledge has to be created to resolve or generate previously unrecognised socially acceptable meaning.

Semiologists distinguish between the signifier as literal meaning (denotation) and the signified as the interpretive meaning (connotation) in language use. This agrees with the contention that the association between the signifier (a word or signal) and the signified (that which is believed to be signalled by the sign or word) is arbitrary (Saussure 1998 [1916]). Words used in describing the world assume meanings when entered into use and become socially adopted to signify what is intended. No individual on their own has the power to change a sign once it has been pressed into a system of linguistic relationships. Therefore, language or system of signs is governed by their own internal logic and rules, consequently people take language and speech patterns with them as they move between social groups and across cultures (Tietze, Cohen and Musson 2007).

Communication must and does follow certain rules in order to retain the power to transmit ideas, concepts and knowledge. To develop socially meaningful understanding of the association between words, we need to defer to other terms that tell us about the linguistic or historical usage of these terms (Fiske 2004 [1982]). The combination of the difference and deferral provide the sum total of what makes arrangement or association of words meaningful (Derrida 1978).

Human communication is immersed and interwoven into a system of meaning Geertz (1973) or 'webs of significance' that he refers to as culture. Language is a central component of the cultural web and plays a central role in the process of socialisation, shaping thoughts about and circumstances in which action transpires ((Tietze, Cohen and Musson 2007).

Our interest influences the way we see the world, what is of importance to us and our capacity to observe the world with total objectivity. Since we cannot observe the world without the bias of our interest, our ability to describe the world objectively will always be questionable. Habermas (1984) argues that all knowledge seeking efforts give prominence to certain interests over others because there is no unbiased and disinterested pursuit of truth, therefore by extension rationality is rooted in the structure of interpersonal linguistic communication. Positivist researchers, like other human beings, also have interests in research outcomes and as a consequence the research process and their interpretations of the world privilege certain interest to the detriment of others. Therefore, any authority including scientific authorities can and should be examined to reveal the interest, values and doctrine supporting any knowledge claim that is presented as unvarnished truth.

Even if we accept empiricists' contention that the mind act as mirror reflecting reality, it is undeniable that what is reflected is often conveyed or presented through the medium of language, using the spoken words or symbols that are subject to interpretation and can have multiple meanings. Scientists may argue that objects and words used in describing them correspond because scientists deal with observable phenomena, however Quine (1960) shows that the association between the words we use and the objects of description is inherently vague in different cultures and system of meaning. Therefore, any arrangement of words is only meaningful within certain cultural boundaries. Therefore, any knowledge claims arising from scientific study should be judged with the understanding that the reality portrayed can have multiple meanings across time and space.

Since the relationship or association between the signifier and the signified is arbitrary (Saussure 1998[1916]) and the arrangement of words in any language must conform to certain rules to be meaningful, then the meaning inherent in any arrangement of words cannot be independent of language. Words derive their meaning through their usage and in relations to other words, therefore language description do not provide a description of the world as it is. In analysing any rhetorical effort to portray the world, language must be recognised as having the capacity to represent different sides of the same phenomena depending on the arrangement of words. Language has the power to create realities serving the interest of one group to the detriment of others, reinforcing or reshaping power relations in social encounters.

Goffman (1990 [1959]) sees language as more than an arrangement of words but as an expression of social action consisting of words, dress and bodily gestures with power to create new realities. Goffman (1990 [1959]) argues that in our interactions we constantly seek to create a socially acceptable public identity while hiding a side of our personality that we do not seek to reveal. Goffman's argument, taken to its logical conclusion, would mean that not only are all acts designed for performance but also to be socially engaged is to understand these rules of performance. Like Goffman, Garfinkel (1984 [1967]) argues that human beings use linguistic expression to achieve rational ends or what is taken-for-granted by borrowing words from other contexts to generate new meanings appropriate for new settings. Garfinkel (1984 [1967]) argues we bring order to an otherwise chaotic world by transplanting words from old into new contexts of use and meaning.

Derrida (1978) argues that the process of making meaning in any language inherently carries within it suppression of alternative construction of meanings. The claim to rationality when critically examined is ultimately hollow because what is presented is the privileged interpretation or meaning at the expense of possible alternative constructions. In traditional view, language is viewed as a reflection of the world capable of conveying the truth about the world and nature of reality. However, since we privilege certain words usage against others and by extension suppress alternative meanings in our choice and use of language, the picture metaphor of language as reflecting reality unmediated is an inaccurate, unreliable and misleading assertion.

In this section, the idea of accepting an individual mind as a source of knowledge or acceptance of empiricists' claim of scientifically derived knowledge based on observations without giving a thought to the role of language is argued to be flawed. Human beings share the contents of their minds, describe and explain phenomena through the medium of language. Using the picture metaphor, our words convey a description of reality but it is not truly representative of the object being described. Since we can only communicate and describe what we take to be true about the nature of reality using words, symbols and signs, then we cannot truly explain and describe the world as it is using the medium of language. Lack of correspondence between our objects of description and what we can describe with language must lead us to conclude that neither positivism nor interpretive approach to research can ever truly convey to us the world as it is. These research methods can only present us with representation of the world according to the rules of language we employ. Taken to its conclusion, language cannot be a mirror of life since it is part of fabric of reality we attempt to describe. As Gergen (1994) argues, activities such as 'describing', 'explaining, 'theorising' are part of a social process of truth telling based on socially acceptable rules. Any description of reality is therefore context bound with limited power outside the specificity of context to which it is connected.

This study takes an interpretive stance predicated on the ontological assumptions that reality is socially constructed, with multiple meanings and influenced by the context (Tadajewski 2006). This is in agreement with Crotty (1988) who argues that meaning comes into existence when we engage with the world. Meaning is therefore constructed and not discovered making subject and object as partners and co-creator in the construction of reality. Epistemologically, interpretive researchers assert that social reality is composed inter-subjectively through human-to-human and human-to-context interactions. To accept this stance is to acknowledge that knowledge is socially generated, collectively owned and cannot be accessed through an external, objective position (Tadajewski 2006) but through lived experience of research participants (Cope 2005). It is for this reason that this research is predicated on a social constructionist stance.

5.4 Epistemological Foundation for Entrepreneurial Enquiry

In the preceding sections, the philosophical case has been made that social reality is jointly created. It has been demonstrated that individuals are incapable of acquiring knowledge of social reality through observations alone, using the mind as a mirror. The role of language in creating different meanings and by extensions multiple social realities has also been explored. If social reality is created through social interactions and different human modes of engagements with world, then how can researchers learn about the constitution of and mechanisms underpinning this reality? This section presents a social constructionist perspective to the epistemological challenge about how human actors acquire knowledge of the self and the social by extending the contention from the previous section that knowledge is socially produced, owned and contextually situated. In taking a social constructionist case, this section also contrasts social constructionist epistemological stance with empiricists and scientific method in general.

We receive sensory perceptions about the external world using our five senses – sight, smell, sound, taste and touch but the way we see the world and how we interpret our experiences of the external world is culturally and historically bounded which changes through time. Therefore, the use of sensory experience as an affirmation and means of apprehending reality is questionable. Social construction transcends these ontological and epistemological challenges by urging human actors to challenge their taken-for-granted view of social reality. Social constructionism as a philosophy is predicted on important and critical assumptions about the world (Gergen 1999; Burr 1995, 2003) such as:

1. There are countless ways of describing and explaining any social phenomena, consequently, there is nothing about 'what there is' that demands a particular account or arrangement of words that could not have been rendered with alternative accounts using the medium of language.
2. Our understanding of reality and the description, explanation and representation of reality emerge out of relationships. Language and other forms of representation gain their meanings only through the way human actors employ them in relationships through social coordination. Therefore, human relationships constitute reality and reality cannot be comprehended without a prior acknowledgement of the role of human relationships. By implication, the world is intelligible to us through our understanding and explication of human interactions.
3. The ways we describe, explain and represent the world not only help sustain intelligibility of the social in the present but has the power to simultaneously create the future. The capacity and potential to create the future through language is what Gergen called 'generative discourses' that challenges traditional boundary of understanding and open up alternative routes of social action.
4. Social constructionism challenges us to reflect on taken-for-granted, accepted forms of understanding that is socially reified and instead embrace new ways of thinking, listening, discursive practices so that we can embark on a journey that leads to alternative framings of reality, suspend obvious understandings, and examine comparative outcomes of multiple constructions of reality.

The case has been made earlier in this chapter that scientific facts are nothing more than a form of interpretation irrespective of the rhetorical authority with which they are presented. The transcription of scientific facts that is presented as unvarnished truths depends on the choice of certain words, preference of certain descriptive language and selection of certain of forms of explanation in preference to alternative interpretations and descriptions cast aside by the presenter.

Empiricists' argument that researchers need to remain dispassionate and reflect the world as it is, keeping a distance between themselves and object of research in order to maintain objectivity should be contested. As Habermas (1984) argues, human beings are not disinterested parties in the affairs they engage in. In the same way, scientists research subjects for a reason with certain expectations as to what ends research outcome could and should be used. Scientists interests in their subject of research show up through the research process at every stage and it is therefore disingenuous to cloak the result of their research in the language of neutrality. By extension, scientists cannot be value free because the results of their research will have impact – negative or positive – on the larger society and by extension influence the nature and content of social reality.

In scientific practice, scientists seek to control the conditions of experiments so as to understand the relationships between causes or antecedent conditions and effects, in the belief that events have preceding causes. They control these precedents, vary conditions, record their observations and postulate about consequences. However, the idea of cause and effect is a social construction read into observations of the world in order to make it intelligible, an 'a priori' commitment that fore-structures what is observed, the way observations are interpreted and the meaningful understanding developed from research efforts. Causal linkages read into events rely on underlying assumptions that are only meaningful when viewed through the prism of a paradigm (Gergen 1999).

Scientists use inscriptions devices (numbers, tables, charts, etc) and convert observations into numerals (Latour, 2005) because language is clumsy and can be an imperfect medium for capturing and representing the nuances and variations in observations reflecting reality accurately. Conversion of observations to numerals allows scientists to deploy statistical tools to explore and understand subtle variations in the data set and reveal cause and effect relationships embedded in the data. This type of statistical analysis allows scientist to present generalised implications of research beyond the immediate confines of research or laboratory settings and make prediction about the future. But numbers are nothing more than another form of translation devices similar to textual description, therefore conversion of observations to numbers bears no greater accuracy about the world than any other form of representation. Also, such translation can mask subtle variation in the data and deny us important insights into understanding the forces that drive social action and change.

Science, and its many disciplines, has developed varied vocabularies with which initiated members of the scientific communities describe the world and engage in meaningful conversations. These descriptions, vocabularies and style of communication are 'outgrowth of communities and not observing minds' (Gergen 1999, p.14) dressed up as scientific truths. For a social scientist, translation of observations to numbers de-personalises experiences with the potential to mask our understanding and influence of context on social phenomena. The choice of which statistical tool is used in data analysis and the outcome of analysis depend on the interest of the scientists doing the interpretation. It is this dependence between outcome and choices made by scientists that makes Gergen (1994) to call statistical tools 'silencing devices' and why Latour (2005) refers to them as 'black box' because these expert devices are inaccessible to most outside the scientific community.

To understand social relationships we need to engage with interpersonal understanding. The study of interpretations provides some guidance to help us understand how we develop interpersonal understanding. Gerger (1999) argue that words and actions outwardly manifest our inner minds, therefore, to correctly interpret or draw logical inferences from a text we need to access the mind of the writer (Hirsch 1967). However, since language is historically and culturally situated, it is therefore inaccurate to argue that a systematic approach to interpretation can reveal the intent of an author or yield uncontested truth without taking the context and socio-historical usage of words into considerations.

Gadamer (2004) argues that our understanding and interpretation of any text flow from a pre-understanding of what we believe which in turn fore-structure what we can meaningfully understand. This pre-understanding delineates the boundary of what can comprehend or what Gadamer calls our 'horizon of understanding'. Our horizon of understanding allows us to access and integrate new information into our knowledge structure by engaging with new 'horizons of understanding'. Gadamer's explanation is elegant but problematic because it is predicated on the assumption that individuals are capable of completely suspending judgement or ignore existing structure of meaning while engaging with a text. To develop deeper meaning from any text, Bakhtin (1981) argues that we need to enter into a dialogic relationship with the text and engage with alternative horizons of understanding so that we can create a fusion of horizons and wider universe of understanding. Bakhtin's explanation is more helpful than Gadamer's in helping us to understand how we integrate new meanings into our existing structure of understanding.

Human actors gain new meanings and understandings not only by engagement with texts but also through human interactions. Interpersonal understanding – our ability to locate the meaning behind other people's actions and words – is central to social interactions and relationships but difficult to understand if we are looking through the prism of the individual mind. A more expansive and elastic conceptualisation is to see interpersonal understanding as the result of interplay between the individual and social practice. This approach allows us to develop greater depth and breadth of interpersonal meaning. Gergen (1999) argue that meaning is an emergent property resulting from coordinated social action and resides within relationships. Therefore meaning can be found in the realm of social interactions and practice, outside of individuals. By implication, meaning is a social property and only meaningful through relational process or supplemented action of others. Our actions and words do not acquire full significance or become completely meaningful socially until supplemented by the words or acknowledged by the actions of others. This action-supplement pairing or relational reciprocity and pairing demonstrates why meaning results from coordinated social action. To behave meaningfully requires us to acknowledge the presence of others and therefore engage in social relationships (Schmidt 2006).

As social agents, human actors carry within them history of relationships and residuals from past interactions to inform the present or future action. Their vocabularies in social interactions rely on and are informed by their history and experience. What is socially meaningful is therefore not static but carried within a dynamic, continuously evolving process where mutation of meaning is driven by intersections of relationships, actions and context.

Social constructionists disagree with the search for a generalised law to explain social reality that proponents of scientific methods seek because no singular arrangement or combination of words and rhetorical devices (tables, graphs) is capable of describing the world as it is without engaging in a suppression of alternative explanations or interpretations. The acceptance of a theory to be true or false based on empirical evidence depends on interpretation to which the data is subjected to and the paradigm that informs the analysis and discourse, therefore no data set, no matter how detailed and extensive, can prove a theory to be true or false. Since any interpretation employed on any data set comes from a paradigm and a set of assumptions about the world, it is unsustainable to argue that any generalised theory derived from any scientific study is a true representation of reality.

Social constructionism does not advocate the search for independent and uncontested truth but rather seeks to encourage a generative discourse that inheres in and co-exists within multiple traditions and interpretations with the capacity to enrich our discourse, deepen our understanding of reality and the world we live. Social constructionists concede that empirical research have produced detailed description of phenomenon and generated theories with powerful ability for predictions, but these strengths notwithstanding, the outcome of empirical scientific research is an interpretation of the world based on a paradigm suitable to a research methodology that cannot and should not be universally applied to all research problems. This philosophical stance encourages the emergence of a multiplicity of meanings in a social space of overlapping relationships, allows social actors develop new horizon of meanings, widen their universe of understanding and empower creative social action (Gergen 1999).

Through these multiple and occasionally conflicting interpretations of realities, we empower ourselves to develop new understandings with a power and inherent capacity to shape the future in a continuous state of becoming. This study subscribes to the view that social reality is local, varies between groups and individuals, actively constructed, and it is a property of groups and not individual. Therefore, from a phenomenological standpoint, research such as this, aimed at studying the innovation through technology entrepreneurs, must access the complex relationships and social forces that propel change through an understanding of the social constructions of process participants.

5.5 Methodological Justification

Scientific research is popular because of its rhetorical authority and its knowledge claims have been proven to be largely reliable. Science and the outcome of its research methodologies have established a track record of revealing aspects of reality and deepening our understanding of nature (Potter 2000). The relative success of science has encouraged proponents of scientific method in the social sciences to seek to discover causal explanation and uncover laws governing behaviours of human agents. On the other hand, in interpretive work, researchers seek to understand how human agents' behaviours are bounded by rules and context (Creswell 2003; Seale 2004). However, social interactions are based on shared understanding, predictability and reciprocity of action, therefore as a researcher who subscribe to the interpretive school, this work is based on the belief that human actors unlike natural objects of scientific interests in physics can be asked about their intentions and motivations to contextualise their decisions and choices (Hindle 2004; Ucbasara, Westhead and Wright 2001).

Day-to-day living depends on our ability to successfully predict behaviour of others and their responses to our action. Our understanding of others and expectation of them is limited by social rules of acceptability. Therefore, our ability to access observational evidence places a limit of what can be scientifically investigated. Scientific approaches seek to provide us with explanations, reasons as causes, cause and effect relationships while interpretive approaches seek to reveal meaning and understanding behind social action (Ritchie and Lewis 2003). Explanations cannot tell us what we really ought to know about the meanings social actions attach to their actions (Bull and Thomas 1993). On the other hand, interpretive study provides us with rich, broad explanation of meaningful social action that is context bound (Welter 2011). Consistent with interpretive inquiry, it is important to understand that explaining a social action is different from explaining causality (Potter 2000) because we can only claim to understand a social phenomenon when we understand the meaning it has for social actors engaged in the action (Weber 2003 [1904]).

Human activities occur in a social space similar to Heidegger's clearing complete with inherent potential and limitless range of possibilities. If the possibilities that could be achieved are limitless, how do we account for the constraining power of social reality? In this study, the innovation site is conceptualised as akin to the social site (described by Schatzki) where human beings and non-human entities interact. The order at the social site consist of entities (people, artefacts and things) having properties such as regularity, pattern, stability and interdependence (Schatzki 2002). Life at the social site is a 'mesh' of practices and order, where practices refer to the collection of organised sayings, doings, tasks and project that are linked through an array of understandings, role and teleoaffectivities structures. Practices and orders are interlocked forming a web of relationships in which human beings operate but the shape and composition of the webs of relationships is contingent and subject to change.

The diversity of components stitching practices together allows practices to retain enormous capacity for change and transformation while appearing seemingly stable (Schatzki 2002). A practice is linked to the orders it establishes but can also be connected to other practices outside of its immediate boundary. The boundary delineating a practice is porous and permeable allowing entities including habitus and influences from the past to move across it. The porosity and permeability across boundaries of practices allow practices to have the resilience to cope with change and the elasticity to adapt to situations in different contexts.

The outcome of any social action may lead to different outcomes because people carry practices with them across spatial and temporal boundaries into many social sites with different orders arrangement. The social site has the capacity to prefigure action acting like a filter for cost- benefit analysis. Social life prefigures activities by making some paths costly in comparison to others; allocate costs and benefits unevenly thereby limiting the range of feasible options open to human actors. How individuals evaluate and decide which path to follow is informed by their habitus. In making choices, actors evaluate costs and benefits, ease or difficulty, and how to accommodate contextual conditions depending on history, experience and context. Since the social site is a type of context, and will be different from cases to cases, what happens at the site cannot be excavated through the search for generalised social laws. Rather, social investigations such as this study calls for a method of enquiry that seeks to understand the motive for social action and what meanings enacted social actions hold for human actors embedded in and enveloped by the social context.

Earlier in this chapter, the provenance of innovation has been traced back to human modes of being and how material objects in the world are disclosed to social actors. In the occurrent mode, human actors confront the limits of existing structure of meanings in a particular context and are forced seek new ways of doing things. This re-examination of prevailing arrangements of materials and practices give rise to new meanings and by extension innovation. However, the power of agency to transform material objects and reshape practices in not unfettered but constrained by contextual and socio-historical factors. As social actors interact and engage with concerns of the moment, they do so in the presence of and in coordination with social others. In the innovation construction process, the social others are the stakeholders with whom technology entrepreneurs have to inter-relate to develop new technology.

Qualitative research places interpretation and meaning of human experiences at the centre of process of interpretive inquiry. Dilthey (1977 [1927]) emphasises the importance of understanding (*verstehen*) and peoples lived experience in their unique socio-historical context to study and understand social phenomena (Outhwaite 1986). Weber (1949) argues along same lines as Dilthey by stressing the importance of understanding in the study of social phenomena, arguing that analysis of material conditions is insufficient for the understanding of social phenomena but rather researchers must also understand the meaning of social action in the context of material conditions. Therefore social science should aim to understand subjectively meaningful experiences.

All participants in the technology development process make subjective choices. Some of the decisions entrepreneurs make are rational and planned in advance while others are subjective, contingent or even opportunistic depending on contextual factors. Entrepreneurs interact and negotiate with others to produce and market technology artefacts within the oil industry. The choices they make often have technical, operational, social and economic consequences. Therefore, entrepreneurs as social agents have to operate within social constraints where interactions, choices and exercise of judgement can be critical to success or failure. The use of quantitative techniques to understand the mix of those subjective and objective interactions driving the process cannot be deep and sufficiently exhaustive. On the other hand, using an interpretive technique in studying these intricate social interactions and relationships can help explore the rich and deep data – experiences and meaning actors ascribed to those experiences - that can help improve our insight of how the emergence of technology innovation is negotiated and socially constructed within the oil industry. This type of study calls for a methodology that is descriptive and flexible to explore connections between various iterative phases that co-evolve, identify enabling and constraining factors and the strategic or tactical tools and devices some entrepreneurs use in overcoming these barriers where others fail. To peel away these layers of complexity and reveal underlying structural relationships and contingencies that drive the process requires use of interpretive technique as the most effective way to seek the views, opinions and experiences of actors and begin to understand the process of technical innovation in the oil industry.

Social reality is constituted through words, signs, symbols and actions of human beings at the social site. It is through communicative actions the need and use for technology is articulated. Through language, among other communicative tools and devices, an entrepreneur can convey innate capabilities and advantages yet to be proven to end-users. Tacit knowledge is tied to an individual and can be difficult to access (von Hippel 1994) but end-users of technology base their decisions on technology adoption in part on tacit knowledge. Although end users may be unable to verbalise their needs or concerns, entrepreneurs need to understand that human choices are moderated by contextual factors even though outcomes can be shaped by human interactions (Sarasvathy et al.

2003). Therefore social interaction is critical to entrepreneurial ability to convince and persuade potential customers. This suggests that entrepreneurship and technical innovation construction are social phenomena shaped by context, social interactions and relationships and ought to be studied as a social system (Anderson and Jack 2002; Anderson and Miller 2003). Since meaning-making is an inter-subjective, this research is aimed at understanding the process of technology development and emergence rather than looking for causal mechanisms.

The research seeks to answer the ‘how’ and ‘why’ question about ‘what’ is going on within the process of technical innovation in the UK oil industry. Patton (2002) asserts that qualitative technique is appropriate for studying a “process” because it is suited to detailed description of how people engaged in a process interact with each other, account for subtle variations in individual experiences within the process and access what sense they make of these experiences based on the words of the actors themselves. Interpretive research technique is appropriate for study of a fluid and dynamic process that cannot be captured by rating scale, and access perceptions of actors engaged in the process to understand how the process function.

In adopting a social constructionist perspective, this research assumes that stakeholders within the process of technology construction are co-creators of the reality they perceive and operate within (Downing 2005). In using social constructionism as an epistemological foundation for this study I am assuming that some of the fundamental assumptions about social constructionism apply to my research. The assumption of social constructionism is predicated on the belief that taken-for-granted knowledge about technology and innovation may be misleading and social manipulation of structural features rather than structural determinism as mediators of innovation construction apply to this research study.

5.6 Research Design

Qualitative research based on an interpretive approach allows researchers to study things in their natural settings to understand actions, decisions and beliefs in the social world (Denzin and Lincoln 1994). To get an in-depth understanding of people, the meaning they attach to their actions and interactions with other actors in the social world, qualitative researchers try to learn about the social and material conditions people live in, their experiences, histories and interpretation they give to their experiences (Lee and Lings 2008). Because qualitative research address questions that seek understanding of context and meaning of social problems it is more suitable for understanding processes or complex social issues (Marshall and Rossman 2006; Patton 2002; Ritchie and Lewis 2003). This research assumes an interpretive stance while accepting the limitations of the research methodology. The research is aimed at understanding the role of social interactions on the process of technical innovation construction and the emergence of new technology in the UK oil and gas industry.

For anyone engaged in interpretive research, the main challenge is how to present the outcome of research in a convincing way to readers. Interpretive research can suffer from a credibility crisis in presenting research outcome because knowledge claims are based on interpretation tied to particular socio-historical and cultural context rather than absolute knowledge. Hogg and Maclaran (2008) confronted this ‘crisis of representation’ and the role of rhetoric in representation by suggesting that knowledge claims are situated and textual accounts that are always fused with traces of the individual properties irrespective of rhetorical devices employed in its presentation. In order to present knowledge claims from interpretive research in convincing ways, Golden-Biddle and Locke (2007) argue for representation of interpretive research using criteria of authenticity, plausibility and criticality.

Authenticity is conveyed by showing the thoroughness of the process of data collection and analysis while disclosing any bias of the researcher. Researchers can pursue authenticity through appropriate research design that is explicit regarding the type of data to be collected, the process through which data will be collected and the systematic procedure to be followed between collecting and analysing data. Interpretive research outcome can be plausible if researchers account for as much of the data collected as possible to ensure there is a fit between explanations provided and field data collected without ignoring inconvenient findings or contrarian cases. Criticality allows researchers to be reflexive, recognise and examine in details differences in the data set, examine contrarian findings so that new meaning and interpretation can emerge. It is important for interpretive researchers to be sceptical, co-opt their readers into the narrative they are presenting and challenge underlying assumptions of their readers (Mingers 2000).

Thus this research has been designed to provide a plausible account of the process of interest, critically examine the role, influence and inputs of actors, and present an authentic account of participants' views by ensuring that data analysis is true to and reflects the views of participants. This study adopts a phenomenological informed approach since it is aimed at seeing and understanding the process of new technology development through the eyes on entrepreneurs and other stakeholders like VCs and oil companies decision makers who are engaged in the process, it will mainly employ grounded theory methodology for data analysis. While a phenomenological study is a good way to address the research questions because the object of interest is the understanding of shared experiences of a number of individuals who engage in or interact with others to bring about new technology development in the oil industry, this research aims to move beyond mere description to the generation and development of theory describing the process of entrepreneurship and new technology development with the oil industry (Seale 2004).

Grounded theory methodology (GTM) offers a framework for analysing field data and inductively building theory to explain social phenomenon (Punch 2000). This approach will allow a theory to be developed and authenticated through systematic data collection and analysis of data gathered from research participants (Strauss and Corbin 1998). A rigorous application of grounded theory approach will allow a theory to emerge from research data that is credible, transferable within limits, dependable and representative of the process of technology development within the oil industry (Bryman and Bell 2007).

Dougherty (2002) argues that grounded theory building (GTB) is a way to understand why and how structural conditions and human actions relate and change over time (p.849). GTB allows the researcher to capture inherent complexity of social life, how people understand these complexities, thereby allowing the researcher to excavate social action that undergirds structural features of social site of interest (Dougherty 2002). In using GTB, the researcher engage in parallel research activities of planning a study, gather and analyse data, and present research outcomes. GTM has peculiar features that make it an appropriate methodology for this research, some of which are:

1. Grounded theory allows a process to be conceptualised 'in terms of sequences or shifts in the nature of action/interaction' (Strauss and Corbin 1998 p. 166) while responding to changes in contexts and conditions agents grapple with as they seek control over or respond to the phenomenon of entrepreneurship and new technology development. There is a lot we do not know about how opportunities are recognised, evaluated and developed into a new technology or innovation either through an existing business or via newly created venture. GTM will allow the nature of interactions between key stakeholders to be explored and how these interactions moderate the nature and pace of innovation and impact on technology development and adoption within the oil industry.
2. GTM will provide a link between macroscopic, structural issues and the phenomenon of entrepreneurship and new technology development. This approach will allow the contextual and structural factors such as access to resources, choices of end users, attribution of value to new technology, role of institutions and individuals, differences in risk perception to be evaluated. GTM will also allow the researcher to explore how and to what effect these situational factors affect technology innovation in the oil industry.
3. There is limited research about technology development in the oil industry in general and even more limited research examining social construction dimensions of technology development in the industry. GTM is most valuable when researching areas where little prior research has been undertaken (Punch 2000). Grounded theory is an appropriate methodology for this study because it is expected that this study will generate new theoretical explanation and understanding that can provide

a deeper understanding of the process of technology development and entrepreneurship within the oil industry.

There is a lot we do not know about the underlying reasons for slow technology adoption in the North Sea oil and gas industry, therefore, the proposed study, conducted in a manner that is not wedded to preconceived theories or notions, using qualitative research methods is the most appropriate way of understanding the process of technical innovation and how it reflects social life while allowing the researcher to study how pattern of events change over time (Bryman and Bell 2007).

5.7 The Research Process

5.7.1 Development of Research Question

This study emerged out of my personal curiosity about the challenges and difficulties technology developers face in successfully introducing new technology to the oil industry. As an engineer who works in the oil industry with personal experience of the debates surrounding new technology trials, I have noticed that only in very few cases are technologies from small companies or owner-managed firms selected over alternatives provided by large, more established, multinational service companies. It appears on surface that the size and reputation of technology developers influence evaluation and selection of new technology. Over time, as I reflect on my experience with technology development and adoption issues in the industry, I became convinced that there are deeper underlying reasons why managers and engineers within oil companies are reluctant to give trial to technologies from small and owner-managed firms. It is this curiosity that led me to the decision to undertake this research to understand the process of new technology development in the UK oil industry.

I came to this research believing that if one could identify the drivers for technology adoption, it would be possible to explain what is going on. I thought the answer towards understanding the difficulties entrepreneurs and owner-managers faced in introducing new technology to the oil industry lies in understanding the factors that drive adoption of new technology and that my research question(s) and methodology should be designed to elicit standardised response that will uncover technology adoption drivers using quantitative technique. However, as I discussed the issues with some of the players with personal experience with the process of technology construction, I became convinced that to understand the process of technology emergence the research has to understand the nature of interactions between actors, influence of their roles on their attitudes and behaviours, and how competing interest and objectives shape the outcome of the process. Before embarking on fieldwork, I engaged with the literature to identify theoretical and recurrent teams about entrepreneurship, innovation, risk, technology adoption and usage. I decided to divide my field work into two stages – a pilot study and main fieldwork stage – to allow familiarity with the issues as identified by respondents to guide the refinement of my research question. The pilot study also gave me the opportunity to identify theoretical themes that were of relevance and separate them from other issues of theoretical conjectures.

The main question for the pilot study was “what is the process involved in technology identification and development within the oil and gas industry and how can we understand them?” The main research question was supplemented by nine sub-questions:

1. Why, when and how does new technology gets developed within North Sea oil and gas industry?
2. When and how does the entrepreneur acquire information and develop business opportunities until a new venture emerges?
3. Why, when and how do the entrepreneurs, VCs and other resource providers, and end-users of technology evaluate risk of new technology? If there are different perception and perspective on risks, why is that so and what are the implication for new technology development and adoption?
4. How does the entrepreneur perceive, evaluate and mitigate risks in his decision-making and allocate scarce resources between alternative investment options under conditions of uncertainties with respect to new technology development?

5. How do entrepreneurs, VCs and end users of technology ascribe value to new technology and what is the effect of different perceptions of value on innovation, access to resources and process of technology development within the industry?
6. What are the drivers and determinants of end-users' attitude to, and acceptance of, innovation and new technology in the North Sea oil and gas industry?
7. How and to what degree do entrepreneurs interact with end-users and/or rely on market signals and feedbacks in making decisions about technology development in the industry?
8. In what way do the social system and interactions within organisations and between actors moderate the process of new technology development within the oil industry?
9. Are there factors that are common to successful entrepreneurs in the way they identify, recognise, develop and exploit business opportunities that can be replicated in new ventures with similar outcomes?

The responses of research respondents from the pilot study quickly revealed that the process of technology development is intensely social with multiple barriers against construction and emergence of new technology in the oil industry. These barriers include:

- Lack of clarity regarding important decision makers in the user community
- Slow decision making by end users of technology
- Lack of or poor access to funding for new technology development
- Risk averse culture within end-users' communities without fully understanding the contextual factors that predispose actors within the industry to be risk averse.
- Lack of enthusiasm for new technology produced by small and owner-managed firms from engineers and managers within oil companies.
- Lack of access to wells to test and qualify new technology

Reflecting on the nature of these barriers hampering emergence of new technologies identified at the pilot study stage, it became obvious that the nature and type of questions to be asked are best served with a qualitative approach. A research that focuses on factors driving adoption will not be able to excavate or reveal the underlying social dynamics responsible for emergence of new technology in the oil industry. Rather than seek to identify factors responsible for adoption, it became clear that what should be of interest is the process of social construction of new technology, the nature of interactions between actors, why critical decision makers in the process think and act in certain ways, and explanation for why some entrepreneurs would appear to be more successful than others in getting their technology introduced to the oil industry.

Analysis of the pilot study data suggested that success in introducing new technology to oil companies is moderated largely by the nature of interactions between developers, supporting actors, facilitators and end-users preceding the emergence of the technology. Data from the pilot study indicates that the manner in which critical stakeholders engage in constructing technology artefacts and the capital they bring to the social space of technology construction are critical factors that not only influence the present but has the capacity to shape the future.

An emergent theoretical model from the data was developed with sufficient explanatory power to be convincing. The model shows that the challenges of technology construction in the oil industry arise from the differences in perspectives, objectives and motivations of the actors. Different interests and roles' expectations shape attitudes and behaviours creating a social space in which an entrepreneur's embeddedness and position in the social network, his stock of social capital and his access to available resources including important decision makers become critical factors in shaping new technology emergence. With the new understanding, the research questions were streamlined into one main and subordinate questions for the second phase of the field work.

The two phase field study approach sensitised me to the fact that entrepreneurs have to develop new ways of communicating, negotiate technology capability with potential end-users, understand installation environment, and see technology as a social and not entirely a technical product. Data from the pilot study and subsequent analysis of research data shows that the manner in which entrepreneurs and end-users of technology manage the social negotiation of technology development and emergence can offer predictive indications of the likelihood of acceptance of rejection. This shift in thinking deepen my commitment to using social constructionist perspective as a theoretical lens and practical way of understanding what is going on within the process of new technology development in the oil industry. The data from the pilot study confirms that the choice of research methodology and method is the right one for studying the process of interest.

5.7.2 Research Method Employed

Research design is always a matter of informed compromise (Bechhofer and Paterson 2000). Qualitative research is flexible and adaptable and able to explore and respond to unanticipated issues as they emerge in the course of research (Ritchie and Lewis 2003). Existing theory can help shape research questions. Although qualitative research does not rely of deductive methods based on development of hypotheses to be tested empirically, good qualitative research design can use existing theories, knowledge and ideas to shape the research design (Silverman 2006). The literature on entrepreneurship shaped and informed my appreciation of theoretical themes that may be of interest in this research before embarking on field work.

Individuals chosen to participate, the respondents, in the research are those with relationship to and experience of phenomena of interest. They are individuals spread across the social landscape of enquiry who are in a position to offer unique, comprehensive information and insight about the phenomena. In that sense this is a purposeful sample.

The initial challenge in research design was to identify the critical stakeholders whose experiences that might shed light on the complex interactions during the process of technology innovation construction and emergence in oil industry. Once it was decided that the research is best undertaken through qualitative research, a purposeful sample population was chosen including *entrepreneurs or owner-managers*, VCs and/or business angels, mediating agencies and institutions, and individuals with decision-making powers within oil companies on adoption of new technology. The data collections method was through semi-structured open-ended interviews.

At the beginning of the study, the key issues and questions to be answered were unclear to fully describe the process of technology construction in the oil industry. The pilot study helped to refine the research questions, identify issues of importance to stakeholders, and test the relevance of theoretical themes from the literature and their resonance with research respondents. The pilot study also helped to delineate the sample population that is best suited to help provide a good understanding of innovation construction process in the oil industry because explanations in extant literature are not sufficiently convincing.

Interviews from field research were recorded and transcribed verbatim. Along with textual and discourse analysis of transcribed data to develop emergent themes. Interview data from the pilot study was coded and analysed to establish relationships between categories and sub-categories of data which produced an emergent model with sufficient explanatory power and deemed adequately convincing for further progress. A preliminary framework from the pilot study data explaining the underlying process of technical innovation within the oil industry was improved upon with additional data from the second stage of field work. The second stage of field work helped to confirm, through data collection and subsequent analysis, the robustness of theoretical model from pilot study and its explanatory power to account for and describe what is going within the process of technology construction in the oil industry.

Qualitative research inquiry has its critics and some of the criticisms are valid since no research design can claim to be perfect. Critics of the qualitative approach to research question the validity of qualitative method of research because generalised conclusions are drawn from a few case studies and that use of interviews can immerse the researcher in the social experience of his research subjects in a way that can affect objectivity of research results. These criticisms are valid in a way and efforts have been made in the research design to minimise the effect of these weaknesses. By trying to understand what happens in the social construction of new technology in the oil industry from the perspectives of different social actors occupying different roles, the effect of bias will be minimised and a deeper insight into the process of technology construction can be developed in a way that quantitative technique using statistical analysis cannot.

During the pilot study, respondents were carefully chosen for their expertise, range of experience, and position so that they can provide different perspectives on what happens during the process of new technology emergence because of the role they occupy. In phase 2 of the field work, the list of interviewees was to include those who can best improve understanding of the process while restricting the population to a select group of actors.

5.7.3 Ethics and Access Negotiation with Respondents

Interviewees were approached individually seeking their consent to participate in the study and arranging a convenient time to conduct the interviews. Respondents who agreed to participate in the interviews were also informed ahead of the interview that the interview would be recorded. Interviews from the pilot study were transcribed verbatim to ensure that all information at this stage of the study was captured.

There are no obvious ethical issues of concern anticipated in the conduct of this research study. All interviewees were assured that information freely given during the interview will be kept anonymous except where individuals specifically request to be named. Selected and relevant sections of interviews from the second stage of the field work were also transcribed.

5.7.4 Sampling Strategy

For the pilot study, a purposeful sample consisting of entrepreneurs, VCs or engineers and managers in the operating oil companies was selected. After analysing data collected from the pilot study and armed with a better understanding of issues, an expanded purposeful sample including the Department for Business, Enterprise and Regulatory Reform (DBERR, a governmental department), industry technology facilitator (ITF), banking representative and other technology entrepreneurs. The purposeful sample population consisting of individual and institutions was selected because these social actors have direct experience of the phenomenon. Therefore they can provide rich, detailed and relevant information about the issues of interest.

Although not intended as part of the sampling strategy, when opportunities arose to use snowballing technique (asking people who have already been interviewed to identify other people they know who fit the selection criteria), I took the opportunity to expand the sample population. This flexibility allowed access to key individual and mitigated against the danger of diminishing group diversity because the minimum criteria for qualification was adhered to. The sample selection strategy also allows phenomenon of interest to be investigated from different perspectives.

The purposeful sample was selected from the field of technology of development in the oil industry as depicted in Figure 5.2. Members of the sample population are chosen with a purpose because of their relationship with or insight of the phenomenon of interest. The sample size has been limited to a size that will generate manageable data size (Neergaard 2007). Key constituencies relevant to the study are represented in the sample population reflecting the diversity of the population of interest (Bryman and Bell 2007); Ritchie and Lewis 2003). Units of research were chosen because they have salience on the phenomena under scrutiny – a sampling approach that Ritchie and Lewis (2003) describe as ‘symbolic representation’. Diversity in the sample provides opportunity of exploring the range of factors that bear on the phenomena of interest and allows interdependency between variables to be examined from different perspectives.

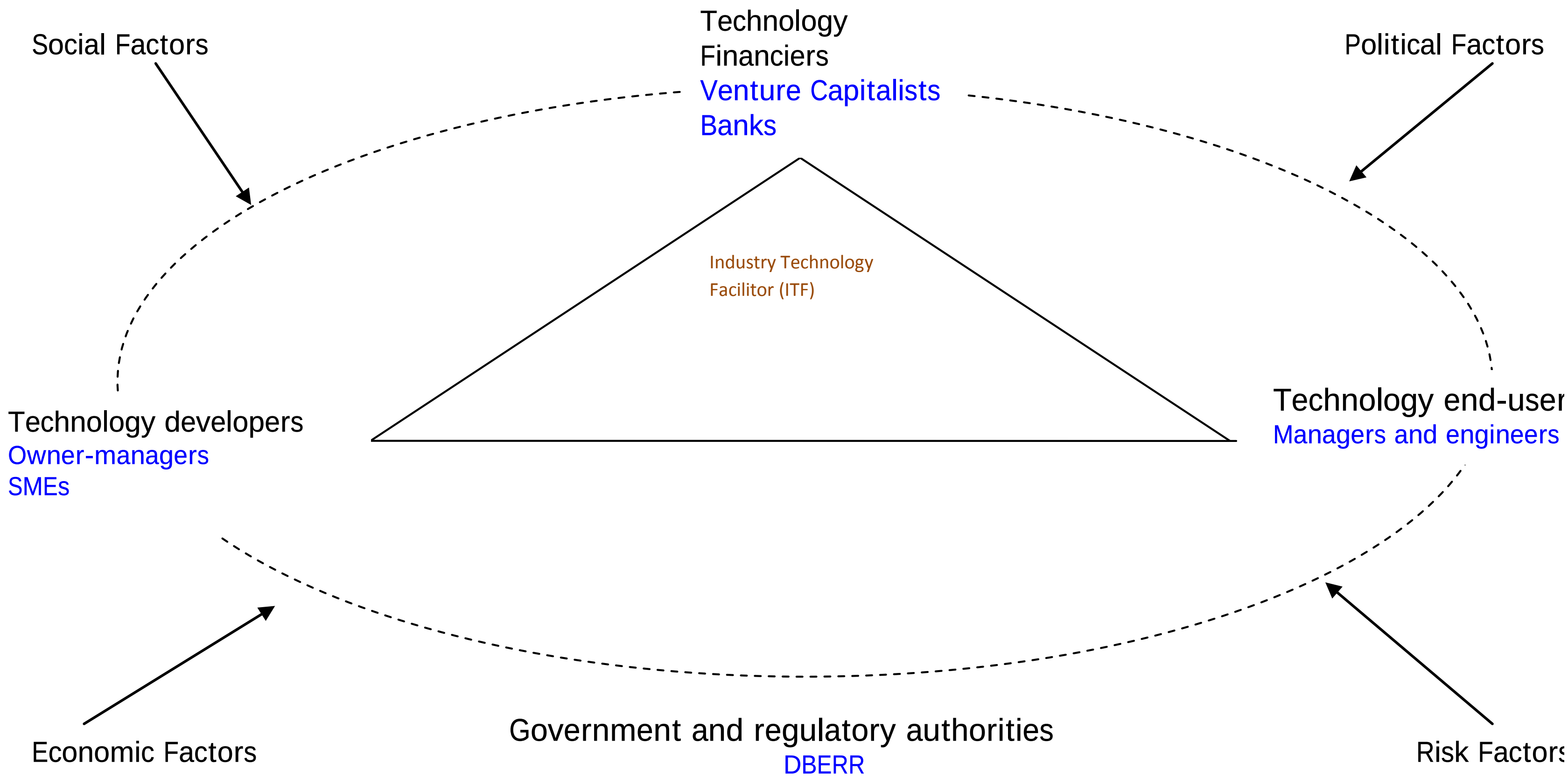

Figure 5-2: Schematic representation of the field of new technology development in the UK oil and gas industry

5.7.5 Pilot Study

In the pilot study, the study population consist of entrepreneurs, venture capitalist and managers within oil and gas companies. These people were chosen because of their experience, their roles and involvement with technology development and construction process within the oil industry. Two entrepreneurs, a manager of a financing bank to the oil industry and three managers within an oil company as end-users of technology were interviewed during the pilot study. The diversity of experience of people interviewed and the roles they play in the process help illuminate the issues surrounding technology development in the industry highlighting the challenges behind the apparent reluctance of oil companies to use new technology from entrepreneurs be it small or owner-managed firms. The sample population for the pilot study was selected for this research to represent entrepreneurs because actors within this sample population have the knowledge and experience needed to develop a better understanding about how entrepreneurs operate to develop new technology within the oil industry.

5.7.6 Selection of Research participants

The study population consists of key participants in the process of technology development within the oil industry who are stakeholders with interests in, interaction with, and effect on new technology development and adoption. As previously argued in chapter 2, new technology development from entrepreneurial small firms and owner-managed firms can be achieved through technology push (*develop innovation and then find a market*) or technology pull (*identify a need and then develop innovation*). Either way, newly developed technology can only survive if there are end users to provide market outlets for its use (Cardullo 1999). The research population for this study consist of entrepreneurs, VCs/business angels who provide funding to entrepreneurs for technology development and decision makers within oil companies with powers to decide on technology adoption. Entrepreneurs included in the sample population are *owner-managers* and *small firms* who are actively engaged in development of technology for the oil industry with one technology under development for introduction to the industry or have successfully introduced a new product to the industry.

There is no doubt that new technology is being introduced in the oil industry, what is unclear is the nature and model that best represents the process of emergence.

Research participants occupy different roles and therefore have different motivations and drivers in relation to technical innovation. These roles may, and are expected to influence the perceptions and attitudes of social actors (Ross, Amabile and Steinmetz 1997; Yeh, Lin and Lu 2011). One of the aims of this research is to understand how social roles influence decision making; enabling or impeding acceptance of technical innovation. The selection of study population and the multiple perspectives they offer provide an opportunity to explore the issues raised in the research questions from different angles and levels while diversity in the sample population provide balance against selection bias.

There is a lot that can be learnt from entrepreneurs reflexively describing their experiences, and the process of new technology development within the oil industry. Although sole reliance on interviews can open research findings to hindsight bias (Silverman 2006) it is also true that hindsight can help illuminate the type and value of learning from experiences that is needed to obtain a rich description of the process. Comparing and contrasting what actually happens in the process from different sub-population of practitioners with different views and responsibilities will help to develop better insights into how social forces push, pull or drive the momentum of innovation.

The purposeful sample for this research has sufficient variety to address some of the weaknesses associated with qualitative research of this nature. The collection of stakeholders have similarities (homogeneity) and differences (heterogeneity) to enable us to gain insights about what is common in relation to technical innovation but also explore what is different to understand the influence of contextual conditions. Homogeneity in sampling is reflected in the commonality of experiences with technical innovation construction in the oil industry while heterogeneity is encapsulated by the variety of experiences and roles of research participants. Since all research participants have experience with technology development within the oil industry, they can shed some light on common characteristics of technical innovation construction process. On the other hand, research participants come from different parts of the industry with variety of experiences in part because of their roles in the technical innovation construction process.

As shown in Table 5-1, the sample for this research is justified because contents of research respondents will have sufficiently similar elements to describe how the oil industry approaches technical innovation construction and the process. On the other hand, there is adequate variety of respondents' experiences to draw out nuances and peculiarities of the process.

No	Research Respondent	Job Title	Organisation	Phase of Study	Process Role
1	Respondent 1	Chairman	Energy Development Consortium	Pilot stage	Serial entrepreneur / End user
2	Respondent 2	Asset Manager	Maersk Oil North Sea UK	Pilot stage	Technology end user
3	Respondent 3	Subsurface Manager	Maersk Oil North Sea UK	Pilot stage	Technology end user
4	Respondent 4	Manager, Advanced Projects Group	Maersk Oil North Sea UK	Pilot stage	Technology end user
5	Respondent 5	Director	Simmons and Company	Pilot stage	Financing
6	Respondent 6	Director	Caledus	Pilot stage	Owner Manager / Technology entrepreneur
7	Respondent 7	Technology Manager	ITF	Phase 2	Facilitator
8	Respondent 8	Business Development Manager	Red Spider Technology	Phase 2	Technology entrepreneur
9	Respondent 9	Head of PILOT Secretariat	DBERR	Phase 2	Facilitator (UK Government)
10	Respondent 10	Deputy Director / UK Regional Manager	DBERR / Red Spider Technology	Phase 2	Facilitator / Innovation marketer
11	Respondent 11	Director, Small Business Lending	Bank of Scotland	Phase 2	Financing

Table 5-1: List of research respondents

5.8 Data Collection Method

The nature of the phenomena of interest dictates the research question, type of data to be collected and methodology of study adopted. Ritchie and Lewis (2003) state that in deciding on data collection strategy, the researcher must take into cognisance the context of action and assess the possibility that participants can provide full or partial recount of their experience of a phenomena. This research seeks to gather generated data as against naturally occurring data because generated data allows participants to describe relationships between context and action, give participants the opportunity to convey their own meaning and interpretation of phenomena and, provide researcher with the opportunity to probe areas of interest during interaction with research participants. Data collection during the pilot and second stage field study was undertaken by combining interview approaches. The interview guides used for each of the interviews take into account the strengths and weaknesses of different interview types (Patton 2002).

When the subject of a study is an event or a process, a structured interview may be the best way to collect research data (Ritchie and Lewis 2003). A topic guide provides flexible direction to the field work process and acts as a mechanism for steering the discussion in an interview but not a prescription of coverage. An interview guide on its own will be insufficient to get the response and rich data needed to enrich understanding of the process of technology construction and emergence within the oil industry. Consequently, conversational interview with an interview guide approaches were combined to provide the needed flexibility to follow up with probing questions when issues and concepts of interest in the research came up during interview sessions (Kvale 1996).

5.8.1 In-Depth Interviews

Given the strengths of qualitative inquiry to elucidate and illuminate understanding of internal dynamics of a process, develop insights into how individuals interact within a process and what experiences these respondents take away from these interactions, the research was designed around in-depth, semi-structured interviews. Complex subject matter, processes or experiences are best addressed by in-depth interviews because it offers depth of focus on individual, opportunity to clarify issues, follow up unexpected avenues for exploration and develop detailed understanding of the subject of interest. Researchers' can probes and delve into understanding the motivations of individuals, reasons for their decision making, the linkages between actions and outcomes to develop new emergent themes capable of enriching understanding of subject of enquiry.

Interviews are conducted to find out from people those things we cannot observe directly by ourselves or by any other independent means (Becker 1998; Silverman 2006; Weiss 1994). In an interview the researcher is interested in the stories of others, he/she is able to enter into the world of respondents, capture their perspectives, and access the nuances of meaning they ascribe to their experiences. To be able to achieve these multi-layered goals, it is important that the interviewer asks the right question that can draw out the deep, rich data necessary to describe a process. In describing this process of investigation, Kvale (1996) uses the metaphors of the miner and traveller to describe two forms any in-depth interview could take. As a miner of information, the researcher digs deeply to find uncontaminated knowledge reflecting ontological and epistemological stances of knowledge that exist but buried. On the other hand, the traveller metaphor induces the researcher to ask questions that make respondents to tell their own stories; going on a journey with the respondents and sharing their experiences and meanings with them. In-depth interviews also allow the researcher to ask penetrating questions, explore emergent areas of interest and seek clarifications or explanations for respondents' actions.

The aim of an in-depth interview is to achieve breadth of coverage across key issues and depth of coverage in relation to contested issues or areas that are not well understood. To develop a balanced and appropriately suited interview scheme, the researcher must have the right balance between content mapping and content mining questions (Ritchie and Lewis 2003). Content mapping questions are designed to open up and map out the research territory while content mining allows the researcher to explore detail issues within issues to access the meaning these issues hold for respondents.

In an in-depth interview, the focus is on the individual because it provides the social setting for research participants to offer personal perspective of how the context relates to and shape action from their perspectives. In-depth interviews offer the individual the opportunity to interpret how the mix of personal history and experience shapes attitudes, beliefs and decision making while allowing the researcher to probe the link between socially complex associations and individual experience and history. In this study, interview sessions were used to explore how theoretical constructs are represented and meaningfully understood in the social world of the participants.

During each interview session, I was careful not to push any preconceived ideas of what I think the issues are but rather listen to respondents' explanations, opinions and views of participants. Follow up questions were regularly asked to provide examples of key issues or problems areas. I also used the interviews to explore my understanding of my respondents' views of other actors and stakeholders with whom they have to interact to produce new technology. Where possible, interview sessions were used to explore relevance of theoretical sensitising themes without blunting ability of participants to describe personal experiences or effect of contextual factors on process of interest.

5.8.2 Data Quality

Individual recall through interviews and organizational records may not capture completely the behaviours, interactions, subtleties of decision-making and interpretation of interactions over the course of the structuring process that is of interest. To guide against risk of inaccurate and incomplete data describing the process of technology development, multiple data sources were chosen as a way of triangulation. Triangulation involves the use of different methods and sources to check the integrity of the data and the inferences researchers drawn from the data. Triangulation allows researchers to develop 'convergence' between the data and the conclusions drawn from the data (Denzin and Lincoln 1994) and allows researchers to validate evidence gathered and presented in the course of social inquiry (Bryman 2003; Ritchie and Lewis 2003). Some argue and challenge the effectiveness of triangulation as a means of validation because ontologically, there is no single reality that can be revealed through sourcing of data from multiple perspectives. In qualitative research, the use of triangulation is not to seek ultimate reality but rather to help define boundary and parameter of shared (social) cognition; triangulation allows the researcher to add breadth or depth to analysis. This study seeks to achieve the same outcome as triangulation by examining same phenomenon through the perspectives and understanding of multiple actors in different roles but relating to same phenomenon.

To maintain high data quality, I paid attention to hints of biases or explanations that may suggest attributing process issues to the actions and decisions of others (Saunders, Lewis and Thornhill 2007). Without being confrontational, I used follow up questions to drill down to understand the critical issues, motivations of social actors and explore how different roles shape their involvement with innovation construction process. For example, when actors seek to blame others in different roles for a problem, I used follow up questions to find out whether there are alternative explanations the respondents has not considered. By pursuing the same theme with actors in different social roles, I am also able to see how different actors can see and interpret the same problem differently because of different social constraints, experience and expectations. The data collection strategy was designed to achieve reliability, validity and generalizability and credibility (Lincoln and Guba 1985). The quality of data collected was maintained throughout the field study so that research results have validity (Angen 2000) and provide the basis for discovery of meaning and understanding (Schwandt 2001) during subsequent data analysis.

Data reliability was aided in the course of the research through detailed preparation ahead of interview sessions. I made sure I had knowledge of the individuals, their past achievements and situational context within the firm they own and manage or the company they work for. All research respondents were told in the letter requesting access for interview about the purpose of the interview, why they have been identified as one of those with insights that can illuminate our understanding of research questions and the manner of data collection through digital recording of interview. Each interview started with a paraphrase of my research objectives, why it is of interest to me and the industry and how I hope they can contribute towards my understanding of the issues. The first question in all the interviews was designed to be open (Easterby-Smith, Thorpe and Lowe 2002), short and clear (Robson 2002) intended to open up opportunities to explore the contextual conditions in which they operate so that we have a shared understanding (Ghauri and Gronhaug 2005). As the interview progressed, when opportunities are presented as a follow up to respondents' comments, I tested and confirmed my understanding of respondents' responses by paraphrasing or summarising. Whenever possible, I tried to collect information about contextual factors (location, date, time), respondents' background (role, gender, post within organisation) and attempted to summarise key points raised immediately after the interview or soon as practicable.

5.9 Data Analysis

I began with a descriptive coding of the transcribed interview data by breaking the text into chunks and attaching labels (words or descriptive phrases) to them. This was followed by grouping labels or descriptive phrases that appears to describe the same concept together. This task of coding was undertaking iteratively involving repeated return to the transcript to ensure that emerging themes from the data are representative of actual experiences, views and opinions expressed by research respondents. In identifying these themes, I used pointers provided by my supervisory team, Charmaz (2006) and Corbin and Strauss (2008) to reflect on and seek answers from the data to questions like what are the problems, issues and concerns of interest to these actors? What do they see as the contextual factors that impede the process of new technology development within the oil industry? How do they make meaning of their experiences and how does this sense-making translate into production of new technology artefact? How does the role these actors occupy within this process influence their predisposition towards each other and to sources of emerging new technology? What are the objectives, motivations and requirements of these social actors to act in their respective roles in constructing technical innovation within the oil industry? Is there an alignment of these objectives, motivations or requirements within the process? If there is misalignment or conflict of interest, what are the outcome and consequences for these actors, the process and chance of successful emergence of new technology in the industry?

Once I was satisfied that all the themes from the data relevant to my research question has been identified, I turned my attention to the search for relationships between these themes and how these tentative relationships help to explain the 'when', 'why' and the 'how' question that ought to be answered to fully understand and describe the process. Here my search effectively began for finding explanation for some of the behaviours and outcomes observed and reported by these respondents. In developing relationships between these themes and concepts, I was interested in finding out the structural issues at play and the consequences for agency and social construction of new technology artefact. I was also interested in looking for existing theoretical frameworks that might explain the observations recorded or fit the emerging relationship between the concepts in my data. As data analysis progressed, I sought to see what is common between what respondents are saying and their different perspective on key concepts like risk, need for innovation and value. Developing this level of abstraction proved the most challenging in the course of the study.

5.9.1 Constant Comparison Method

Data analysis strategy was designed to develop a theory from research data using grounded theory methodology (GTM) which offers a framework for systematic data collection and analysis of field data and inductively build theory to explain social phenomenon (Corbin and Strauss 2008; Punch 2000; Strauss and Corbin 1998). GTM was chosen as the best method of data analysis because it is likely to produce theoretical explanation that is credible, transferable within limits, dependable and representative of the process of technology development within the oil industry (Bryman and Bell 2007). In using GTM, constant comparison method was used as way of grasping meaning from the data, re-examination of categories and alteration of initial interpretations, moving from description to abstraction in my analysis (Corbin and Strauss, 2008). The use of constant comparison method in analysing data from the pilot study also helped to identify questions to be answered in phase 2 of the study and subsequent refinement of the research questions and interview guides.

Textual data from transcribed interviews was used in the first instance to develop emerging themes from the field data and to compare and contrast perspectives of technology development process by the various stakeholders – entrepreneurs, VCs/business angle and oil operators. In the second phase, data collection stopped when emerging theory 'plausibly and usefully captures the underlying complexity' (Dougherty 2002 p.856) of social action under investigation.

Part of the analysis was also to find out the gaps in the emerging theoretical framework so as to inform the sample selection during the second stage of fieldwork. For example, at the beginning of this study I did not consider the government and regulatory authorities as important stakeholders in my sample selection. However, at the end of the pilot study it became clear that government and regulatory authorities are central to understanding some of the attitudes and behaviours of oil companies' actors towards small firms creating technology in the industry and use of new technology in general.

Throughout the research, coding and analysis was done in a way that establishes what emerges as analysis of field data is credible by maintaining close relationship between analysis and field data. Data analysis maintained internal validity by submitting researching findings to research respondents who are happy to read my analysis and provide feedback to strengthen the explanatory power of the analysis. This approach allowed me to develop my analysis in conjunction and collaboration with my research respondents. This is to ensure that what emerges as analysis from this study earn credibility and can claim to correctly explain what happens in the social world of all actors involved in constructing technology within the industry (Bryman and Bell 2007). This approach helped to strengthen the explanatory power of my data analysis if co-actors who are engaged in the process of new technology development can confirm if analysis provided is validated by their own experiences.

Strauss and Corbin (1998) provided procedure for data analysis using grounded theory methodology. Using this approach, participants interviewed are theoretically chosen (theoretical sampling) and data analysis was carried out by constant comparison by taking information from collected data and comparing to emergent categories. Coding proceeded through stages of open coding where major categories of information were identified, through to axial coding where core phenomenon was identified and categories of data were created around the central idea through to selective coding through which an emergent model was developed that describes or tells a story of how technology develops from an idea into a physical artefact in use. Data analysis procedure also borrowed from constructivist grounded theory (Charmaz 2006) that advocates an alternative to the single process of Strauss and Corbin (1998). Constructivist grounded theory emphasises constructivist dimensions such as diversity of contexts, multiple realities and complexities of action in understanding social phenomena although Charmaz (2006) makes no suggestion on data gathering, coding and sampling strategies. Elements of these two approached have been combined in this study to retain maximum flexibility to explore contextual and intervening factors that shape strategic choices actors in the process of technology development make and understand the consequences or outcomes of employing chosen strategies.

Along with textual and discourse analysis of transcribed data to develop emergent themes, interview data was coded and analysed to establish relationships between categories and sub-categories of data. Relationship emerging from the data was validated and refined until all interpretive work required was done and the data from analysis could be integrated to provide, a convincing theoretical explication of the technical innovation process. Coding procedures, memo writing and diagrammatic representations linking and/or establishing relationships between concepts was be used as part of data analysis strategy.

5.10 Justification

Research methodologies based on objectivist foundation see reality as hard, external and objective independent of human actors while subjectivists seek to understand various ways human actors create, modify and interpret the world they live in (Burrell and Morgan 1979). Intrepretive researchers labour to be heard in an environment dominated by functionalists to justify their research, present convincing results and increase acceptance of research outcomes. Cova and Elliot (2008) argue that all scientific study is grounded in interpretation because some form of interpretation must be applied to data be it from laboratory experiment, field survey or interview (Holbrook and O'Shaughnessy 1998). Since interpretation is embedded in all human effort to understand the world, Gummesson (2003) submits that all research is interpretive while Cova and Elliot (2008) argue that interpretation is common to and influential in all forms of research. Therefore, interpretive researchers should see interpretation as an asset and not a burden. This is an interpretive research that will employ phenomenological approach because, as amply demonstrated in this chapter, the issues of interest can only be accessed through an interpretive research framework.

In chapter 4 of this thesis, it has been argued that innovation and entrepreneurship are social phenomena but the social practices that underpin and sustain these phenomena are not sufficiently understood, especially in relation to technical innovation construction. Entities are disclosed to social actors in different modes and human mode of being is critical to how we engage with the world and produce innovation (Heidegger 1963). Research respondents as technical innovation process participants carry their habitus to the innovation construction space where agency is empowered to create new combinations but social actors contradictorily act in the presence of the social others (Bourdieu 1997). The habitus of different individuals demonstrates that individual arrive at the innovation site through different trajectories of experiences. Consequently, the way these actors seek to rearrange material entities and existing practices (Schatzki 2002) to create new combinations is bound to be varied and contested. To recognise a need for innovation, social actors must engage with the world in the occurrent mode (Heidegger 1963) and then proceed to act in concert with others to develop a shared definition of the problem. No matter the amount of knowledge available about the performance issues at stake, elements of a problem will be distributed among stakeholders. The entrepreneurs must engage with these stakeholders to make sense of disparate information (Weick 1995) and develop a shared understanding and tentative options that can be investigated to develop an acceptable solution. Innovation construction process allow human agency to use occurrent qualities of material entities to create new combinations and change practices. Creation of innovation and modification of practices require participation of other social actors and must therefore be investigated using a technique that allows us gain new insights through the eyes and interpretations of process participants.

Phenomenology allows researchers to understand lived experiences of individuals and groups and what a phenomenon mean to them collectively (Creswell 2007). Phenomenology allows us to investigate the meaningful ways things are experienced, how people make sense of their experiences and how social actors enact phenomenon in their everyday life. It is impossible to separate one who is experiencing something from experience itself. Phenomenology is not concerned with truth seeking but only in trying to understand the experience itself. This approach neither presumes the existence of a priori objective world nor denies the existence of the material world but rather it is a philosophical stance that contends that human actors always experience the world in meaningful ways. It is the meaningful ways things manifest themselves and apprehended by actors that shape attitude, behaviour and choices social actors make in relation to the world. Therefore, in order to understand intensely social and deeply interactional phenomena like entrepreneurship and innovation that are immersed in context and have multiple meanings for human actors, a phenomenological approach is an appropriate route of investigation.

Notwithstanding the phenomenological bent of this research, this study is not simply about understanding the lived experience of participants but at a broader level, the study aims to explicate the process of technology development and nature of social interactions within it. To undertake such a research, this research employs GTM using constant comparison method to construct analytical schema that best represent the process and increase our understanding. Grounded theory allows researchers to move beyond individual experiences and their description into an arena where substantive theory about phenomena of interest can be generated (Strauss and Corbin 1998). The research design and approach provide an opportunity to investigate effect of taken-for-granted factors on the process of technology development. Chosen research approach allows researchers to probe contradiction in accounts and data to reveal central issues of interpretation and understanding of human behaviour. This is in line with Fletcher (2006) who stresses the importance of dialogue and social interaction through which meaning is constructed and knowledge produced.

Pittaway (2005) argues that positivist approach to studying entrepreneurship denies researcher the opportunity to explore the role of voluntarism, purposeful human action and diversity in social meaning in studying the phenomenon of entrepreneurship. While scientific methods have their place, Gill and Johnson (2002) argue that the social world cannot be understood by studying experimental simulations. This is in agreement with Jack (2005), who argues that qualitative research is better suited to studying process, contents and dynamics of networks. Since entrepreneurship and technology development activities are situated, context bound activities that are intertwined with social interactions and relationships, the approach selected for this research is more likely to produce credible result and deepen our understanding.

5.11 Limitations of Research Design

The choice and use of semi-structured interviews as the primary means of data collection presupposes a number of assumptions on the part of the researcher. First, I am assuming that the interviewees have information that I want because of their experiences. At the commencement of the research, my understanding of the phenomena under investigation and the interviewer's comprehension of, and attitude towards, the phenomena was hazy. The need for greater understanding subsequently led to a shift in my research stance and refinement of questions used during the interviews. In trying to interpret data collected from research respondents, I tried to place myself in the shoes of respondents and trying to see things from their viewpoints. This was very challenging because interviewees' responses and perspectives can sometimes be contradictory (Fine 1994). This is one of the limitations of my chosen approach because it is impossible to fully comprehend the experiences of others and the meaning they attached to them. Consequently, the breadth of generalisation derivable from data interpretation is limited by the quality of the analysis and the context in which these experiences took place.

Generally, the interviewer constructs the frame within which the interviewee responds. By the nature and direction of the questions the interviewer creates meaning from interviewees responses. The quality of the questions, underlying assumptions that led to the questions and intention of the interviewer in asking the questions may colour the interpretation interviewees make, the meaning they ascribe and what answer they provide. To reduce any misinterpretation of research respondents during data collection stage, the interviews were carried out in a conversational mode, listened attentively to their responses to my questions and followed up with probing questions to elicit further information or seek clarifications.

In analysing data from interviews, depending on breadth of understanding of the interviewer, the meaning that is ascribed to respondents' responses may be incomplete, partial or strongly biased in favour of interviewer's opinion. Since an interpretation that partially describes or under-explore the phenomena of interest is unlikely to result in a good and generalisable theory with good explanatory power, my decision to carry out the field study in two phases help to reduce the effect of this problem. Results of pilot data analysis help to develop a theoretical explanation of the technical innovation process, which was in turn used to refine the research question and interview guides for the second phase of study.

Although qualitative research technique is most suitable for understanding meanings humans attach to their experiences, it has its own limitations. Findings from qualitative research are not generalisable because emergent theory only based on the experiences of research respondents. However, if a good explanatory model emerges that describe the phenomenon of interest outside the immediate context of the research, it may be possible to generalise findings through higher level of abstraction.

In this research I have adopted a social constructionist perspective to studying the development, construction and emergence of new technology in the oil industry. Although some of my research respondents and subsequent analysis of the data have considered some aspects of technical attributes of new technology, most of my effort has been invested in understanding the drivers of social interactions within the social space in which technology is constructed. This does not mean that technical attributes of new technology is not important to its emergence, my efforts simply attempts to explain how powerful the nature of social interaction is in moderating the process of emergence. This is without doubt a weakness in the research but the data from the pilot study indicate that social interactions has a bigger influence on the process of technology emergence and subsequent determination of acceptance or rejection. The slant in favour of deeper examination of social construction process of technology construction has been shaped by my interactions with research respondents and increased understanding of the issues as seen and reported from the views of the respondents.

5.12 The Research Journey – My Reflections

In this section, this research students attempts to chronicle his research experience, the twists and turns of the research journey, the evolution of his worldview and the shift in his research stance. The summary here explains the development of the conceptual framework of research and how the shifting perspectives informed the research design, data collection, analysis and subsequent development of theoretical explanation.

I graduated with a Bachelors degree in Chemical Engineering from University of Lagos, Nigeria in 1989. In 1991, I joined Shell as trainee Drilling Engineer and started a journey that has culminated in this study. In the early years, I worked in different office and offshore roles in Nigeria before I was transferred to Shell Expro UK in Aberdeen in October of 1996. After a year offshore, I accepted the position of Planning Engineer for the Brent Bravo platform in 1997.

The Brent Field was the crown jewel of the assets that Shell operated in the UK sector of the North Sea then. In the same year that I took the position of Planning Engineer, I also registered to study for my MBA at Aberdeen Business School, Robert Gordon University which I completed in 2000. In the course of my MBA degree, I became sensitized to the plight of technology developers outside of the main big multinational service companies and their struggles to attract the attention of engineers in the oil companies, including myself. I sat in meetings where we looked at technology offerings from some of these technology developers, but in almost every case, the decision on what technology to deploy to solve identified problems favoured the established multinational service companies. I started to wonder, what are the factors driving adoption of new technology in the oil industry? Why is it so difficult for new technologies from technology developers without any track record to be accepted by end users? The seed of curiosity had been planted. Although it would take another seven years after I completed MBA to take the decision to do this study, the questions around emergence and use of new technology in the oil and gas industry was an abiding presence in my day-to-day engagement with my work.

I have been privileged to have been involved with different drilling projects that required development of new technology, some of which are documented in published technical papers. The experiences from these projects vary but in all cases these projects could not have proceeded without these innovations. In the role of Project Engineer, I had to identify challenges to be resolved, how these challenges might be resolved and had acted on occasions as an advocate for innovation. In the roles of Project Engineer, I had the opportunity of interacting with different technology entrepreneurs with ideas about how a set of problems might be solved. My fascination about the underlying process and the forces that drive this process only increased through these engagements.

My reflexivity herewith presented is informed and guided by social constructionism which allows us to see representations for what they truly are: creations of social actors deploy to develop meanings in interactions with social others. The social otherness with and for whom we create these representations is fluid, constantly changing in the constant flow of now. This view of the social world is relational and in this context focuses the attention of the researcher to engage with himself/herself, respondents, data and audience of research outcomes.

5.12.1 What is Reflexivity and Why is it Important?

This is a qualitative, interpretive research during which as a researcher I have engaged with individuals who have direct experiences of developing new technology for UK oil and gas industry. What I have presented in this study is an account of their lived experiences, their thoughts, motivations, understandings and expectations including their engagement with and response to others and social structure. I have interpreted these accounts to produce a process of innovation construction in the oil industry that is situated, contextually grounded and socially constructed.

Reflexivity describes the process through which a researcher critically reflects on the self as the instrument of research (Guba and Lincoln 1981) and his/her relationships with research respondents or objects of research (Finlay 2002). Reflexivity allows the researcher to examine his/her engagement with the research topic, objects of research and respondents. To be reflexive is to also apprehend the role of the multiple selves that are embodied in the researcher as the human instrument (Lincoln and Guba 2011; Watt 2007).

As a researcher undertaking the study of innovation construction process in the UK oil and gas industry, I bring multiple identities to the social setting of research. As a Drilling Engineer with some experience, I have certain experiences, good and bad, with technical innovation regardless of my fascination about its process of emergence. My experience as a Drilling Engineer also invested me with certain mental handicaps about how the world should work and what constitutes good and best practices. Therefore, my experience affords me certain understandings but also endows me with certain historical, social and personal perspectives. Consistent with my argument in relations to habitus (Bourdieu 2003; Johnson and Duberly 2003), my experiences delimits my universe of understanding before I engage with others to explore the issues involved with new technology development. As a researcher, my objective is to understand what transpires during the process of innovation based on the accounts and lived experiences of the individuals who graciously agreed to participate in my research. Given my own experiences in the field, it is impossible to pretend that I can provide an objective account of new technology development process. At best, what I can offer is an account that increases our understanding of the goings, happenings and actions at the innovation site that is based on these lived accounts.

My experience, history, environment and multiple roles in the course of this research therefore imposes an obligation on me that needs to be kept in sight throughout the research process. This obligation demands that I reflect on my role in the research process while carrying the burden of a set of embodied dispositions, assumptions and perspectives that may colour my interpretations or influence how I render the accounts of the respondents. Therefore, it is my responsibility to interrogate myself about how my multiple identities could have influenced the research process, how I interpreted the data and the conclusions I drew from the data. In this chapter, I will try and account for these different selves in relation to this study.

Different scholars (Alvesson and Sköldberg 2009; Finlay 2002; Johnson and Duberley 2003) have argued that the researcher needs to examine his/her own presuppositions which inevitably will affect the way research is conducted and how findings are presented. The subject of research, as in this study, and how we choose to investigate phenomenon of interest cannot be divorced from these presuppositions, assumptions and prior understandings we bring to a research. The habitus does not simply bleeds into our chosen colour scheme as we construct our research methodology, it is important to understand that we are not painting on a blank canvass. MacBeth (2001) argues that reflexivity is a deconstructive exercise through which the researcher can locate the intersections of ‘author, other, text, and world’ (p. 35) to help in penetrating the representations researchers present as outcomes of research. Therefore, reflexivity should go beyond our philosophical positions regarding research to encompass the totality of our being and positions we hold as a research in relation to research participants, research data and how it is interpreted.

Why do we have to care about reflexivity in the context of this or any other research? Reflexivity is important for me because it allows me to take stock, look back on the meandering road I have travelled, explore unexpected turns, revel in some surprising moments and draw critical lessons for those who may chose to walk a similar path in the future. As I was approaching the beginning of this study, I thought that the issues of interest to understand the process of technical innovation construction would probably be best studied through surveys. Over time, as I engaged with the literature on the twin social phenomena of innovation and entrepreneurs, I became increasingly convinced that a meaningful study needed breadth and depth. While the scope and breadth of the issues may be dealt with a study using questionnaires and surveys, the depth of the social issues underpinning the process cannot be unravelled through such a process. I did not settle for but come to genuinely believe through my engagement with the literature and interactions with respondents during the pilot study, that reality is socially constructed and practices that perpetuate this reality is socially legitimated.

Since this is a naturalistic inquiry involving fieldwork that puts the researcher in close proximity to research respondents and their worlds, the researcher has to strive not to be too involved with respondents which can cloud one's judgement or be too distant and lose understanding. This stance is what Patton (2002) refers to as 'empathic neutrality' (p. 50). During my interviews with respondents, I was engaged and open, respectful but probing, sensitive and curious in the search for meaningful understandings and research findings. The research methodology adopted allow me to interact with respondents and engage in data analysis to understand what is going on at the individual (micro), relational (meso) and contextual (macro, coupling an individual to others and structural features in the environment) levels in the innovation construction process.

It is impossible to discuss innovation and entrepreneurship without grappling with the concept of change. In the interviews I was interested in the stories of these participants, exploring some of the anecdotes and allowing their stories, words and experiences to guide my understanding and what they did and they adapted in the vortex of change.

5.12.2 Evolution of Research

My research process can be divided into six phases. The phases have been so identified for ease of description rather than an affirmation of episodic changes in the research process. These phases are by no means distinct but form a continuum, blending and morphing into each other as I transited through the research process. The phases I will discuss briefly in this chapter are:

1. Familiarisation and alignment phase
2. The pilot stage
3. Exploration and discovery phase
4. Second data generation phase
5. Evolution of understanding and meaning
6. Writing up phase

5.12.2.1 Familiarisation and Alignment Phase

As a researcher with an engineering background, I came to this study with some assumptions about the difficulties of developing and adopting new technologies in the UK oil and gas industry. I have watched and participated in decisions on whether to deploy a new, untried technology or not and have noticed that only in very few cases are technologies from small companies or owner-managed firms selected over alternatives provided by large, more established service companies. It appears on the surface that the reputation of technology developers is a strong determining factor in the evaluation and selection of new technology. I read papers on innovation from Society of Petroleum Engineers (SPE) conferences to understand more about new technology adoption in the industry. Slow decision making and a pervasive risk averse culture are two of the dominant reasons practitioners in the oil industry advance for the paradox of advocating for innovation and reluctance to actually use new technology.

Over time, I became convinced that there are deeper underlying reasons why managers and engineers within oil companies are reluctant to give trial to technologies from small and owner-managed firms. My curiosity about forces shaping the way new technology get used led to the decision to undertake this research. In the beginning, I thought the answer towards understanding the difficulties entrepreneurs and owner-managers faced in introducing new technology to the oil industry lies in understanding the factors driving adoption of new technology. I came to this research with a view that my research question(s) and methodology should be designed to elicit standardised response that will be best analysed by quantitative techniques.

In the early stages, I read as much as I could about innovation and entrepreneurship. As I read about the twin phenomena, engaged and discussed my evolving understanding with my supervisors and other casual conversations with people within the oil industry, I started to change my research orientation. I started to see innovation in the context of my study as a product of social interactions with multiple individuals with the entrepreneurs at the centre of this process. The shift from a quantitative to a qualitative study had begun. Still uncertain but leaning more towards a study focused on the social processes driving new technology development, I decided to split my research process into two: a pilot phase and a follow up phase. The rationale for this division was to use the data and improved understanding gained from the pilot phase to orient the data gathering in the second phase.

5.12.2.2 The Pilot Stage

With some understanding of the theoretical issues in the field and some of the issues that should be investigated in this research, I developed a set of questions to be used as an interview guide in the pilot phase data generation phase.

A list of potential respondents was drawn up for the pilot stage of the study. Potential respondents were identified based on their roles as owner-managers or founders of SMEs engaged with technology development in the industry or managers in the oil companies that end users of technology. I sent emails to these potential respondents explaining the objective of the study and why they have been identified based on the experience as producers or users of new technology in the industry. Six potential respondents were identified for the pilot phase and all of them accepted to participate in the study. I also promised to keep their anonymity when publishing the research findings.

The questions in the interview guide were designed to be broad yet address specific history and circumstances of technology developers or the company they represent. These questions were also designed in part to explore some of the issues raised in the academic literature about innovation and the practice and craft of entrepreneurship. As an example, in the table that follow, I am reproducing the interview guides I used for my first interview and the other in my engagement with managers within on oil companies. In the tables I have provided a list of the questions and why the questions have been structured the way they were.

My first interview was with Andy, a serial entrepreneur who founded an Aberdeen based service company and later co-found an exploration and production company in the North Sea. At the time of interview, Andy was the Chairman of another company based on a new business model of funding and executing developments of proven undeveloped reserves in the North Sea. My pilot study felt like a journey into the lion's den to interview an accomplished and successful serial entrepreneur like Andy armed with an interview guide and little experience in the skills and techniques of conducting in-depth interviews. The questions had been designed around major themes from the literature that I felt I have to explore in the study.

My first interview went well as I was able to use my interview guide (Table 5-2) to steer the discussion and ask follow up questions depending on Andy's responses. As a novice in the art of interviewing, I was not able to think on my feet quickly enough and missed asking some important issues. After the interview, I wrote a recap of the interview, summarising the key points made by the respondents after each interview session, asking critical questions of what these responses mean and jotting down my initial understanding of the responses. After each interview, I also identified questions that I could have asked during our interactions that may increase my understanding of the responses. I updated the interview guide to reflect these questions that I used for the second interview. In this manner, I continually improved the quality, breadth and depth of the questions as my pilot study progressed. The last three respondents during the interview stage were managers and engineers who are end users of technology. The issues raised by two technology developers and a respondent whose job is to finance SMEs engaged in technology development were all reflected in the interview guide I used with my sessions with the end users. The list of questions in Table 5-3 reflects my increasing understanding of the issues in the research and the emergence of tentative themes that will guide the second stage of the study. The questions in Table 5-3 are designed to assess the views, perspectives, assumptions and attitudes of end users in comparison to technology entrepreneurs and actors who provide funding for new venture and technology development.

	Question for Serial Entrepreneur	Thinking behind questions
1	You have been a successful serial entrepreneur, where do the ideas behind your business successes come from?	*Question designed to elicit information from respondent about the role of past experience (prior knowledge), work, training, education, family and friends (networks) in recognising a potential profitable business opportunity? How is the business of new venture creation helped or hindered by access to knowledge, skills and ideas through networks available to the individual?*
2	How do you screen business ideas?	*This is aimed at understanding how the entrepreneur determines that a new profitable business can be created to fill perceived gap. What are the influences of changes in socio-economic and technical environment on ability to recognise opportunity? Is ideas' screening only internally focussed or does it reflect events and forces external to the firm/entrepreneur?*
3	With your vast experience in new venture creation, have you found an easy way of transforming business opportunities into new business venture?	*Aimed at finding out about information processing (OPPORTUNITY DEVELOPMENT) to test the viability of business idea. What are the benchmarks or reference points that he/she uses in ascertaining the viability of a new business venture should one be created? How is information about intended market (market research, size of market) for product accommodated during the evolution of the process?* *The literature presents a linear process of development consisting of idea generation (concept), feasibility (proof of concept), product development (development, prototyping and testing), and implementation (marketing and product launch). Question designed to tease out real life experience of practitioner.*
4	You have been successful in developing and	*What is the role of credibility and legitimacy of individual or*

	Question for Serial Entrepreneur	Thinking behind questions
	exploiting business opportunities, what in your opinion set you apart from others who have also tried to replicate your approach without the same level of success?	*organisation in the process? How does social capital help or hinder the process of new venture creation? What influence has access to funds has on the process of new business creation? How do cultural attitudes to risk and failure influence the opportunity development in the process of entrepreneurship within the oil industry?*
5	How have your experiences over the years shaped your approach to entrepreneurship and process of new venture creation? What would you consider the important factors that drive your desire to create new business venture and why?	*This is to tease out the evolution of the interviewee as an entrepreneur and how failures and successes have moderated his views and the choices he makes in the process of idea development and exploitation?*
6	What is your experience with seeking funds for new business creation? Do you think existing avenues for securing funding new business venture helps or hinder entrepreneurship and process of innovation?	*What are the challenges of getting funds from VCs (VCs)? What formal process (business plan, etc.) has to be undertaken to meet VCs' expectations? Do entrepreneurs actually follow through with presented business plans? How is changing business environment accommodated in the planning process while talking to the VCs?*
7	How have you dealt with risk and uncertainty as you proceed through the process of new venture creation?	*This is to test theoretical perspective that entrepreneurs are actually not risk takers but simply make manage information in a way that reduces risks sufficiently to undertake creating a new business venture. At what stage during process of entrepreneurship does risk become a consideration? What type of information processing allows entrepreneurs to reduce inherent venture risks? How do they diversity residual risk at the point of deciding on new business creation? What differences exist, if any, in the inherent risk of new-to-market product and incremental-innovation product? Does the entrepreneur risk appetite change over time with experience, success or failure?*

	Question for Serial Entrepreneur	Thinking behind questions
8	How helpful in your opinion are VCs and their experience in helping entrepreneurs and ensuring the survival of new business venture?	*The literature shows that VC-supported businesses have a higher chance of success compared with businesses not supported by VCs. What type of experience and skills do they bring to bear upon a new business? What is responsible for VC ending up with a higher stake in a new venture than they originally started with at the point of exit in general? Do VCs actually manage NBV for the benefit of the entrepreneurs or for their own advantage to ensure decent return at the point of sale?*
9	What has been the role of technology in your ventures? Would you consider yourself a developer or user of technology?	*This is to tease out the role and importance of technology in the business? What attitude has he to new technology development especially from his experience with Venture Oil? What does he think of the efforts of entrepreneurs developing new technology for the oil industry? Does he think these entrepreneurs understand the business drivers of the end-users of technology – the oil companies?*
10	Why do you think operators (oil companies) are slow in taking up new technology?	*How well does the entrepreneur understand the requirements of the end-users of the product he is engaged in developing? What mechanism exists in the process to seek, receive and respond to market signals (GO or NO GO decision points)? What are the cultural issues within the industry that influence the rate of new technology adoption? How does the entrepreneur "quantify" or "demonstrate" the value added of new product or technology to the end users (operators)? What consideration is given to striking a balance between installation/implementation risks of new technology/product against expected value to the operators?*

	Question for Serial Entrepreneur	Thinking behind questions
11	How do you think technology adoption can be improved within oil industry?	*It is hoped that this will also tease out information about customer intimacy and interaction. Will want know how much customer interactions shape or even define the product/technology specification developed.*
12	What in your opinion drives innovation within your business and the oil industry at large?	*Is product/technology development technology-pushed, market-pulled or driven by opportunism? What degree of business planning, strategy development and product positioning is undertaken by the individual firm to create competitive advantage?*

Table 5-2: Sample 1 of interview guide and rationale for constructing questions

	Question for Managers and Engineers	Thinking behind question
1	What do you see as the role of new technology in the North Sea in general and your company in particular?	*This is to gain an insight into operators' perspective as to the role and importance of new technology?*
2	How does your organisation access or scan for information about new technology that may create value in your business?	*This is to find out if oil companies have a formal process of scanning the environment and communicating with potential technology developers/entrepreneurs.*
3	What are the major drivers that determine which technology gets evaluated, selected and adopted in your organisation?	*This is to find out if there is a distributed decision-making process for assessing potentially new technology. I also hope the response will throw some light on how information about new technology actually gets handled with the company and how decisions are made to try or reject a new technology.*
4	How flexible is your business strategy and processes to take advantage of technology opportunities that may be presented to your business by entrepreneurial technology developers?	*This is another way of trying to understand if there is a mechanical process that must be followed to assess and evaluate new technology.*
5	Some of my respondents say "oil companies do not want to be first but would rather prefer to be second to try out new technology". Do you agree? If you disagree, what is your view and why?	*This is to try and understand the desire of oil companies desire to try a piece of technology after another oil company has successfully tried and deployed the technology. This is frustrating for most entrepreneurs because if everyone adopts the same attitude, the technology will never get a chance to be tested.*
6	When, under what condition and at what stage of development would you or your organisation be willing to contemplate adopting or trying out	*This is another way of trying to find out the underlying requirements of oil companies with respect to new technology requirements for their operations.*

	Question for Managers and Engineers	Thinking behind question
	a new technology in your business?	
7	How do you evaluate the risks associated with any new technology before deciding on whether to adopt the technology or not?	*Risk aversion and assessment of risks have been a recurring team from earlier respondents. This question was to test if there are different perceptions of risks and how that plays out in the process.*
8	Some have argued that a major problem with new technology adoption in the industry is the absence of a universal way of assessing value of new technology, how do you as a business assess the value of new technology to your business?	*Oil companies have always argued that one of the problems with new technology adoption is the absence of universally acceptable way of communicating value proposition of the technology. This question is to find out how individual oil companies confront this conundrum.*
9	What is your organisation's attitude towards unmet expectations or even outright failure of a newly adopted technology?	*This is to find out if there is an acceptance that adoption of new technology is likely to fail to meet expectation in the first instance and require commitment and sustained period of development and fine-tuning to reap associated rewards.*
10	If you take an industry-wide view of technology development and adoption in general, what is your view is preventing a wider adoption of new technology within the North Sea?	*This is to get oil companies perspectives that can be contrasted with what entrepreneurs and VCs think about this problem. It will also be interesting to see how these different perspectives shape up against published research.*
11	How are the technology needs of your business communicated to entrepreneurs/technology developers within the industry? How do you ensure that information asymmetry in this communication process?	*This is to find out if entrepreneurs actually have a way of really understanding the need of oil and gas companies as they set about developing new technology.*
12	How does your organisation share learning and experiences across the business about new	*This is to see if there is a mechanism within the business through which innovators or early adopters can use their experience and*

	Question for Managers and Engineers	Thinking behind question
	technology implementations?	*credibility to influence a more sceptical population and shift attitude in favour of new technology. This question is also designed to see how oil companies treat failures of technical innovation attempts.*
13	Some of my respondents assert that a lot of new technology adoptions fail to deliver intended results. Is that also your experience? If you agree with this assertion, why do you think that is the case?	*This is to elicit a view as to why end users think innovation failed in the past. What understanding and lessons do they draw from these failures from the past?*
14	Given that the trial of a new technology may not necessarily deliver intended results at the first trial, how do you get your employees to take risks and consider adopting new technology?	*This is to see if there is any mechanism to encourage employees to take risk with new technology even when management understands it is risky. Is there any career consequence for individuals who try new technology and did not succeed?*
15	There is a widespread belief in the industry that culturally, the industry has shifted from its excessively towards cost reduction to the detriment of value creation through application of new technology. Do you recognise this as an issue or problem in the North Sea today?	*Some industry observers have argued that the move towards asset based organisation and "management by objectives" have skewed attitude almost exclusively towards cost considerations to the detriment of long-term value creation. This question is meant to test if this view is recognised within oil companies in the North Sea.*
16	When and under what condition would you or your company be willing to support a technology that requires upfront investment with expected reward at a later time in the future?	*This is to check if oil companies agree with the observation that individuals within these companies are reluctant to commit to new technology that may pay off later and may not directly affect their own careers.*
17	What form of material support or collaboration do you offer entrepreneurs who are engaged in technology development that you may be interested in?	*This is to try and check if these managers are supportive of attempts to develop innovation in the formative stages.*

	Question for Managers and Engineers	Thinking behind question
18	Some of the entrepreneurs I have met who are engaged in developing new technology for the industry say that oil companies give preferential treatment to big multinational service companies even when small firms may have developed technology that would create greater value in the long run for oil companies. Is this true? If true, why is the difference in attitude?	*This is to try and check if some of the data emerging from my field research from the perspective of entrepreneurs is recognised by operators.*
19	What suggesting do you have on how best to share the risks associated with adoption and application of new technology developed by entrepreneurs in the North Sea?	*This question is designed to tap into the experience of respondents to access their views on how things ought to be done from their own understanding. It seeks to reveal their understanding of risk and how it should be managed in the innovation process*
20	What do you think can be done to improve the support for entrepreneurs developing technology in the North Sea and how can adoption rate be improved upon?	*This question attempts to put respondents in different roles from the ones they occupy or are accustomed to, checking what new insights they offer looking at same issues assuming they are operating from a different role.*

Table 5-3: Sample 2 of interview guide and rationale for constructing questions

5.12.2.3 Exploration and Discovery Phase

This is a research methodology based on naturalistic inquiry, research design is emergent with each successive step built upon previous research steps (Lincoln and Guba 1985). Therefore the process of data generation and data analysis is iterative and recursive. Consistent with the social constructionist stance of the researcher, data is seen as a product of social interaction and exchange between the interviewer and the interviewee. What is produced as data is shaped by assumptions of the researcher and the respondents. The nature of the questions, what the researcher deemed important to ask questions about, and the arrangements of words used by the researcher and the respondents all create data. Lincoln and Guba (1985) argue that 'data are the product of a process of interpretation' (p. 332). Therefore one can argue that data is the product of active human intervention, creation and selection that cannot be separated from the meaning and understandings of social actors involved in its generation.

At the end of the pilot phase, I transcribed all the interviews verbatim and started work on the '*raw texts'*. I started the process of coding that data. Coding is a way of organising text in a transcripts and discovering patterns from within the organisational structure of the codes. For each transcript of interviews with the respondents, '*relevant texts*' were identified and chunks of data were highlighted dealing with specific issues of interest in the research. Sections of the transcripts were highlighted if they meet some or all of the following tests:

Does it relate to my research concerns or research questions?
Does it help me understand my research respondents better?
Does it clarify some of the issues relating to my research question?
Does it confirm or contradict something in the literature?
Does it seem important, even if I couldn't judge at the time of highlighting?

This process was repeated for all the six respondents who participated in the pilot stage and '*repeating ideas'* were identified. In the transcripts, if participants express the same idea in the same or similar words, this qualifies as "repeating ideas". Whenever text is highlighted in the transcripts, I wrote notes on the side of the transcripts to record why I thought that particular selection was important, interpretation of what respondents mean and any other thoughts or ideas simulated by the text. Wherever possible, names were given to repeating ideas using the words of research respondents or a sub-theme from the interview guide. A list of repeating ideas from the data relating to particular issues or questions was created from where similarly relating ideas were grouped together and given a label as a '*theme*'. A number of themes were then organised into '*theoretical constructs'* or concepts that is used to create a theoretical narrative to explain the phenomenon of interest.

The process in Figure 5-3 show how the researcher worked through different stages of analysis from raw texts from research respondents to what is presented as a theoretical description of the process of technical innovation construction in the oil industry. The journey of creating a bridge from the raw tests to the 'research concerns' of the researcher cannot be separated from the active interpretation of the researcher.

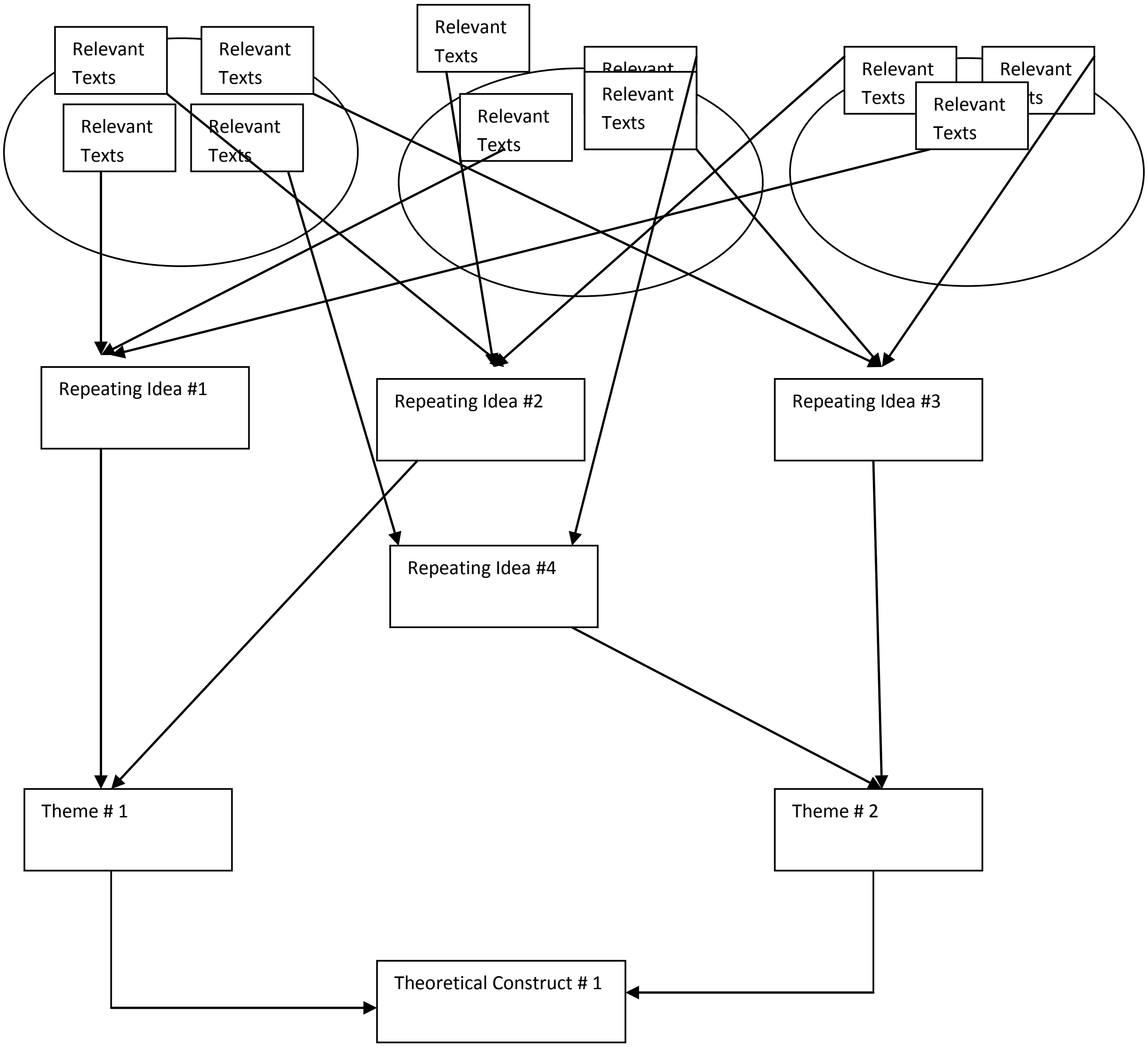

Figure 5-3: A pictorial representation of the data analysis and interpretation process

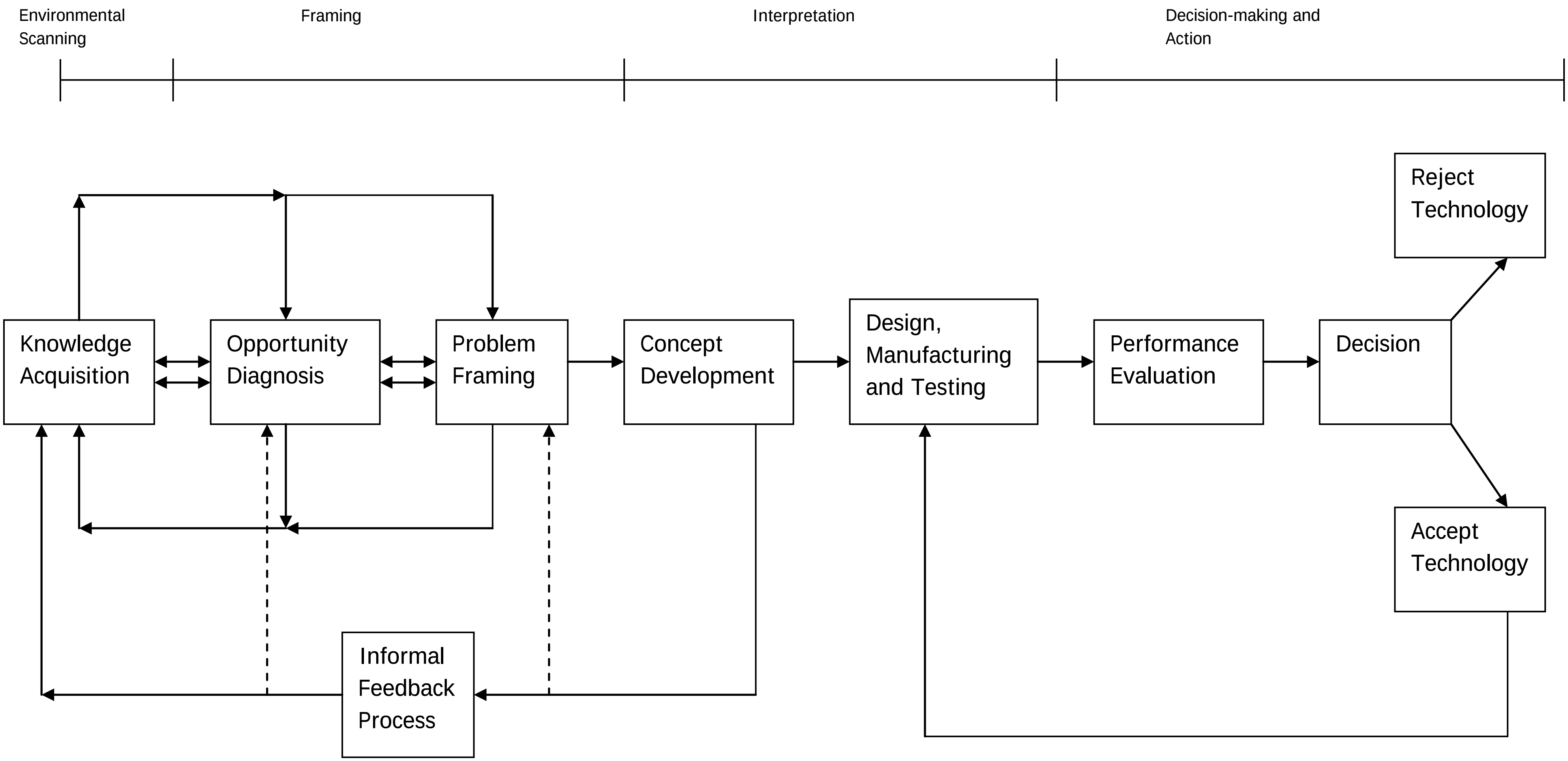

Figure 5-4: Initial conceptual model of innovation construction from pilot study

Data generated from the pilot phase was processed and interpreted to create a new level of understanding. During the stage of the research process, I engaged with the data using *constant comparison method*, a methodology that allowed me to continuously compare evolution of coding and development of categories with the data and improve understanding of context and meaning. After analysing transcripts of the six interviews I undertook as part of the pilot study until new insights could no longer be developed, I developed and interim model of innovation construction. Analysis of the data also showed gaps in my understanding of the process and some of the players in the process that should be interviewed. This understanding helped me to refine my questions for the second round of interviews and draw up a refined list of potential research participants. The new list was expanded, based on the data from the pilot study, to include the Industry Technology Facilitator (ITF) and DBERR.

5.12.2.4 Second Data Generation Phase

The second data generation phase of the study allowed me to fill in some of the gaps in understanding from the pilot study. As shown in Figure 5-4, data from the pilot study indicated that problem framing is important in the process of innovation but there was insufficient data and cases to articulate how framing occurs and what drives it. The data from the pilot study had been sufficient to describe the series of stages technology entrepreneurs go through in converting ideas into technology artefact without an explanation of the social dimensions of the process. Some of the respondents had suggested that the government do not provide sufficient support for innovation or even understand the industry but none of the respondents in the pilot stage could provide me with government's perspective on the issues. There are clues in the data about where ideas from innovation come from but insufficient to describe a representational model of the transactions and transformations that accompany the twin social phenomena of innovation and entrepreneurship.

To address these gaps in understanding, specific respondents were sought in the second phase of data generation. These respondents specifically included were DBERR to access government's view on innovation for the oil and gas industry and what reward they offer to support it. The ITF was included to hear from an organisation tasked and trusted by the oil companies to help identify new technology to serve their needs. The ITF was of significant interest because it had to work in a collaborative way in order to function to bring technology developers and end users together. If there is such a thing as *market pull* technology, the ITF will be able to provide unique insights into how it is developed by the industry. To complete the list, I also interviewed a Banker with responsibility for lending decisions to SMEs, another technology developer with a number of successful commercialised new technologies in the industry and a respondent with prior career history in the academia, the government and was working as Business Development Manager for Red Spider Technology at the time of the interview. These respondents offer unique perspectives in their own way to the way new technology gets supported and developed for the oil industry. The respondent with prior history in academia, government and business development was uniquely qualified to offer insights into government's position and also academic portrayal of entrepreneurship and innovation with the benefit of working from the trenches of practice.

Questions in the interview guide for the second phase of interviews had been designed to reflect some of the theoretical issues identified in the pilot study. The questions were more open-ended with the breadth to capture identified gaps and depths to confirm or disprove some of the findings from the pilot study. In Table 5-4 below, a sample of the interview guide I used in the second phase with the ITF is presented to demonstrate how my focus on the issues had developed and how I have used the pilot study to refine the questions. The thrusts of the questions for the second phase are broadly similar but modified to suit the respondents I was talking to any particular time.

	Questions for Research Respondents
1	Tell me about the role of the ITF in the process of identifying and developing new technology in the oil industry?
2	Can you tell me about the membership of ITF and what qualifies one to be a member of the ITF?
3	What is the relationship between the ITF and entrepreneurs and owner-managed firms aspiring to develop technology for the oil industry?
4	Can you describe the process you use in developing new technology from the moment you identify a new technology until it is ready for field deployment?
5	Some of my respondents contend that there is a communication and awareness gap between entrepreneurs developing new technology and oil companies' engineers and managers in that oil companies are often unaware of the diversity of technologies at different stages of development that may help solve some of their problems. Can you tell me how ITF gets to know about technologies at various stages of development out there that you should be interested in?
6	How does the ITF select what technology to be developed from a number of alternatives?
7	How does the ITF identify and deal the risks associated with new technology development.
8	Along with risk is the consideration for value. How does the ITF determine the value successful technology application might bring to operators?
9	Some of my respondents assert that oil companies generally treat new technology from small companies and entrepreneurs as more risky than new technology from big service companies. Do you think this is true? If you do, do you have an explanation for this attitude?
10	Entrepreneurs complain that the greatest obstacle they face is the reluctance of oil companies to test new technology prototypes to establish performance envelope and test technology reliability. How have you been able to manage your technology development process to get oil companies to test prototypes that emerge from your joint industry projects (JIPs)?

	Questions for Research Respondents
11	In your JIPs, there must be different interests and priorities of the various members (companies), how does ITF manage the process of agreeing the functional and technical specifications for any new technology?
12	Would it be accurate to assume that not all new technologies developed through the ITF ultimately achieve industry-wide acceptance? If that is the case, what do you think separate successful new technologies from others that were less successful?
13	What lessons have you learn from unsuccessful technology developments and what changes have you made to your process in response to past failures?
14	Where a new technology has not met the expectations of your customers (the oil companies), how do unmet expectations affect their attitude of your members the next time you call for support for new technologies?
15	Some of my respondents, especially VCs, argue that there is a lack of management expertise around to manage the process of transforming new ideas into final usable technology. Do you share this view or not and can you explain why?
16	How well do the oil companies take up and use technologies that have been developed through the ITF?
17	Do you think entrepreneurs and technology developers who come through the ITF route are more successful in getting oil companies to use technologies compare to others whose technologies emerge through other routes?
18	There is the reluctance within oil companies to be the first to try out new technology. How have you dealt with this reluctance to get oil companies to approve trials for technologies that you are helping to develop at the prototype stage?
19	I take it that some refinement of technology is often required after testing the prototype. How do you get the oil companies to accept unmet expectations and secure continued support for technology development even if test trial results are disappointing?

	Questions for Research Respondents
20	Some have argued for the appointment of technology champions within oil companies to influence attitude facilitate adoption of new technology. What is your view about this suggestion?
21	Trust and power appear to be major issues for entrepreneurs and SME developing technology in the way they relate to big oil companies. How do you ensure that big service companies that are members of the ITF do not get an undue advantage regarding new technology ideas?
22	Oil companies argue that the government does not understand the oil industry and the nature of international competition for resources. They argue that there is insufficient tax or fiscal incentives to encourage companies to take more risk through the application of new, unproven technologies. Do you share this perception?
23	Entrepreneurs complain that the greatest obstacle they face is the reluctance of oil companies to test new technology prototypes to establish performance envelope and test technology reliability. How have you been able to manage your technology development process to get oil companies to test prototypes that emerge from your joint industry projects (JIPs)?

Table 5-4: Sample of second phase interview guide

The interviews' guides were designed to help the researcher elicit data that can further shed light on the process of technical innovation and engage in data analysis simultaneously with data generation. The pilot study provided a basis for limited understanding, therefore my task was to get information to help clarify my understanding during this stage of field work. The questions were focused on seeking answers to some aspects of the research questions or filling the gaps in my understanding. In the interview sessions, my interviewing skills had improved and I was able to be more quick-footed in asking follow up questions without loss of attention.

5.12.2.5 The Quest for Understanding and Meaning

Although curious and interested in how technical innovation emerges in the oil industry, I started this research as a novice with little knowledge about the craft and practice of research. Through engagement with the literature in the field, I started to develop tentative understanding of key concepts, ideas and theories about innovation, entrepreneurship and more importantly, what constitute social reality and how we can apprehend it better. In the first few months after I started this research, I became convinced that a quantitative study is unlikely to provide the type of insights and understanding I am seeking about how new technology gets developed for the oil industry.

In the early days, I did not know too much about the foundational role social constructionism was to play in my research, I found its fundamental assertions and principles appealing, convincing and probably suited to my study. By advocating that researchers abandon taken-for-granted knowledge, accept the constructive and constitutive power of language, asserting that knowledge is constructed through social processes and acknowledging social interactions as the key influence on agency (Burr 1995) rather than individual traits or structural determinism, social constructionism appeals to me as the appropriate ontological stance.

At the end of the pilot study and even after developing my initial conceptual model of technical innovation, I was a student in search of understanding. Although I have been able to identify some of the building blocks of the technical innovation development process, I lacked a coherent framework around which to hand a plausible and convincing description of the innovation process. I started to realise that I needed a conceptual framework that ties my ontological stance to the type of knowledge (phenomenology) required to understand the twin phenomena of interest and methodology of research. I started to grope for a conceptual framework, a ladder of understanding through which I could access the meaning behind and embedded in the data.

I read about different social theories around which I could build such a framework of understanding without too much success. On a fateful afternoon, one of my supervisors introduced me to a book, *The Site of the Social: A Philosophical Account of the Constitution of Social Life and Change* by Theodore R. Schatzki. This book was to plug the holes in my understanding and provided the foundation for developing my conceptual framework of research. Schatzki (2002) in arguing that social life is contingent and constituted by a mesh of practices and material orders that constantly changing in response to context, I found the raw materials to undertake a study of innovation and entrepreneurship within the vortex of change. Until now, I had struggled to conceptualise how I could bring elements of Structuration Theory, Habitus, Heidegger's work in Being and Time and sense-making together in a coherent arrangement to explain the subtleties and variation of happenings and doings in the course of new technology development.

Social ontology allowed me to start seeing social reality as comprising of objects, events and entities with which human actors have experiential access without relegating the unobservable mechanisms that drive practices and propel social life. Through Heidegger (1963) I was able to see how our modes of being preconditions what we see, apprehend and can envision in our day-to-day engagement with the world. To create and sustain innovation, human actors have to demonstrate understanding of what is available and how elements of the material world can be re-arranged to achieve new combinations. In pure Heideggerian sense, understanding is more than just a cognitive activity, it is a means of seeing what is possible and how materials and practices can be combined and projected onto different possibilities. Interpretation allows human actors to see something as something else and working out how what is possible can be feasibly arranged and created from available resources. My apprehension that understanding and interpretation are inter-twinned created the foundation to start asking probing questions of the data from my research respondents and helped developed new insights into their responses.

Social reality in relation to innovation and entrepreneurship underlines and describes human co-existence, coordination and joint actions. Schatzki (2002) provided a detailed account of the constitution of social life and his account provided the inspiration for me to see innovation as a social activity that occurs at a conceptual innovation site. Heidegger's account of properties of things and how human actors relate to non-human entities help to see innovation as a product of human imagination and material rearrangements at the innovation site where the constraints of how things are used is loosened but not completely negated. By piecing together how human lives intersect with non-human entities and how things hang together at the social site, it was possible to see how the transactional and transformational that constitute innovation occur at the innovation site. The theoretical framework developed acknowledges the simultaneously enhancing and restraining power of context. Finally, I arrived at a place where my appreciation of the power of context on social action was no longer a theoretical concept but can be felt and understood through the experiences, words and actions of my research respondents.

After the second stage of data generation and armed with my conceptual framework of research, I re-engaged with the task of data analysis with greater vigour and clarity. I was now able to ask myself penetrating questions and dig deep in trying to interpret respondents words and the meaning these responses hold for them and the phenomena of interest. A work that is underpinned by social constructionist stance, I took interest in the taken-for-granted assumptions of my respondents about other actors who co-participants in the process and others they have to interact with in order to be successful. I started to pay attention to how these taken-for-granted assumptions are tied to problem definition and understanding of what is possible as likely solution(s).

The challenge that technology developers have in convincing likely end users about new technology started to take new meaning. Rather than accept on face value the explanation of an industry populated with risk-averse individuals, I started to see how knowledge and experience of entrepreneurs filters the way they see the work and how they are likely to present potential solutions to would be customers. The social construction of technical innovation can be seen at all levels and at every stage of the process providing an alternative explanation for success or failure of new technology offerings.

I could see how the power of language can help create a shared picture of problem to be solved. Entrepreneurs able to use language that describes their understanding of a problem that mirrors that of end users and present solution that customers find credible are more likely to be successful. I started to see how technology developers can misunderstand a problem and develop innovation end users do not need. I also started to see through the voices and accounts of these respondents that where entrepreneurs work with end users to jointly understand the problem, acknowledge that desirable future state is yet unborn, social space or multiple paths to the future is possible. By creating a mental representation of the future even though the destination is unfixed, a skilled technology entrepreneur can satisfy customers' quest for understanding by proposing solutions that customers can see as something familiar.

How technology entrepreneurs choose to communicate ideas matter; inability to communicate an idea effectively lessens the opportunity to convince and co-opt others to accept a narrative of how to transit to a desired future where proposed innovation can be realised. Although the literature alludes to the benefits of innovation champion (Smith 2007) or lead users (von Hippel 1986), I came to realise that technology entrepreneurs will be better served if their explanations are tailored towards these informed actors but their language should also be accessible to less informed actors. Technology champions or lead users are likely to quickly grasp a solution being proposed or make connections that others struggle to cognitively grasp, however, entrepreneurs need an explanation that everyone can understand when trying to describe new technology or innovation.

While frequency of occurrence of a concept may suggest that it is present in most cases of innovation, I learnt through critical engagement with the data, and in trying to access the meanings behind actions of social actors, not to given undue weight to a concept in my analysis outside of what it means to participants (Boeije 2010). In the course of data analysis, it is tempting to find quotes from other respondents that support researcher's first interpretation which can lead to unbalanced interpretation. Rather than seek to validate my early impressions during data analysis, I adopted a critical and sceptical stance towards my evolving interpretation, reading and re-reading my interpretations to see how it fits the data. Where I came across views that contradicted my emerging narrative, rather than ignore these views, I sought to understand why actors see things differently. Are these differences just outcomes of context of actions or are there deeper underlying social forces at play? How do these different views play out in the actions taken? How do actors with different perspectives resolve their differences and engage in coordinated social actions? And when they succeed in joint action, why have they suppressed their different views to pursue a common purpose? These types of questions drove the analysis, constantly refining the emerging conceptual model of innovation to ensure that it reflects the subtleties and variations in the social fabric at the innovation site. I also shared my interpretation with colleagues in the oil industry to see if the unfolding explanation is convincing and mirrors their experiences. Through these steps I was able to continuously ground my interpretation in the experiences of my respondents and reassure myself that the findings reflect the understanding of the larger community of professionals.

Through context, people, material objects and ideas are brought together at the innovation site. Context therefore helps to link the innovation site with the real world of social actors, making an idea or story understandable and useful, thereby helping technology entrepreneurs to create and present the big picture. I have also seen through the data that context also helps technology developers to acknowledge existing practices and investment in certain proven and pragmatic ways of accomplishing goals. When fully acknowledge and incorporated into the innovation process, technology developers are able to create solutions that fit into existing practices and workflows. Where changes are necessary, critical users and stakeholders are sufficiently invested in the changes that it is easier to overcome organisational inertia and outright resistance.

In the end, I arrived at the stage where what initially appeared to be a collection of unrelated ideas, concepts and propositions fit neatly into a coherent framework for developing a narrative about technical innovation construction. Although, I went through the neatly presented process of data analysis as shown in Figure 5-5, I arrived at my destination chastened and wiser. I have come to realise that the process of research is non-linear and tortuous with unexpected turns, twists and discoveries. Through the disappointments and reversals, I came to see the process of technical innovation construction through the voices and lived experiences of my respondents in a way that would have been impossible without the guidance of my conceptual framework.

The quest for understanding and meaning started with a search for a ladder to stay afloat but ended with interpretation of respondents' accounts and experiences that deepen my, and hopefully other readers of this thesis, understanding of the process of technical innovation in the UK oil and gas industry. Through the entire process of data analysis and interpretation, I never stopped to question my own assumptions about the world and the phenomena I am investigating. The self reflection and awareness forced me several times to re-examine what is at issue in the data and descriptions of respondents, how best to resolve questions of inter-subjective meaning between process participants and implications of actors position for the practice and creation of new technology. I come to the end of the journey convinced that innovation is contingent and tentative, an artefact that meets the needs of the moment in context but subject to change as context evolves. This understanding has implications for how the phenomena should be studied to go beyond surface effects and excavate the underlying social forces that underpin technical innovation construction.

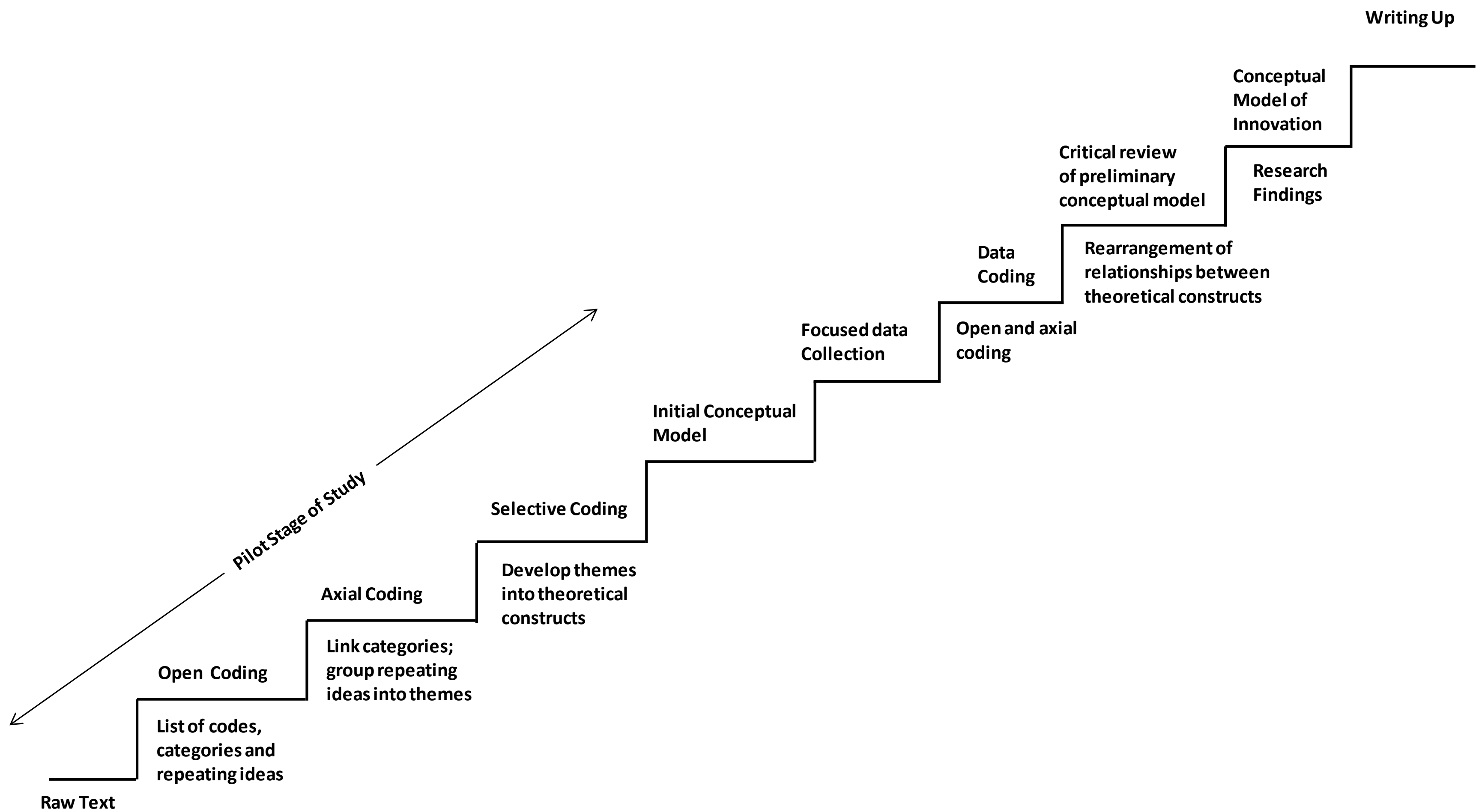

Figure 5-5: Process of qualitative data analysis for the study

5.12.2.6 Writing up Phase

The writing of this thesis began before the completion of the pilot study. Although there are plenty of books on how to write and report qualitative research, I found out that the best training was to write and refine the output through the duration of study. The early chapters were written before and during the pilot field study. As a new research student, I started off not knowing what is important and what is not. Making choices about published work that should inform this report was difficult at the start but with experience I developed confidence in making the choices necessary.

My goal at the writing up stage is to produce a thesis that is convincing, laying out an argument that readers find persuasive (Charmaz 2006). I have been lucky with the quality of supervision I have received in the course of this research. During one of my early attempts at writing the theoretical framework of research, my principal supervisor's comments were critical. I remember leaving his office and him telling me that anyone can make presentation of ideas difficult but the mark of scholarship is to make academic writing accessible and easy to understand. I felt chastened by the experience but determined to find a way to make some of the more complex ideas that are the building blocks of the conceptual framework accessible. Although combining Heidegger, Giddens, Bourdieu, Weick and Schatzki was always going to be a challenging task, through the accounts, words and lived experiences of my respondents, I was able to recognise elements of these social theories and began to understand their interrelatedness. The proposition about how these concepts relate to and influence one another is mine but research data support of the logic of my representation. To improve accessibility of my writing, I sought willing volunteers to read the theoretical framework of this research to sense check if it makes sense. This was an interesting experience in itself as I was called upon several times to explain some of the theories and application in everyday settings. The exchanges with the kind volunteers who offered me their views helped enormously to improve the writing and hopefully accessibility too.

Aside from research findings, the researcher also has a duty to be able to demonstrate methodological accountability, showing what was done, how the work was carried out and why the research was undertaken in the manner it was done. Demonstrating the link between the data, themes, theoretical constructs to the conceptual model of innovation presented as outcome of research. The themes or categories developed from the raw text have been arranged to show the inter-dependence and influence of different social forces. In chapter 6, this thesis demonstrates the linkage between the raw texts and the themes developed through data analysis. The narrative in this chapter was designed to allow the voices and lived experiences of respondents to come through showing how the themes are grounded in the data. The process of analysis was completed in chapter 7 where the researcher, using the conceptual framework rooted in social constructionism, critically engages with the themes and underlying data to present an arrangement and relationship of theoretical constructs underpinning the innovation model. In this work, I have tried to present a thread from the raw text to research findings in a way that I hope is transparent, and I hope convincing, to the reader.

5.12.3 Challenges and Lessons

One of the main challenges the researcher had to deal with is his own biases as a professional in the oil and gas industry with experiences and views about technical innovation. I deal with this bias by relying on the voices, accounts and lived experiences of the respondents while drawing on my understanding to ask probing questions during the interviews. Another challenge was my relative lack of knowledge and understanding of social theories at the beginning that later formed the bedrock of the theoretical framework. The lack of experience and limited knowledge about relevant social theories led to waste of time and energy reading up on areas that later proved to be unsuitable to the research. For example, I started out with the assumption that Structuration Theory will be the basis of the study but became obvious early in the pilot stage that it would be insufficient to addresses some of the issues raised in the research sub-questions.

Identifying appropriate respondents with relevant and direct experience of the phenomena under investigation had to be management with care and tact. Some of the respondents are difficult to reach while others were simply not interested in participating in the research process. I had to be flexible about timing of interviews given the busy schedule of the respondents.

On data management, I started using two digital recorders during interviews after the digital recorder malfunctioned after one of my interviews. Fortunately, that was after I had downloaded the digital audio file onto the computer. I also had the misfortune of losing my hard drive and all the text of transcribed interviews I had done with no backup. I was able to get some of them back because I sent the raw text to my supervisor after the pilot stage but for others (five interviews in total) I had to re-transcribe the audio files again. Because of this incident, I lost the files of one of my research respondents because of hard drive failure and subsequently removed all references to this respondent from the analysis, even though I had the interview notes I took on the day I interviewed him.

In the course of this study I took some time off because of poor health to recover from a major surgery. As a professional in the oil industry with responsibilities, juggling my work commitment with the demands of family life and research was challenging. It would have been almost impossible to complete this study without the support of my Principal Supervisor. His understanding, experience and calmness guided me through some of the loneliest phases of the study encouraging when required and giving me a kick to 'get on with it' when necessary. Overall, I learnt valuable skills about managing large quantity of data and how to impose a structured approach on large volume of data in the course of data analysis and interpretation. In the process, I have also improved my ability to think critically and/or engage with others to create shared understanding.

5.13 Conclusion

In this chapter, the ontological and epistemological foundation of this research has been presented. A strong case has been made for social construction of reality, knowledge and action, including entrepreneurship and technical innovation construction. An explanation has been provided on how these beliefs and assumptions have been used in the research design from sampling strategy to data collection and analysis. Consistent with the assumptions of social constructionism, the conduct of the research and how respondents world view have guided the evolution of the research has been explicated.

The reflective section of this chapter chronicles the journey of discovery and development of the researcher, articulating how the joys and travails along this journey have transformed the worldview of the researcher. The experiences of the researcher demonstrate how engagements with the research question, interaction with respondents and reflection of the researcher have been transformative, opening the eyes of the researcher to the richness and expansiveness of seeing the world through a social constructionist lens. The researcher came to understand the importance of listening to the different voices even when the multitudes of voices make it difficult to discern the music from the noise. The joy of the researcher is amplified when he/she can cut through peripheral issues to identify the core issues and meanings while investigating a phenomenon. This researcher has enjoyed the thrill of the search for meaning and understanding. While it is impossible to fully recount every experience, disappointments, obstacles and lessons encountered on this journey of discovery, the reflective section has allowed the researcher to chart the important stage posts along the way, giving the reader a flavour of the thrills of the journey. In the end this researcher feels rewarded that the journey has brought some understanding of the process of technical innovation construction. While this thesis marks a rest point along a journey, it is also the beginning of further adventures in a continuous search for understanding and meaning. This journey of discovery and inquisitiveness will continue, albeit in different forms and under different guises, but the search of the researcher will never be the same again armed with the experience offered by this study.

In the next chapter, analysis of data from research respondents will be undertaken to explore some of the social forces at play interact with the context of action and the relationships to the conceptual framework of study. The data analysis will explore how different roles, experiences, history, perspectives and understandings in the technical innovation construction field influence attitudes, motivations and shape decision making in the process of innovation development.

In chapter 6, the voices of the respondents are presented, laying out how they see the world from their different positions within the innovation and technology development field. The evolution of the researcher's understanding discussed in this chapter come into full realisation as the researcher engaged with worlds of these actors, and through this understanding, the next chapter lays out a thematic analysis of the data.

In chapter 7, using the conceptual framework as a theoretical guide to stand back and explore the meanings new technology development has for these actors, an integration arising from researcher's understanding of the themes from the data is presented.

Chapter 6

Research Findings

6.0 Introduction

The research findings reported here examine and describe the process of technical innovation construction in the UK oil and gas industry and how we can understand it better through the views and experiences of process participants. In the preceding chapters, a theoretical foundation has been laid to make the case for entrepreneurship and innovation as socially constructed phenomena. At the same time, innovation has also been presented as the medium through which entrepreneurs exploit change (Drucker 1985; Schumpeter 1934). As already argued in this study, innovation emerges as a product of discontinuity in our everyday engagement with the world, when familiar and routine use of tools and practices fail to meet contingent demands of everyday practical coping (Heidegger 1963). Innovation embodies change, promises progress but is intertwined with uncertainties and ambiguity. The sources of the uncertainties and ambiguity associated with innovation in general, and technical innovation construction in the UK oil industry in particular, requires an understanding of how social actors make sense of situations. Extant literature on innovation does not provide sufficient account to allow us understand the peculiarities and contextual conditions in which innovation is constructed in the oil and gas industry.

To address these issues of theoretical and practical interest, the findings of this research will be presented in terms of the study objective and research question of the 'who', 'what', 'where', 'why', 'when' and 'how' questions about what transpires within the process of technical innovation construction in the UK oil and gas industry. Qualitative technique is suited to studying processes because it allows the researcher to access rich descriptions of people interact, how individuals and groups make sense of their experiences by capturing their voices, engage with different actors transit from multiple perceptions and meanings to instantiate coordinated social action (Patton 2002). In this chapter, a descriptive account of different actors in different social roles under different pressures is presented in their own voices, providing an opening into the character and forms of social interactions underpinning innovation construction.

In the reported descriptive accounts that follow in this chapter, and in keeping with the agreement reached with research respondents, actual names of respondents have been replaced with fictitious names to provide anonymity.

6.1 The Role of Technology and Innovation

There is an acceptance by different stakeholders and across different social roles in the technical innovation construction process that innovation is critical to maximising hydrocarbon from North Sea assets. The importance of technology in the oil industry as reported by respondents include extending the range of exploration tools, boosting productivity, overcoming technical challenges and as an enabler to achieve previously unattainable goals and objectives.

Kerry, an asset manager describing the impact of a technology in particular and the general effect of technology said:

> *"we couldn't have developed Gryphon without these Vortoils… we do require that technology to allow us to extend the growth through the North Sea. And when you look at the current volumes that we see left in the North Sea; if you look at the large Ninian platforms, er, I think Ninian's, it's something like 2 billion barrels in place, and back in the early days you would get 35% recovery, or 30% recovery, and now you're up, you have 50% recovery.*
>
> *So I think technology development is fundamental for UK plc to actually continue to thrive going forward … if the right technology's in place, like I say, the reserves that we have just now, you could actually develop them further because people tend to think that there's one big large hole, but it's not, and the means of getting it out is, is so important to make it happen.*
>
> *A good example there was for Gryphon, was Turret manifold, it's a manifold subsea system, and the Gryphon was the second to use that because the Engineering Manager at the time went and did a bit of research, identified it, and it's really expanded what the Gryphon can do."*

Using technology to solve operational challenges is a common theme within the oil companies. Mark, a subsurface manager with Maersk oil emphasized the importance of technology, stating that

> *"the role of technology is everything we do, whether it's the use of existing technology, it's development of new technology, we use it every day to produce oil and gas. It's as simple as that."*

Similarly, Peter, an exploration manager with Maersk agrees that technology is central to the evolution of progress made in the oil and gas industry. In his view while technology is important, the benefits that accrue from the use of technology derives from correct application.

> *"you know, if you look back in history, you can track discoveries against technology and in the mid-eighties when 3-D seismic became the norm there was a huge upsurge in drilling and discoveries at that point … so technology can make a huge difference if correctly applied"*

The views of three end users of technology working within an oil company, Maersk Oil, in different roles but unified in the views about the role of technology. Although these different views support the use of technology, these views also point to different conditions under which technology gets used by end-users. In the first response, there is the recognition of the utilitarian role of technology to help users achieve certain desirable ends; something to be deployed when there is a goal to be achieved. The second response reflects a more ubiquitous role of technology that is ever present in everyday lives and activities while the third response is a view of technology as a driver for the growth and progress of the industry.

Andy, a serial entrepreneur, described the central role of technology in maximising production from the North Sea while also making the distinction in approaches between the major Oil Companies and the smaller Operators. He pointed out that

> *"The role of technology, as I mentioned earlier is all. It is technology that's taken us from a 2% recovery to a 50% recovery. Without it, we wouldn't be there. So it's all encompassing and … it's fair to say that role of technology will continue forward. If you take the North Sea for an example as*

a mature basin, you know… it's about applying technology, … and if you take the instance of the North Sea, that there's not a single oil field that's changed hands from a large oil company, you know, a Shell or a BP who've owned it to a small oil company where that small oil company hasn't significantly enhanced it. Now why is this? Well … I think first of all they'll do things, they've got a low overhead, they've got a, a clearer shorter decision making process, they will apply, not necessarily, technology but they'll apply state of the art ways of doing things. They won't necessarily lead technology game, and in fact what you'd find by and large that there's enough low hanging fruit that you don't need to extend the technology, risk factor where, you can get it, you can get an awful lot of value just by getting, becoming current and doing it better, faster."

The view of a serial entrepreneur above is similar to other end users of technology quoted earlier yet different in significant ways. We see from Andy's response that engineers in smaller oil companies have variety of experiences which exposes them to different ways of looking at some of the challenges they confront. In this response we see how size and organisational culture may be influencing how problems are perceived and solved. One of the question that these subtle differences in views and what technology means to different individuals is, do these different meanings of technology have a bearing on the way individuals and group relate to technology and innovation? If technical innovation has different meanings to different people, are social actors in different roles motivated to seek innovation by same or different factors? What is responsible for the subtle differences in meanings these actors ascribe to technology? These questions will be examined later in this chapter.

6.1.1 Perception of Self and Others in the Technical Innovation Process

The different players in the innovation process see their roles differently, sometimes complementary but occasionally have conflicting views. Technology entrepreneurs see themselves as developers of new technology for the oil and gas industry, who deliver value to the customer, pioneer new ways of doing things, break down barriers and challenge existing business models among other things. Harry of Caledus said *"what I decided was that I wanted to create another small oil and gas service sector business and I wanted to develop some technology that was potentially game changing. I didn't want to be involved in an oil and gas service company that was me too that was doing the same as other people were doing. …the main driver for me or the motivator for me is being involved in something that other people haven't done before. And to be first and to be ground breaking in those things. …at the core of the company it needed to be something that, was stimulating and… and interesting to develop."*

Through the response above, we see an entrepreneur who sees innovation and technology development as a means of assisting change but in a way that does not simply recreates the past. There is a strong identity associated with wanting to be different and original. Some of the end users also feel they are empowered and motivated to use innovation provided they have the right application and context, raising the issue of fit between new technology and suitable application. Talking about support for innovation within Maersk, Mark said

"I think it needs to be supported from the creativity and the innovation side of things, need to be supported from the highest level in the company. … We should all be encouraged and I think we are. I certainly feel empowered, encouraged to go out and look for new solutions, I wouldn't ever feel that I couldn't bring forward new ideas or if I wanted to try and execute them and, you now, that's probably a different story, and executing them would probably have to be done on a business requirement basis."

In the same way, those who provide funding also see themselves as being very supportive of innovation in general and efforts of technology developers to create innovation in the industry. Ben of Bank of Scotland said

"Bank of Scotland is obviously not directly involved in the production or the development of technology but our role I suppose is to provide funding into the industry to ensure that it continues to grow and develop and meet the requirements of society as a whole albeit within the boundaries of what banks will generally lend against. Our role as I see it is to provide funding for the companies working on emerging technologies system in producing and commercialising these technologies."

From the government side, John of DBERR also said

"Our role in the technology development is one that helps me to secure funding for technology through the Technology Strategy Board. We can affect things directly but we always direct small companies towards funding that can help them out."

Unsurprisingly, the ITF, an organization created to help oil companies get access to technology they require to maximise recovery from North Sea assets also proclaim their support for new technology development. Eric of the ITF described their role as follows:

"*ITF is a not for profit organisation. We have a membership made up of operating and service companies. The role of the ITF is essentially to as a conduit between the end users of technology, the operators and the development community. That development community as we see it is a global community because what we are about is to access the best technology to bring out the best solution that the oil industry needs. So in that sense we are driven by industry. What we do is to talk to our membership to identify what the issues are in terms of developing needed technology.*
We operate in the upstream of the industry we cover anything from subsurface in the reservoir right through to subsea applications to the wellheads, the platforms. In order to identify those technology needs, we have an approach we go through which engages the industry all the way."

All the players in the technical innovation construction process see themselves as being supportive of technology and innovation. Although oil companies may see themselves as being supportive of innovation, technology developers hold a different view. Harry of Caledus in assessing the attitudes of oil companies to new technology said

"I think that the oil and gas business is a fairly orthodox business. Em, you know, we are, despite what many of us say, we are quite risk averse. Technology development does take longer than you think it's going to take and often when it does take off, it doesn't necessarily even take off in the manner in which you think it's going to take off.

You know, we have a glass half empty approach to the implementation of new technology. We talk about it a lot and we meet about it a lot but we…you know, it's not to say that it's not done because clearly it is done but I'm just trying to demonstrate how difficult it is."

Also assessing what help VCs can provide to technology entrepreneurs other than money, Alastair of Red Spiders gave a fairly lukewarm assessment when he said

"They tend to leave you alone when things are going well. They tend to give you retrospective advice when things go bad. It's too late, you should have done this eight months ago or where were you when we needed you? So I don't know; it's hard. I wouldn't want to put all of them in the same band but I don't know how committed some of these guys are."

Even though there is an overlap of interests between these players, we see in the responses that there are subtle differences in motivations amongst the players, and in some cases individual views of other actors sharply contrast with how they view themselves. While technology developers want to create innovation that is potentially game changing, the end users are concerned about the right application of technology and providers of funding have an eye on commerciality. What is responsible for some of these contrasting views and how these differences in motivation play out in the innovation process will be explored further in this and the next chapter.

6.1.2 Innovation in the UK Oil and Gas industry – The Context

In the previous section we see that end users support innovation but only for suitable cases and application. As the data shows, the North Sea is a high risk and high cost environment where the implication of unsuitable application of technology can be expensive. Due to the harsh environment, the standard required of innovation in the North Sea is also very demanding. Consequently, the price of failure can loom large in the decision making of engineers and managers when considering technical innovation that is not yet proven. Even for proven technologies, applications in new environment carry risk that engineers may be unwilling to accept.

Technology entrepreneurs recognise the challenges of operating in and developing new technology for the North Sea. Harry of Caledus gave his views as follows

"the UK is not necessarily the best ground to be on to be trying to develop new technology, particularly in the offshore oil and gas sector is that we're in a fairly high cost environment. ... and naturally that makes it a fairly risk averse environment. The volume of wells is not prolific. We have very many different types of oil and gas wells distributed around the UKCS. There's no incentive, other than the benefit of using the technology for the operators and in other parts of the world there

are some tax incentives and some R&D offset, incentives, therefore developing new technology. But the bureaucracy and the red tape of setting up and running and managing a business in the UK is quite challenging in itself. So you add the challenges of developing new technology, and getting it front of a customer who's going to use it coupled with all the other barriers that are there and I call them barriers because they're obstacles that you have to get past to have a commercial successful business."

Gary agrees with the assertion that the harsh environment of the North Sea creates additional hurdles for technology entrepreneurs to overcome to get technical innovation into the market place. The cost of failure is likely to be higher in the North Sea and implication of failure amplified not because of inherent features of an innovation but the recovery cost to the customer. Gary described the issue as follows

"If you want to run something downhole, offshore in the oil and gas industry in the UK, it's a very, very high risk environment. … But a reality is that running something in a very harsh environment to great depth is risky as opposed going somewhere else where you can run in another well, on land. Bring a simple rig on the back of a truck, drill and deploy. So that's the difference. It's heavily dependent on those high rate, high cost things. So that affects technology development as well."

"The North Sea is a particularly harsh environment, so a company like the one we are sitting in right now has to go beyond what you would do somewhere else, and as a result developing and operating something in the UK sector is a badge you can take anywhere else in the world."

Aside from the harshness of the offshore environment, it is also a challenge for technology developers to have a good understanding of the downhole environment in which new technology could be deployed and building the necessary flexibility and tolerances to cope with a range of conditions. Technology developers with experience may have more success dealing with this variability but it remains a factor that may affect end users' attitude. Andy gave an example of how he dealt with this challenge when designing his first technology as follows

"if I have a problem in a well, let's say, let's go very simplistic and let's go back twenty five years ago. If I was trying to set a plug in a well with old wire line nipples and we had been wire lining and coil tubing through that well and we had been flowing well effluents of a nominal characteristics at various rates that included sand productions so we are going to have many erosional, scale, deposition etc, etc, and then I start to set a high tolerance plug in a nipple that I put down there,

weeks, months, years before, then I'm below expectation… that everything's going to work together. So my first piece of technology was a plug that doesn't matter what's down there. It's got enough operational capacity and window to actually work for what I want, which for all I want to do is plug the bloody well, you know, to do something, you know, further up or to isolate reservoir while I'm conducting another activity. So, you know, we developed a range of tools and that worked very well."

It is in this harsh environment where failure can be expensive and difficult to recover from that end users have to decide on whether to use new technology or not. Therefore, end users may take steps to assure themselves that any innovation can deliver expected results or cost of failure will not be too expensive to recover from. Against the background that in some cases, technical innovation may have no case history to minimise the fears of end users, it is clear that the specific conditions of the North Sea context form a significant part of the subject under investigation.

6.2 Drivers of Technical Innovation in the Oil Industry

The views of research respondents indicate that different actors are motivated by different things to engage with and in the technical innovation process. The end users of technology seek technical innovation to meet a challenge that cannot be resolved by existing technologies and/or practices. While some end users are driven by micro and local considerations, other are motivated by larger, global drivers.

Peter, an exploration manager explained how immediate operational issues and challenges focus internal attention and efforts on the need for solution, saying:

"whether it's big exploration or if it's a specific problem we are trying to battle with, you know, some obvious ones within Maersk [like] chalk … there's a lot of effort goes into research and technology and control, geology deposition, fracture analysis but also the drilling production side as well."

Beyond the immediate concern of everyday operational challenges, Peter went on to say that some attention and limited resources are also devoted to likely or anticipated challenges of the future. However, long-term planning for technology needs is invested in external bodies like the Industry Technology Facilitator (ITF), R&D organisations and universities.

> *"... other areas as far as the ITF is concerned it tends to be more kind of blue sky type research, something that may be of use in the future but isn't applicable to a specific problem."*

On the other hand, Mark, a subsurface manager with Maersk, situated the drivers of technology within a larger context of value creation but went on to suggest that the responsibility for developing technology rests with the service industry. Mark summarised his views on drivers of innovation as:

> *"Extracting value, execution of field development plan, and solving problems, er, that, you know, coming our way.*
>
> *You know oil companies are, you know, these days at least anyway, are not the ... what's the word, they're not the generators of technology. We openly, you know, accept that. We're the users of it, and we will, I mean, you know, where we have a business need we'll encourage the service industry to develop solutions for us and yes, we'll use them where appropriate."*

Other players in the process of technology development also have similar views, accepting the fact that innovation allows oil companies to reach hydrocarbon deposits previously deemed impossible to access and produce. Ben, a manager with Bank of Scotland with responsibility for lending to SMEs, said:

> *"The key driver we see is that oil is being found in increasingly more difficult to exploit areas. The easy to find oil is being or has been exploited, either it's in inhospitable waters or areas or the nature of the oil is not easy to produce, its heavier oil or tar sand or whatever and as a result it can't just be produced as easily as the hydrocarbon that has been found today."*

Ian, a senior manager at Simmons & Company International, an investment bank for the energy industry, recognised that different players are motivated by different factors. His view suggests that social roles and the context of action have direct influence on what drives innovation in the oil industry. He observed that

> *"I think the commercial drivers at the end of the day ... I think that people develop new things if there's an economic incentive to do so.*

So from an oil company perspective you know in our experience all the major oil companies have, you know, innovation as an area of interest because they see the long term benefit to them from having access to new technology.

So there's an element of that probably which is less economic or that it's not short term economic drivers, it's more long term, you know, to sustain the industry.

So it might be, you know, solutions for heavy oil or you know uh through-tubing drilling or you know uh, new subsea technology. Something that's important to them in terms of developing new fields or increasing production from existing fields.

a perception that they have a duty to the industry in some part to allocate some resource to innovation. Just, you know, for the greater good. … So I think my view would be those are the oil company drivers. I think at a service company level, um, I think they're purely economic. So it's really down to if, you know, is there a profit opportunity from new innovation?"

Another respondent, Gary with previous career in the University as a lecturer, in government in DBERR and latterly as a business development manager for Red Spider Technology in Aberdeen raised the regulatory environment as possible driver for innovation. In his view, the demands placed on the oil companies by government as condition for operating their licenses induce different attitudes towards innovation. He compared and contrasted Norway and the United Kingdom to emphasise the point that oil companies may not pursue innovation as much as they should if there is no obligation for them to do so. He summarised the effect of regulatory demand on innovation as follows:

"I also know that if you look at Statoil and Hydro, their recovery rates matching what their government wants is sort of 65 – 70% recovery rate. Now I know that requirement isn't there on the UK side. You can also say, why is that? In Norway, if you win a license to own a block, you must do R&D. It's enshrined in there, you must do R&D. So it's not necessarily too surprising that companies do R&D because they wouldn't get the block otherwise. So it's part of the contract. For Norway, oil and gas is a huge part of the GDP, therefore there is a lot of vested interest to get it right, to truly maximise it."

Alistair, a technology entrepreneur and one of the co-founders of Red Spider Technology, described the drive for quality and the need to redress failure of big multinational oil companies to meet the needs of their customers as driver for setting up the company. Alistair stated that

> *"We are sitting there with big companies and we are watching them letting people down week after week after week. Telling people that they are going to get their stuff in three weeks time when they knew for a fact that it was going to be twelve. We think that the industry can't work like this you know and there's no trust between the Operator and the Suppliers."*

> *"So when we started off we said right, we are going to do things right, we are not going to bullshit, we are not going to short cut, if there's something wrong, we are going to tell people, be honest with them, work with them… I would like to think that Red Spider would never take a project on just to do a 'me too'. I would hate to think that we are going to get to a position where we would take somebody else's tools and copy it, and just basically market the same tool, with the same specs, with the same features , with the same performance. What we are about is looking for an opening in the market and understanding what can we do to make this... and it's about value."*

In order to address market and technological inefficiencies that Alistair described as an unacceptable situation, Red Spider Technology (acquired by Halliburton in 2013) was founded to design and produce quality engineering products and technology to meet customer needs. In using the analogy of different car makers, Alistair summarises the company drivers and approach to innovation as

> *"you need to decide which level you are coming in at. I said right, what do you mean? I like cars so I always make examples of cars. Do you want to be the Lada, a rock bottom car, and you are selling thousands? Do you want to be the Ford and the Vauxhall, good cars but it's a mass market type cars? Do you want to be the Volvo type, Saab type car? Maybe a notch up again or do you want to the BMW, Mercedes, Audi? Or do you want to be the Bentley or Rolls Royce? Now the Bentleys and Rolls Royce are too high, you are pitching above what most people want. BMW, Mercedes, Audi, I will say that's where we set out to be."*

Even if they all recognise similar needs for technology development, the priorities they attach to these needs differ, suggesting that actors see and interpret information differently. The views of different respondents show that drivers for innovation differ depending on individual position and relationship to others in the innovation construction process. Some of the drivers of innovation identified by these respondents point to reservoir challenges, economic necessities, commodity prices, cost reduction, personal financial rewards, fore sighting are some of the drivers of technical innovation.

Whatever the motivation of the different actors to engage in the innovation construction process, the ultimate driver is to be able to produce more oil and gas out of North Sea assets. The need to find new solutions to the challenge of the day propels human actors to develop new technological solutions and practices. Andy captured the core driver of innovation in the industry when he said

> *"it's basically challenges at the reservoirs, the environment and the movement in commodity price throw up for us, creates a requirement to basically come up with a solution ... if we had not gone offshore in our search for oil and gas on a global basis we wouldn't have the offshore technology now, but we were forced to go offshore because, quite simply we couldn't find enough oil and gas reserves onshore, because if there had been enough onshore we wouldn't have gone off shore because it's a lot harder"*

The accounts of these respondents indicate that recognising the need for innovation cannot be divorced from individual experiences with everyday life. These social actors recognise different drivers of innovation from their vantage positions in the innovation process. Therefore, it is logical to explore how these different positions in the process filters the cues and signals that individual recognise and how social actors gets sensitized to the need for innovation.

6.3 Sensing Technical Innovation Opportunities

6.3.1 Sources of Ideas

Responses of respondents identify a number of sources where ideas for innovation come from. Technology entrepreneurs predominantly identified experience as the source of ideas although there are other sources of ideas for innovation too. End users of technology are not necessarily sources of ideas but their knowledge about ongoing problems make them good sources for entrepreneurs to understand issues that they would like to see resolved.

Andy, the serial entrepreneur, identified engagement with the world in day-to-day interactions as the main source of ideas for innovation. According to him, his prior experience about what ought to be and unsatisfactory state of things in the present sharpens his awareness of what can be improved. His description of where his ideas for innovation come from was described as follows:

> *"I think the ideas come on your daily journey, ..., working in the industry and, and for me I've been in this industry for over thirty, well over thirty years in fact. And, during my, what I call my daily journey of trying to do business I just see road blocks and road blocks are commercial, they are technological. And really what I do is, is there a way of getting through this road block, is there a piece of technology that is missing that we need to looking at in an industry? Is it something I can have an influence on or is it a commercial business structure that doesn't work and can, can I actually create a, a different structure. So I think you learn it by doing the job"*

It is important that Andy also identified learning by doing as a way of learning and a source of innovation in his response. His response indicates that there is a value to practical involvement with situations and how things get done. This view of experience as the primary source of ideas for innovation mirrors that of Harry, one of the co-founders of Caledus whose take on where innovation ideas come from is also rooted in experience albeit applied with the benefit gained from the past on how to grow small businesses. Harry said

"I learnt a lot about growing small business, about developing new technology, creating niche markets and so on and so forth...and started to brainstorm pretty much by myself and it was no more complicated.

So I went out into the market place as a one man band in the Spring of 2003 and really just started to shake the tree to see what was out there that people were interested in and what kinds of technology could be developed and I came across two or three interesting things ... one of them is a casing reaming shoe, the other is a cementing tool and the other is a a down hole swivel type tool. And these are fairly ordinary, run of the mill products and services.

But the most interesting thing I came across during that… during that sort of diligence, er, period was this technology called Slimwell … some patents that he had applied for in the late eighties which were all about constructing the oil and gas well from close clearance flush jointed liners. So the method of creating wells using that technology were… had become patented and the development of that technology had never happened."

In Harry's account about how he identified the technologies and products to focus on at the start of the company Caledus we see how experience allowed him to identify likely areas where certain improvements could be made to existing market offerings and establish a foothold in the market place. He has been in the industry for over 18 years and has multiple patents to his name so he is familiar with the process of developing ideas into tentative technical solutions. Harry said

> *"I joined the oil industry when I was 18. I spent ten years in the field with BJ Services and five years in the field, well sorry, three years in the field with Nodeco and spent some time offshore at the very beginning of SPS because there was no one else to go. That has given me an insight into what actually is viable and what is practical … and I think that's one of the things that's very important for companies to do.*
>
> *I mean over the years … I've been involved in applying for lots of patents, ideas that have been stimulated by perhaps a problem or an operational difficulty that an oil and gas operator has experienced or an approach from an operator that says, you know, we've got this particular problem, can you come up with a widget or a gizmo that will fix this? … I suppose my name must sit now on something like 60 patents. And of those patents my estimate now between what's at Caledus and what's at SPS is probably half of those are commercial."*

Aside from experience, Harry identified end users as sources of ideas for technical innovation when they approach technology entrepreneurs with a problem description seeking quick solutions. Harry's view of experience as the primary source of ideas for innovation mirrors that of Alastair, one of the co-founders of Red Spider Technology. In Alastair's view, experience is the primary source of innovation ideas as he explained

> *"One thing we've got is experience. We have a huge bank of experience in house. Most of us have been in the industry since 1980, 1981; twenty five, twenty six odd years. We have worked for big service companies. We've worked for small service companies, some of them successful, some of*

them not so successful and you can't buy that. Because you learn from your mistakes, you do and we've all made hundreds of mistakes in our careers and the companies we've worked for make thousands of mistakes.

When we started, I would argue, you know there is a learning curve for new technology. One of the ways we sold the company when we first started all we had was the people. So you have to sell, this is what we have in house, this experience. My argument is that learning curve you go a bit flat then it start ramping up. We are half way up the ramp before we even start designing a tool because when we were at PES, we tried this and it didn't work so we are not trying that. We tried blue when we were at PES and it didn't work, we tried red when we were at Halliburton and that didn't work. We tried yellow when we were at Baker, that worked slightly but it could have been better. So could have learned from all those colours and say green was the way Schlumberger went and that worked. So we are already on the right colour trail, so how do we make it better? What are its weaknesses? Okay we know this the weakness and strengths. That's the strength we have, we know what's on the market. Some of the tools are tools we've sold before, we've been involved with the development ourselves and we know the strengths and weaknesses. And also then critique the competitors, we also know their strengths and weaknesses. So we get huge knowledge base of what's already available."

In Alastair's response we see that experience is important not only in helping technology entrepreneurs recognise potential ideas that can be transformed into innovation, it is also an asset that can be packaged and 'sold' to potential customers to improve outcome of transactions. Experience becomes a resource that can be traded to gain attention of and audience with likely end users; it increases the credibility of likely solution that a technology entrepreneur may be pitching to end users.

From the perspectives of the operators, necessity is the main driver for innovation; engineers and managers see the need for innovation when existing tools prove incapable of meeting performance expectations. As users, they see a need for innovation when they encounter operational situations that existing technologies and practices either cannot resolve or handles inefficiently. This recognition of situational challenges as potential source of innovation is summed up by Mark, a subsurface manager with Maersk, who said

"In the area that we work in at the moment that I look after, it's mature field development, the underlying theme I would say is that necessity is the mother of invention. We're facing problems

every day, we're faced with new approaches, and out of those immediate problems, we develop solutions.

... sometimes you look out over the wall and you go oh! It might not be the exact thing that you're looking for, it might not be the exact that would have application, but suddenly it sparked an idea and you think well, if we could take that widget there and turn it into a left to right instead of a right to left, we turn it upside down and paint it green, we could actually use that here in this application and we would have some benefit."

Whether individual technology entrepreneurs identify ideas that can be transformed into innovation or approached by end users with a description of a problem, the role of experience in initiating the process of idea generation cannot be denied. These responses demonstrate that individuals need to have some experience to be able to recognise ideas with potential for technical transformation into innovation. In the next section a descriptive account of respondents is presented about how individuals scan their environment for cues and ideas with potential for technical transformation.

6.3.2 Scanning for Innovation Ideas

Human actors in their engagement with the world have access to myriads of information. The same is true of different stakeholders in the technical innovation construction in the oil industry. Given the avalanche of information that these social actors encounter on a daily basis, there must be ways they filter out the noise and can truly apprehend market signals.

Kerry, an asset manager with Maersk Oil, recognises the importance of technical innovation but has no time to scan his environment for new technologies that may be helpful in his operations. His dilemma is captured in his response when he said

"Well, having said on one hand it [technology] is a key enabler. The role I'm in now the difficulty I find is I don't have the time to actually go and look at the new technology because if you're that close to the day-to-day operations and what's required, what happens is the only place that the new technology tends to come

through is perhaps at a project stage or where you got an organisation that is large enough to have a group that is looking at new technology, and is actually keeping its finger on the pulse.

I'm certain there are many good ideas out there, a large proportion of which could help me do my job daily, but that's not actually available to us. … I don't have the capability on a daily basis to look at new technology … you want to make sure your R&D Department has the right practical people in it. You don't want long-term scientists. I suppose that's the nearest we have to an R&D group is, is a couple of Engineers that are taking the, the reservoir parameters from exploration and saying well, if we've got to make this fly this is what we've actually got to do"

Kerry's response is instructive in that it shows that environmental cues for innovation will more than likely register with end users when confronted by problematic situations. Peter, one of Maersk Oil exploration managers, identified the Industry Technology Facilitator (ITF) and the Universities as vehicles for technology scanning on behalf of the oil companies. There is a lack of resources internally within the oil companies for scanning the environment for ideas that can be developed into technology that can then be deployed in their assets. Peter argued that

> *"We are a member of ITF which is the industry technology facilitators and they do basically the scanning on behalf of the ITF members and bring forward projects for funding that might be of interest. They are not restricted to the G&G but subsea technology, drilling etc but of course I am more interested in the G&G side so there's that side. We do a lot of work with universities, funding projects, funding research students, funding specific projects on which research students might take part. … we really don't have the resources to support development, which is why we outsource it. Um, there are one or two staff or maybe more than one or two but a few staff who will become actively involved in projects, but the amount of time that they spend on it very small."*

The ITF was formed to act as a vehicle for helping to aggregate the views of its members, the end users of technology (the oil companies) on what is important and type of technologies that should be developed. Also DBERR as a government agency with an interest in maximising recovery from the oil industry work hand-in-hand with the ITF to support technology development.

These accounts of some of the end users show that it is challenging for technology entrepreneurs to have direct access to decision makers within the oil companies and make them aware of potential technologies or ideas with potential to solve their problems. Therefore, if technology developers cannot easily have face-to-face encounters with end users of technology, they must developed means of extracting the right cues from the environment to develop technologies that meet the needs of the users.

6.3.3 Screening of ideas

Different actors in different social roles see the idea screening process differently. Resources of time and money are scarce, therefore it is logical and prudent for technology entrepreneurs to screen potential ideas and focus on the ones most promising. Account of technology developers show that they select ideas they pursue based on ability to solve problem deemed important by the customers, solutions likely to create value for the end users or provide solution to direct request from the customer.

From the accounts of the respondents, prior experience helps to filter out the noise and to recognise promising ideas. Alastair described how experience helps in the idea screening stage as follows

> *"The other thing we did when we were at PES, it was almost like the first port of call for a lot of clients, if they have a problem they call PES and we'll come up with a solution. So we've been involved with people's problems for the last ten, fifteen years. You get huge amount of experience on the back of that."*

Alastair went on to describe how and why they developed the first technology Red Spider Technology marketed in the following example

> *"The first tool we did was a water injection valve. I have been selling them at Halliburton but there have been issues but they [Halliburton] were determined; a valve is a valve and they were not changing it. I says yeah but there are problems but they say, yeah who cares we are selling a bunch of tools. So that was flagged up as a big issue. If we could handle the issues, then there is a big market. So we came up with a design, we played around with the design on paper, fine tuned it. And then we showed it to a couple of people to see what their thoughts were, people we trusted, customers. We sought feedbacks from them, is this something you would consider if we were to*

prove it? We got encouraging feedback, yes it looks great, if it were to work, we'll try it, you know this type of thing."

Even in the early stages of technical innovation construction, technology entrepreneurs are already thinking about commerciality of what is likely to be developed. Harry, one of the founders of Caledus, summed up the importance of commercial success even in the early stages when he said

> *"one of the things that I within Caledus is try and make decisions about what we're actually going to do and what we're not going to do. Because there are lots of ideas that could be developed and they actually could be technically successes but they sit on the shelf because they're not commercial successes. And companies are not built around technical successes. They're built around commercial successes"*

Although technology entrepreneurs may not have direct access to end users of technology, we see from Alastair's account that they can use their contacts and engagements with members of their social networks like Red Spiders principles did while developing the water injection valve to get critical market feedback. Feedbacks from end user are important to technology developers to assess if their proposed solution has the potential to leap across the technology-commercial success chasm.

The responses of these respondents raise the issue of how risky technical innovation development can be and how others relate to the inherent risks associated with new technology. In the next section, different accounts of how different actors perceive risks and how these perceptions shape their attitude towards new technology will be explored.

6.4 Attitude to and Perception of Risks

Innovation is inherently risky because there is no way of foretelling what the likely outcome of the innovation process will be. In the preceding sections, respondents have described how their experience and know-how have been critical to recognising ideas with potential for technological transformation but like Harry of Caledus said "***companies are***

not built around technical successes. They're built around commercial successes ". Making the transition from having an idea with latent potential to developing a prototype and finally a commercialised technology is challenging and fraught with many pitfalls. The challenges that technology entrepreneurs encounter take many forms but risk and uncertainty are key issues for technology developers, those who provide funding to support technology development and the end users. In this section, using respondents' own words, an account of how individuals perceive risk and implications for their attitude towards new technology is presented. There is also an exploration of the implications of how different attitudes to and perceptions of risk affect decision to use new technology.

6.4.1 Perception of Risks

Risk perception is a subjective judgment that different social actors make about the nature and severity of risks associated with new technology. One of the challenges of dealing with risks associated with technical innovation construction is the absence of common language and description of what risk means. Gary, whose career spanned the academia, government (DBERR) and now in the private section, summarises the issue as

> *"Risk is a word that is incredibly misused or used for a variety of things. I did some work in actually defining that, risk has a very, very large range. It is like the P90, P10 or is it P10, P90, it is the full range. It's called risk. ... I look into it further and we had a short study run internally and we look at that and discovered that some people would take what comes out of the risk model at face value. Some people would go beyond that and apply a common sense element beyond that, and some use that as part of further models that is incorporated. So not only can risk mean different things to different people but it can be defined differently before you express whether it means different things to different people."*

To the end users of technology, engineers and managers' perception of risk cannot be separated from fear of failure, loss of production and other unmet expectations, all of which are influenced by ghost of past experiences. Within the oil companies, there may be champions of new technology but no single individual has the sole power to decide that a new technology will be used. Often the decision to try a new technology will be made by a team after going through a process to assess suitability. Consequently, to take Gary's contention about what risk means, assessing inherent risk of any new technology will be difficult if process participants have different understandings of what risks should be mitigated in the use of the technology.

Peter, an exploration manager, describe the process of assessing risks associated with new technology as an end user but concede that there is no consistent approach. The quantification of risk is often subjective and relies to a large degree on the experience and interest of the actors involved in the process. Peter said

> *"I guess certainly in some circumstances we will do a value of information exercise which will try to give a quantitative assessment of that risk. In others cases it's very much a try and see what happens, it's not consistent I would say. ... And things like buying technology the risk associated with that is pretty much a grab a number out of the air, it's what it feels like, is it thirty percent risk? Sixty percent risk? That's about right. And that's really what it comes down to."*

> *"the quantification of risk is very important but also the size of the cost of that technology has a bearing as well, but the risk on the outcome is by far the biggest factor."*

The inconsistent approach to risk evaluation demonstrates that context matters, the makeup of the team is critical, and how risk is perceived depends on interpretation. Notwithstanding the inconsistencies of the process of assessing risk Peter outlined above, changing perception of key actors about risk is very difficult. In describing this challenge, Peter said

> "*the industry being a fairly conservative industry in that, we have our ways of assessing risk and value and that is something new and it takes a lot of persuasion. ... People are comfortable with estimating some types of risk and not comfortable with others and it's really that estimation which needs to be worked on.*"

Peter's view suggests that individual perception of risks, although subjective, is intimately linked to what they know and understand. There is also a social dimension in which higher losses can be tolerated provided there is a collective acceptance that it is a risk worth taking. These accounts suggest that perception of risks has little to do with the inherent risk of any particular piece of technology but rather affected by understandings and expectations of different actors. Peter's account below is quite revealing.

> *"You can get into the attitude of being penny wise and pound foolish, people can argue about the risk of seismic survey which may cost ten million dollars, whatever, a piece of new technology which may work or may not and, the most you are going to risk in that case is ten million dollars and you probably wouldn't even get that far, it would probably be aborted if something went wrong, but all the time we risk geological prospects, and feel comfortable risking geological prospects and are willing to throw hundreds of millions of dollars at a well to test that risk. So it's a concept of relevance and, and that estimation of that risk which people are very poor at and that may come back to better methodology and assessing risk."*

Peter's account suggests that prior experience lowers the threshold for accepting certain classes of risks while raising the bar for others. If understanding of risk is varied and individual perceptions of risk differ, then it is to be expected that individual attitude towards risks and new technology will also be different. In the next section the implication of different understandings and perceptions of risk will be explored through the account and lived experiences of the actors.

6.4.2 Attitudes toward Risk and New Technology

The data shows that attitude towards risk cannot be separated from the positions individuals occupy in the innovation construction process. How individuals perceive and relate to risk is linked to what is at stake and how they are affected by the decisions they make or choose not to make in relation to new technology. Individuals have varying views as to whether the industry in general and oil companies in particular are ***risk averse***. However, engineers and managers within the oil companies concede that there is always a preference for not wanting to pioneer new technology application if it could be helped. Mark, a subsurface manager said

> *"the people I've come up across in my career haven't been averse to new technology. The question's always there, has anybody done that before? That's always the first question because yeah, nobody likes to be first, nobody wants to go into it, and if there's experience to draw on, why not?"*

The propensity to demand for prior experience on new technology is itself a paradox for an industry in which there is broad agreement among actors that technical innovation is critical to its survival and achievement of its strategic and societal goals. The paradox of needing innovation but wanting evidence of previously successful application is explained by the pervasive culture of being comfortable with the known and discomfort about uncertainty. Kerry, an asset manager, described the dilemma facing engineers and managers as follows

> *"within Maersk you're looking for a P90. You're looking for conservative, you're looking for stability. There's no incentive to actually make use of new stuff... although as an Engineer you'd love to get involved in it ... I think it could be partly because the margins are big enough already... The incentive isn't there to actually make it happen"*

Kerry went on to describe the culture within the organisation and its effect on the way individuals relate to risk and new technology.

> *"if you've got a job to do or an issue to look at you will never be criticised if you're actually using a well known and well founded approach to a solution. If you go out and look for something innovative you will get a credit if it works, but if it doesn't work it's you, you're criticised for it. So there's no advantage to me personally as Operations Manager ... to go out and look for new innovative technology... we're still making a decent profit out of it. Looking very short termism, I realise it's not a very long term view, but that's what pays our salaries and what pays our bonuses, is the approach in the short term side of things."*

Andy, a serial entrepreneur, also identified this problem, arguing that the incentive structures within the oil companies discourages risk taking and consequently slows down uptake of new technology. In Kerry's response above, there is some indication that engineers may be interested in new technology but the consequence of unmet expectations is too high a burden to bear. Andy argued that

> *"they don't pay their employees to take risk, there's actually an anti-risk culture in most of these companies. So, in one hand the company has an objective saying 'we're in this game' but on the other hand the way they behave towards their employees and their reward and remuneration etc, then these people are not incentivised to take risk. ... So people don't take risks inside oil companies*

by and large. Now, there are always exceptions to the rule in any sphere of life. There are people who actually do it, but they're few and far between. … Nobody can be criticised for doing something conventionally which is always the way we've done it because we've always used Schlumberger for all logging, we've always used a Baker plug, we've always drilled holes with these casing sizes. If you don't veer from that and something goes wrong, people can't condemn you, they can't say 'well hold on, it's gone wrong because you changed this and this and this'. The fact is that … you're never going to get improvement unless you take some risk, unless you do something differently."

Although this attitude to risk and new technology is understandable, the intention of some of the managers within the oil companies is to improve innovation uptake. Some of them have mandated their staff to seek new innovation but within the same companies, if personal price attached to failure is high, then the incentive is to be conservative to achieve operational targets. Mark, a subsurface manager explained how he tries to get his team to bring forward innovative ideas and remain open to new ways of doing things. He explained his approach as follows

"we have system of encouraging our employees to be creative. We do that through our performance review process,…we promote the creative mind set. And then it's up to the individuals to bring forward new ideas, technology, whether it's the development of new technology, whether it's the use of existing, whether it's some kind of reverse engineering, and morphing of that technology into something else. It comes from the individuals, … They come forward in a whole different kind of way you know … sometimes one day you're faced with a problem and you deal with it and you might have to investigate new ways of attacking the problem, or you might simply be reading a magazine, you know, one of your company magazines or something like that JPT, reservoir engineering SPE stuff, it could be anything."

From some of the views reported, it is clear that an ad hoc approach like Mark's encouraging innovation does not appear to be effective in generating new ideas for innovation. Peter explained that one of the main reasons why oil companies are risk averse is because of significant amount of money is at stake each time an unproven technology or practice is used. When innovation fails, millions of dollars could be lost to the oil company, therefore there is incentive towards failure avoidance. Peter said

"I think in a lot of senses oil companies tend to be risk averse, … you know there's so much money tied up in drilling and extraction of hydrocarbons that new technology can be a huge risk. It's not

just whether the technology may fail but it may critically damage the whole project as a result and so they tend to look at more prudent technology and be a follower. And that has, I think that attitude pervades the whole of the industry in that, even technologies that are not critical in project success or failure people tend to be second followers."

Concerns about potential loss in the event of technology failure are tied to individual assessment of personal risks to remuneration and position. Any consideration of new technology is against existing practices and systems with known operating envelope and performance benchmark. Since no one can know with certainty in advance how a new technology will perform, individuals have to make decision about new technology under conditions of uncertainty. The risk that a new technology could fail and the outcome uncertainty that create are the drivers for individual and group attitude towards new technology. Gary argued that the impact of any failure on personal remuneration is a key factor in individual decision making, saying

"Now companies are primarily driven by assets, then the asset will have a target. You will be successful if you have that. And coming right down to the individual, the person running the asset will have a bonus based on delivering that asset's performance. Now if that asset is working and delivering, then the bonus is assured. The person will get the bonus. Literarily the family can go on holiday and get a new car. These are not company things he wants personal things now. So if you come and say you know that thing that keeps failing, you know if we put this in it wouldn't fail any more. Yes of course, but I don't know if it would work. I know exactly when those things can fail, it's programmed in and it doesn't impact on success. So you put something even though it means production will go up 10%, he doesn't necessarily capture it. Even if it is, why risk to your bonus or an enhanced one on a promise of what could be. …why would you risk something like your personal bonus for the chance of a bit more when you can have what is good by doing what works. It basically comes down to personal economics."

There is a strong individual component that is aggregated across and within groups thwarting or slowing down the uptake of new technology. Within the oil companies, most of the decisions about new technology will be taken by the employees of the company but in a lot of cases, some of these roles are also occupied by consultants. These consultants are in these roles because of their experience but their job is temporary, and some suggests it is likely that they may act in ways that may not be conducive to the use of new technology. Alastair of Red Spider Technology summed up this effect as follows

“Now consultants are taken in as experts, supposedly to use their expertise to change the game. That’s the principle, that’s the theory. What’s the driver for a consultant when he is paid daily, so if a job lasts for ninety days, he get paid for ninety days. If you come up with new technology that’s going to take thirty days out of the operations, what’s the incentive for him there because he is just going to end his contract quicker as soon as the project is finished.

There is also the risk that if they’ve run a plug and prong for the last ten years, if he uses the same technology they’ve been running and screws up, hey you guys have been running this for the last ten years, it’s not my choice. It’s your choice. If you go to him and say these Red Spiders guys have a great kit here, it’s going to take thirty days out of the operation, and you see his eyes lightening up, this is going to go down well with the boss. Then he’s got to think the contract is going to finish quicker and then what if? What if it doesn’t work and he screws up? Instead of thirty days savings, it added thirty days on, then they are going say we’ve run plug and prong for the last ten years, whose idea was this? And the consultant puts his hands up, the guy they’ve only got for two weeks totally change the way they did things and screws up. So I think that’s a problem that the industry has got. It’s that they are risk-averse and there are reasons why they are risk averse. There is no encouragement for, there is nothing in it for them. All they can do is lose their job.”

In some instances, engineers and managers may not be willing to live with the uncertainty that is associated with new technology. They want relative certainty either because of personal preferences or due to institutional pressures. Kerry of Maersk Oil said

“personally I’m a very, I’m a conservative style person, so it does mean that I wouldn’t want to do it. You’re looking for the secure option, and Maersk is an organisation that’s even pushing me more into the secure option because if you say something or make a commitment to something within Maersk, the expectation is that you will deliver on that. Now that’s almost a mutually exclusive statement to a new technology“

6.4.2 Liability of Size

A number of respondents agree that small and medium enterprises (SMEs) are likely to more innovative. Respondents ranging from managers within oil companies as end users and investors all agree that SMEs are nimble, with faster decision making and can quickly meet customer needs when engaged to develop new technology. Eric of ITF said "*small companies, I believe, are the ones that come up with the ideas. We usually find, it is typical that it is small companies who usually find those ideas but they don't always have the wherewithal to fully exploit them."*

John of DBERR also agrees because in his view small size is an advantage to generate new ideas and pursue them. Talking about the role of SME, John said

"good idea comes from small companies because in small companies, individuals tend to have a lot of autonomy to come up with blue sky thinking whereas in large companies they may be restricted. So I see them as having an important role in the future."

Andy, the serial entrepreneur, compared and contrasted large multinational oil companies and concluded that SMEs are more innovative because they have to be as a matter of survival. He said

"for me it's small companies who develop technology or instigate the development of technology because they have to do that to claim their place. … because it's their only competitive tool. They have no history to dwell on so they've got to create the future. And normally within those companies too, it's individuals who've come out of an organisation where they've had this stifling, intellectual stifling, where they've, they've known and feel that there's a better way of doing things and they haven't been allowed to do it"

Andy went on to offer an explanation in his view why big, multinational oil companies are not as innovative by saying

"You've got to remember it, … the large oil and service companies it's not necessarily in their interest to be continuously changing technology. Once they have capitalised that technology, once they have a service methodology and rental tools and processes to run it, then new technology can affectively upset the apple cart, you know, and may not make them the returns that their existing technology would be. And they are financially driven, not technologically driven, the larger the entity. It's small companies who develop technology because for them that's the opportunity to move the process ahead."

These respondents all agree on the role of SMEs in generating innovation, but paradoxically some of the technology entrepreneurs also argue that being small is a liability because it denies their technology the credibility with some of the end users. Harry talking about SlimWell technology that Caledus described said

> *"sometimes the technology doesn't have a big enough company sticker associated with it. So that means that an individual engineer, whether it's an asset manager, a drilling manager, a drilling superintendent or the drilling engineer for a particular operation, if he makes the decision to use a piece of technology... new technology perhaps from a very small company and it fails perhaps that's his fault and he'll get some blame associated with accessing that technology from a small company when the finger could be pointed to say, listen guys, you know, they weren't big enough to have the support, the infrastructure and the back up to, to put that technology in the field and whether that's the truth or perception that's perhaps part of the finger pointing exercise. If he had accessed that technology from one of the big sticker trade organisations, you know the companies with tens of thousands of employees, if he had accessed that technology from one of those companies and it fails there's not perhaps as much personal liability associated with that decision"*

This perception of the size of the company producing the technology being a factor in the decision to use or not to use technical innovation is shared by others actors who are familiar with the process even though they are not technology developers. John of DBERR concede that there may be some problem relating to size but gave a different explanation for this perceived attitude, he said

> *"I think there may be a pecking order in the whole supply chain and sometimes companies can be too ambitious in who their target client is. And sometimes may be instead of trying to market their products to the big operators, maybe they should go knocking on the door of some of the first-tier contractors to get their products into the market. ...I think that there are a number of companies who are operating as second-tier operators who have got different views towards that. I think it's probably true what you say about the big multinational companies but for smaller companies that are aggressive, far sighted companies, I think their doors will be open to small companies producing technology"*

Gary, formerly of DBERR before taking current position as Red Spiders' Business Development Manager, argued that this attitude, if it exists, stems from ignorance. He said

> *"Sometimes a smaller badge can just be ignorance of the company. Who are you? There can be that factor. We mentioned hundreds of companies, you don't necessarily know them all even though these companies do all the right things to make themselves known. On the other hand, what we see in the*

company here, is if you are doing something which is very high value, you can address a problem, a specific problem quickly with a quality solution, then it's very difficult to challenge that kind of turn around. SME can certainly be the badge of choice in certain niche applications and certain wider applications where they can compete where a larger company can say we can offer all of this, you'll get it next year and then say we can offer this bit, this bit and that bit and work with these guys on this bit and this bit, how does next well sound? That can be difference, can have an effect. So I think the badge, it's down to the quality behind that badge."

Asked about the perception that oil companies sometimes discount innovation from small companies, Eric of ITF disagrees and provided an example to make the case when he said

"No, definitely no. We've got examples. We have just recently I think in the past few weeks, a prime example of a technology that is still in the process of being developed through a University department. It's not a local University by the way. That technology was deployed by one of the main oil companies, the major oil company. It was essentially a technology that they tried because all of the methods they've got have failed. And that technology, whilst is still in the development stage although getting towards the end of it, they took a large unit out and it succeeded in providing a solution.

Now okay, there may be issues in terms of reliability of that equipment but it offered a solution, which is the important thing. Turning it into a reliable technology, this is where the large service companies may come in. The idea comes from a small developer, research institute or small company, but to probably turn it into something that's reliable is where a service company can come. And the service companies have a vital role to play, that's why we introduce them to our membership in agreement with our operating members because it's recognised that the operators cannot deploy the technology themselves. It has to be through the service companies. That is the way the industry is, that's the way it works. The operators don't have the wherewithal to do that, they have to use the service companies. It's just how our industry is made up.

So it doesn't necessarily have to be engineering by a big company but sometimes a bigger company can help in that process. But there are a number of companies out there, small companies that have developed some really good, reliable products. So it's not always the case that it has got to the big boys."

These accounts show that end users may be more cautious about using technical innovation from SMEs but not necessarily because of the size of the company but probably due to concern about reliability of technology. However, it is impossible to completely discount the notion that engineers and managers may feel more secure to use technology from established and larger companies because there is lower personal cost in the event of failure.

The role of self interest is a common theme across these responses. The engineers and managers may be genuinely interested in new technology but making a commitment to risk the known for the unknown is difficult to justify to themselves and their peers. Most of the concerns about new technology relate to fear of unmet expectations and consequences for production targets and by extension the financial performance of the company. However risk is just one of many factors in the technical innovation construction process. What is clear from these responses is that end users have no systematic means of quantifying, estimating or relating to the inherent risks associated with new technology other than through experience. Therefore, it may be possible for technology entrepreneurs to help end users understand the risk envelope of the technology better, but to be effective, they also need to have a good understanding of the other factors that end users are concerned about. Since experience will be varied, individual understandings of a problem and expectations of how it can be solved will likely follow different paths of interpretations.

6.5 Barriers against Technical Innovation Emergence

In this section, respondents' accounts of other impediments to new technology development in the UK oil and gas industry will be presented. Referring to chapter 3 of this thesis, human action is intimately bound to and intertwined with the context of action. In the process of technical innovation construction, the context can be empowering or disabling depending on the human and non-human entities present. Barriers to innovation form part of the context of technical innovation, therefore, the process should and cannot be studied without exploring how these barriers shape the context of new technology development.

The barriers that are presented in this section from research respondents reflect the varied experiences of the players, the power they have within the process and the outcome they seek. The barriers to be discussed will include influence and impact of regulatory environment, influence of financial and operating environment, influence of social roles, influence of peers, prior experience, access to test well among others.

6.5.1 Regulatory Environment

One of the themes that emerged from the data is the difference in attitude to new technology between Norway and the UK. The two countries prospect for hydrocarbon in the North Sea but anecdotal evidence points to a greater commitment to technical innovation in Norway than it is the case in the UK sector of the North Sea. Entrepreneurs and managers within the oil companies put the difference down to insufficient government support for technology in the UK. In exploring this perceived difference, it is important to establish why that could be the case and if the contextual conditions are similar to justify a fair comparison.

Kerry, an operations manager for one of Maersk Oil's North Sea assets, argued that the UK government does not understand the industry. In his view, this lack of understanding is reflected in the attitude to taxation and insufficient support for new technology.

> *"it probably goes back to the government itself doesn't understand the fragility of the oil and gas industry. …they don't understand what the industry is like.*
>
> *They end up taxing it but don't realise, it's not like farming or fishing where people can't leave because the resource is there, all that happens is now West Africa and elsewhere. …it would take 2 years probably for Aberdeen to become a ghost town if they ended up adding another 10% on the Corporate Tax, because the industry would just move out. So I think there's a lack of understanding at the top of government of what the oil industry is, and hence the reinvestment side of things to make things cheaper actually it's a bit like trying to solve world poverty [laughter] than to get the government to understand what's involved."*

Kerry's argument about the global nature of the industry and the ease with which industry actors can move investments around the world is a valid case but Gary, previously of DBERR and now Red Spider Technology, challenged this view. Gary's view is that while oil companies may demonstrate a greater commitment to technology in Norway, it is not out of altruistic motives and the contexts are totally different. He argued that

> *"I also know that if you look at Statoil and Hydro, their recovery rates matching what their government wants is sort of 65 – 70% recovery rate. Now I know that requirement isn't there on the UK side. You can also say, why is that? In Norway, if you win a license to own a block, you must do R&D. It's enshrined in there, you must do R&D. So it's not necessarily too surprising that companies do R&D because they wouldn't get the block otherwise. So it's part of the contract."*

Also in Norway, the government is a major shareholder in the assets. It is also the case that oil companies in Norway pay considerably higher level of tax compared to their counterparts in the UK. Therefore, it is an unfair criticism of the UK regime to demand same level of government support for what are in essence private businesses, the oil companies, without a change in taxation.

John of DBERR also agrees with Gary's view of about the contextual differences between Norway and the UK and made the case around taxation, saying

> *"We have got a different system. First of all, in the UK, most companies in the UK pay 50% tax, in Norway they pay 79% tax. To fund technology that means the government take 79% of the risk. That's good from that point of view. Oil companies in the UK will not want to pay 79% tax. It's okay for them to point to 79% tax relief for new technology but they will not vote or accept to pay 79% tax in the UK. That's an unfair comparison because that's cherry picking saying we like this bit and we don't like that bit."*

> *"I think there is government support, financial support. We in government help set up ITF and we are still very supportive of ITF. To support technology development in the industry, we have a range of technical specialists. We do understand the technology challenges, however what we do have to accept is the risk. We don't have a national oil company in the UK so any financial risk has to be fully borne by the companies. And it is something we have to respect because we can't force companies to do something except they can see that it has got an economic benefit"*

It is not only managers within the oil companies who make the point about inadequate resourcing for new technology, entrepreneurs also complain about the difficulties of aggregating resources to develop new technology. The government has put in place a number of schemes to help relieve financial pressure on SMEs but as Gary argued, existing schemes are undersubscribed.

> *"I lobbied to get more funding etc. Taxes is always the one that comes up. There is R&D tax credit. I remember looking at in great detail at the Scottish Executive overlapping program whether you were a business that was growing, how big you were, where you were, whether you were into export and things overlap to give a continuity of support to help your business grow. A lot of it is there. The reality is some of the forms are very hard to fill up. They can get very bureaucratic atimes. I remember the funding we have from our office directly, people said it is incredibly easy to deal with you people, you do it, you tell us and we do it, that's it.*
>
> *Again as soon as you are dealing a public purse there is a responsibility to the public. You have to put appropriate checks in place. That would be right. I certainly wouldn't want people handing out money without taking due care but at the same time, it's getting the balance right as well. Because certain companies, if they had too many difficult hurdles to go through, it's very hard to succeed.*
> *At the same time, when all these funding exist, it's put in place and there's poor take up, then where is the argument that the funding isn't available. I mean the funding is there, it should always be oversubscribed. If it's oversubscribed, you have a case to ask for more. If it's undersubscribed, well were you really serious in the first place? I used that example of we need more money and then it went to we don't have enough people."*

If technology developers see access to financial help as a concern and there are existing schemes funded out of the public purse that are undersubscribed, it may suggests that there is a communication and awareness gap surrounding these schemes. The larger issue of regulatory influence deserve closer examination. Some of the companies operate both in Norway and the UK sectors of the North sea but these anecdotes point to different behaviours in different context even when the challenges and the need for innovation is similar.

6.5.2 Financial and Operating Environment

6.5.2.1 Financial Challenges

In the views of technology entrepreneurs, the challenge of access to funding by SMEs handicap new technology development. Entrepreneurs have limited avenues for funding for technology. From the data, the common sources of funding for new technology development are company's own resources, funding from the customer or potential customer(s), approaching VCs, banks or investment companies and from public sources through different government agencies.

Andy, recalling his days at Petroleum Engineering Services (PES) said that what *"**we did is we took a very, very large piece of that profitability and we ploughed it back into R and D**"*. This act of subsidising in part or wholly funding new technology development was a recurring theme from technology developers. Companies or technology developers with insufficient resources may be discouraged from embarking on process of new technology development because the resource hurdle is too steep. Subsiding new technology development for these small companies is a survival strategy based on experience as Harry, the founder of Caledus explained

> *"we've got this thing we call the three Rs which is reputation, relationship and revenue. And the other products help us to generate revenue that offsets the cost of developing technologies and to a degree that derisks that development because as we have discovered and I'm sure many companies before us… things usually take longer than you think they're going to take. They usually cost more than you think they're going to cost and… they are more complex than you think they're going to be. So if you add all that together it takes longer and costs more than you think it's going to cost. And if you weren't aware of that at the outset, if you haven't got any other business stream to start… offset some of that risk you can find yourself in a pretty deep commercial hole pretty quickly."*

Getting funding from the bank is also difficult because the lending criteria is unsuitable for companies trying to develop new technology but do not yet have the customer base to be able to demonstrate commercial viability. Technology developers need user acceptance to be able to demonstrate financial viability but cannot access funding unless they show that the company or new technology can be financially viable. Ben, a lending manager with the Bank of Scotland described the lending considerations as follows

> *"The way we look at it is that we have to do significantly due diligence primarily around the commercial aspect, we would class as market due diligence. You know, does this product meet a need and are there sufficient clients out there to meet the financial projections that are being put in front of us? And on that basis, it's vitally important that we can get somebody independent to tell us that this is a product that not only meets a need in the market but it will also meet those revenue aspirations. As I said that's a test of viability that there are clients willing to buy it. Even then, unless they have a confirmed order or something, then it's still just in the potential bracket, it's not proven anything at that time. Somebody can produce something clever that can do a job it is not necessarily cash generating business at that point in time. So it's very difficult to raise bank debt from the outset.*
>
> *I guess the key thing is differentiating between what we class as debt risk and equity risk. The key differentiator there is I suppose is if it's equity risk, we are still in a higher risk situation there where the bank is not comfortable with either the viability of the proposal or ability to generate cash flow or the safety behind the proposal. That is if the viability fails, are the assets worth anything to anybody else? And if we can't be comfortable with the viability or the safety then to banks that will be an equity risk. …a bank will not fund something that seen as equity risk generally although being said, if someone is willing to commit significant equity then in certain situations the bank will be able to come in. For a pure start up, it is very difficult to raise bank debt because it's not commercially proven, it's not generating any positive cash flow at that point in time. That's the key hindrance to most company trying to raise money, proving viability and that it's something that's going to work."*

The account above makes clear that most technical innovation will likely not qualify to access funding from a bank. Approaching VCs or investment companies also comes with its own challenges. Raising finance from investors is also be challenging because of perceived risk for which investors demand adequate return in the event of success, leading to significant equity dilution for technology developers. Ian laid out some of the considerations an investing company like Simmons & Company would consider in the following account

> *"we don't feel we're well positioned to make money raising a million or two million pounds for a company because the economics are relatively small. You know the amount of work required is substantial. There's not much capacity to pay financing fees. So there … you know, we do look at materiality as one first test.*

But obviously the most important thing is a judgement on the quality of the opportunity. So if something's very early stage, you know, we would tend to guard against it. … we tend to get involved in financing businesses that already have proven the concept, have almost certainly already built a prototype or prototypes, have almost certainly started commercialization.

And we're probably best at getting people … matching companies with investors in order to commercialise the technology, you know, build the business on the back of something that's already proven.

we will make an assessment of the technical merits of anything that's proposed to us. … judgement call is you know, how disruptive is the technology going to be to the industry? How material an effect will it have? You know is the value proposition to the industry very significant or not or marginal? You know I think you're looking for something that makes a huge difference. You're looking at the quality of the people, obviously, is critical.

The barriers to entry, you know, if something, you know, is a new concept protectable? Because if it's not then, you know, it's unlikely to be an attractive investment for somebody. So intellectual property and other related values are absolutely critical for us"

In the accounts given by Ben and Ian we see the challenges of raising funding for new technology. While the bank want something that is already at the cusp of commercialization, the investors are often looking to the technology entrepreneur to have at least develop a prototype, have a proven concept that can then be commercialized. To the VCs or investment companies, the real challenge is finding a competent team they believe has the experience to manage technology development process. Ian, the managing director of Simmons & Company in Aberdeen argued that

"I think capital is always cited as the biggest obstacle. So companies that will tell you that their biggest obstacle is cash. Investors will tell you that there's plenty of cash, not enough good ideas and not enough good people. … I would probably say that the biggest barrier is actually getting the right teams together where you can combine great engineers with people that have a … understand the commercial risks and challenges of a business and can put the right controls in place to, you know, to protect investor interests. And make sure that, you know, people who take equity risks, have a reasonable chance of making a return

... there probably are too few people of high quality and I'm talking about technology entrepreneurial side of things. You know there are probably too few high quality people prepared to get involved in technology businesses ... higher risk business opportunities. And I suspect it's because the majority of the good people are working away happily in the oil industry, you know, for Shell or for Halliburton. And prising these people away is hard. They just haven't been brought up; their background is not one where they've ever thought hard about taking risks.

You know we've had situations in the past where we've met very good quality people from big companies who tell us that they're interested in setting up a business or becoming part of a management team. But when you sit down and talk about it they can't understand that they have to surrender their Shell pension, you know that they have to invest a lot of money, that they, you know ... I think people often just struggle with the real risk attached to these ventures and many people are not prepared to do it"

Ian of Simmons & Company also pointed out that *"**equity investors who want to take those risks look for very big returns. So they tend to be selective. And if they do put their money into something they want, you know, a big equity stake.**"* This can be a barrier if and where technology entrepreneur may want to give away as much of his company as the investors are demanding.

The other source of funding for new technology is from the oil companies who are the end users. The examples from the field data show that oil companies will fund new technology development for a particular need they have identified. Harry of Caledus gave an example of this type of funding based on application specific case

"*We developed a new tool, an individual widget or gizmo. Not a system like Slimwell is but an individual piece of technology in 2006 for Chevron here in the North Sea... it's a down hole swivel tool and it's for installing sand control screens. So the operator was installing the screens already and he had a solution and he had a way of doing it but it was more time consuming and more costly than he would have would have liked and he approached us to ask us if we could come up with a way of making it more operationally efficient and thereby reduce operating time which reduce operating cost and perhaps at the same time enhance safety by having a single operation rather than a multiple operation. ... we took that problem and we brainstormed it within our own organisation. We came up with a concept. Before we went back with that concept to the Chevron engineers that approached us ... we guestimated that the same issue would exist within other operators in other environments trying to achieve the same thing. So we believe that there was a market for that technology once it* *was developed. We would probably have decided to do it for Chevron and Chevron alone if it was only a Chevron application because it's one of the things that I mentioned before about the three Rs. It would generate, revenue, reputation and relationships with Chevron. So from that perspective it would have been worth doing anyway. Coupled with the fact that, you know, through a little bit of diligence and questioning of other people within industry we estimated that there was a market for this. We sought a modest amount of investment from Chevron to develop the tools and test them."*

An additional challenge for technology entrepreneurs approaching banks or VCs for funding is the issue of business plan. Fund providers require a business plan to allow them make a judgment about the viability of the business. Asked about the role of business plan and likely effect on venture performance, Ian of Simmons & Company said

"I think that there is a correlation. I don't know how strong the correlation is. It's, you know, it's not a perfect correlation, put it that way. It's probably a strong correlation. … I think I've learned don't be taken in by something that on the face of it looks, you know, a beautifully presented business plan, you know, because the substance may not be there. So, you know, it's part of the assessment. I think that the ability for the management team to articulate their business strategy is very important."

Although Ian makes a strong case for the role of the business plan in assessing the quality of a business and forming part of the mosaic of factors considered by the investor, Ben of Bank of Scotland gave a mixed assessment of the importance of the business plan when he said

"We've seen some appalling business plans coming in and the companies have been absolutely roaring successes. Whether that's just by luck or that they are not just good at preparing business plans I don't know. Generally, a well prepared and well thought out business plan gives you more comfort that these people have done their homework, have done their research, the due diligence, they've prepared thoroughly.

Now, generally they would not have prepared the business plan themselves. They would have gone out to an independent consultant who will take all the thoughts and the great ideas and the thinking that the entrepreneurial team would have and condense it and put into a bank or an investor friendly format. You get and it's nice and easily digestible document. A good business plan doesn't necessarily make a good business and vice versa. Most businesses that are professional and thorough will want to provide a thorough and professional document to allow you to make an informed decision on their *business. Just because it is a nice business plan doesn't necessarily mean it's a nice business and something we would want to back."*

These accounts demonstrate the challenge of aggregating resources to develop new technology for the oil industry. While it may be easier to get funding for technology development where the customer initiates the process, products designed to solve problems that is not of immediate concern to the end users face tough hurdles to gather resources. As the account of technology entrepreneurs demonstrate here, in such cases, companies often have to rely on their internal resources to develop technology.

6.5.2.2 Operational Challenges

New technology is developed to address known challenges and meet a clear need. The data shows that in a lot of cases technology entrepreneurs develop new technology that are either inadequate or incapable to cope with the operating conditions when deployed in the field. This mismatch between expectations and actual benefits of new technology makes end users less enthusiastic and suspicious of claims about new technology. Kerry provided an example to demonstrate the mismatch between expectation and actual performance delivered by a new technology when installed offshore

"a good example there we put on a, a Netcon unit on Gryphon, which is a system for further polishing oil and water, and we probably spent about £2 million putting that on there, and the reason we're looking, it was for final polishing to get less than a 30 ppm. And unfortunately it's failed abysmally, and we're still struggling to try and get this to work and it would be considered leading edge technology, but the impression you get is it's just not been developed sufficiently."

A performance such as the one described by Kerry lead to disappointments and raises the bar of suspicion and caution that another new technology will have to overcome in the future dealing with the same end users. Kerry vocalizes this point when he said

"I'm just thinking about issues when you've got new technology coming forward, the people that bring it forward, it's probably there. … I can speak from the point of view of having, probably never having, I think, had an original idea in my life so therefore I envy these people that have these

original ideas, but they've got the one big break, that they've come up with an idea and you sit down and, and talk to them, ... and they end up being so focused in on their idea and not understanding the issues of how you've got to apply it, and the almost incredulity that they have that why you wouldn't you, can't see the advantage that they're coming forward with. ... they're so wrapped up in themselves, they almost don't realise that there needs to be an economic eye on it."

Technology entrepreneurs set out to develop new technology that can earn their place in the market place, therefore it is inconceivable that any technology developer would have embarked on a process of developing a product that is not fit for purpose. The question then is how and why do technologies get developed that is not fit for purpose? Ian of Simmons & Company located the source of this mismatch in the occasional disposition of technology developed being consumed by pursuit of a technological solution without due consideration for market and operational conditions. Ian presented his explanation as follows

"I suspect there's also an element in there within smaller companies which is that engineers like to innovate. ... And quite often you find companies are set up by engineers that maybe don't have a lot of commercial experience but they just feel they'd like to develop the next solution."

Another explanation could be that technology entrepreneurs do not fully understand the operating conditions under which technology would be used. The explanation of poor understanding arising from a communication gap between end users and technology developers point to how the critical part social interactions play in the construction of innovation. Gary recalling his experience from his days in DBERR provided an anecdote to make the case

"I remember a company I think had a failure I remember but that's because it hadn't been told about the environment properly and it was something in the fluid which they didn't know. So what I am saying is that it can be really innocent both ways on that. We told you there was this problem but did you mention this? Why, is that important? Yes, do you actually know that might effect on this and this. So it can be very innocent on both sides, lack of knowledge."

It is important to understand the role of individual and organisational memory in the decision making about innovation. Since engineers and managers have to work in concert with peers, bad experiences from the past can be amplified drowning out potential of new technical innovation. Therefore the language of discourse that technology entrepreneurs employ must recognise bad experiences from the past and make claims about new technology that end users find credible and can relate to. As already demonstrated, it is easier if technology developers have information to convince potential end users that lessons have been learnt from failures of the past or that the technology works in a way that makes it impossible for such a failure to re-occur. Technology entrepreneurs can only engage at this level of discourse if they have access to relevant information and knowledge from the past and about the present.

This shows that how technology developers access critical information to understand the conditions under which their technologies could be used is a critical aspect of the technical innovation process. This aspect of social interaction, if not handled properly, can grow into a major impediment against new technology acceptance. Since new technology can be developed either jointly with end user or separately away from users, how technology entrepreneurs handle this aspect of innovation construction will be explored to understand the social dimensions of the process of technical innovation emergence.

6.5.3 Timing of Developing New Technology

One of themes that emerged from the data relate to the timing of new technology development. Oil and gas are commodities traded globally; consequently, the macroeconomic environment has a direct bearing on the operations within the industry. Timing of innovation is not just about the oil price which necessarily influences the choices engineers make, it is also about whether the industry and end users are ready fof the technology.

Ian of Simmons & Company argued that innovation can be sometimes be misdirected arising from the propensity of engineers for attempting innovation for innovation sake. He said *"quite often that innovation can be misdirected and ... it's born out of engineers being engineers ... you know people probably do not understand how long it takes to get technology to market. So, you know, trying to solve a problem today that doesn't need to be solved for 30 years."*

Eric of the ITF sees a lot of technology proposals and observed that innovations can be before their time; technology developer can develop a technology that is not needed in the present. Although the ideas may be very innovative, without a need, development cannot take place, and even if it is developed, it is unlikely to be successful. Eric described the challenge of timing as follows

"I think the technologies that get deployed are the ones that are needed and that's the fundamental basis, I think. There's got to be a need and certainly in the mature province of the North Sea for example, we've got a situation there where the important driving issue I suppose is that you are trying to maximise the reserves that you've got. You are trying to get the most out of that resource that's there. … And so if a technology comes along that allows them to do that, and hit their bottom line, then that's going to have priority, definitely. If someone is coming along with a technology that is not proven or doesn't really fit into that need, then it's difficult and I would suggest that technologists [developers] that are complaining about that are probably not hitting the right mark.

We see some wonderful technologies coming through us which our members don't support. We sometimes fail to understand why they are not supporting it but they don't support it. Probably because it's too long a term or does not fit into immediate need. Sometimes they will pick on some issues and develop it but ... it's a question of priority and focus in terms of what the operators have and what technologies they will support. … We see some wonderful ideas but they may be ten to fifteen years away before they can go into fruition, and that sometimes may be too long for their priorities. Wonderful ideas, wonderful projects"

It is not uncommon that there can be a mismatch between what a technology entrepreneur thinks the market need and what actual users need. Experience about how to solve particular problems must be supported by some means of verifying user needs to avoid expensive mistakes. Recalling an instance where technology has been developed that failed to meet users' acceptance, Alastair said

"There's got to be a need. There's got to be a need, and I have made this mistake and RedSpiders have done it where we identify a tool, it's a great tool but so far only one has been run. The tool is still on the shelf, never ran. Okay we got the money from the tool we sold, we got our money back

but that's not what we are about. That's an example, it was a tool we even identified before we even started the company, we did the injection valve which was a great success. This is an example of one where I thought there was a huge market and there's not. The clients don't want it, we don't need it. So you can get it wrong."

Where there is established market need, the macroeconomic environment may still influence attitudes and priorities of end users. John of DBERR was of the view that in a low oil price, oil companies are likely to be more risk averse and therefore avoid new technology saying

"I think there is the culture in the UK which you can describe as risk averse but I think we have an opportunity to change … In the space of ten years, we have come from oil under $20/bbl to $40/bbl [interview conducted in 24 July 2008]. I can see and understand that in the low oil price, risk is important."

However technology entrepreneurs take the opposite view arguing that oil companies are likely to investigate and consider seriously the use of new technology when oil price is low. Harry of Caledus said

"in a high commodity market it's not necessarily the best environment for developing new technology because people are perhaps more interested in drilling and completing wells based on conventional technologies as promptly as they can to get a return on the investment that they're making in drilling and completing those wells.

So I think an environment of low cost and relatively low, lower commodity cost and lower activity are probably better conditions for entrepreneurs … to be able to get them into the market place because in low commodity prices people are interested in reducing well construction costs more.

if the question about an environment that's more conducive to developing and implementing and getting success with the technology then I think probably lower commodity prices and lower activity in my view makes it easier… I think that if you could time it right, you know that you start to develop your technologies on a high so that when it's ready to be there for the low you then drive, you ride the crest of the increase in activity."

In responding to a question of when is the best time to develop new technology, Alastair of Red Spider agrees with Harry because he argued that

"It's a funny thing. People think high oil price is good for everyone. Right now the oil price is too high for Red Spider. When the oil price is high, we found this at PES, when we worked at PES. PES were often busiest when the oil price is low. Reason being when the oil price is low people are looking for fixes because they can't afford the higher rate, they are looking for fixes because they can't afford to work the well over. Wells all of a sudden become marginal like TTRD [Thru-Tubing Rotary Drilling. If the oil price is too high there is a line, you cross it, shit we can just drill a new well. … Small companies developing technologies I think fall into that category very similar to TTRD, there is a line and you cross that line, the standard widgets because normally what we are selling are widgets, yes they would save time, yes they would add value and this type of thing, but who cares it's $100/bbl.

However, when it's low oil price and all these guys are sweating because their jobs are under threat, then they start trying to get their bosses' eyes and say guess what guys, I have chat with Red Spider and they've a tool that I think we take a bit of cost and risks out of our operations. I am seeing the oil price come down and I am saying brilliant."

From the foregoing, the need determines whether timing for technology development is right or not. We see from Harry's comments under what conditions Schumpeter's creative destruction come alive in the oil and gas industry. In a depressed oil price environment, price and profit pressures force engineers and managers to think of new ways of doing things and give impetus to innovation construction. If a new technology meets the needs of end users then the timing should be right. Ben of Bank of Scotland agrees with this assessment when he said

"I guess the key thing is that there is a market for something. Now, as I mentioned earlier, certain products come out that nobody expected or has even envisaged that they can create a market. I guess they are probably in the minority. Most products are developed to service a requirement or to meet a need in the market. It is right that a product is developed not because somebody thinks it is clever or appeals to them, they have to be working on something that's going to meet a need and somebody wants to use.

So that's the right time to make something but without the blue sky thinkers out there we wouldn't have the internet, we wouldn't have iPod, we wouldn't have cars. But yes, I think is knowing that money is scarce and it would have to be used appropriately."

This response from Ben encapsulates an interesting aspect of technical innovation construction in the oil industry. If it easier that innovation will succeed where there is end users' input or accept technology they can understand and relate to, how can radical innovation be developed in the industry?

6.5.4 Lack of or Insufficient Credibility with Critical Stakeholders

The social standing of a technology developer, proxy for successful entrepreneurship, is very important in aggregating resources for technology development. From the data, it is easier for someone with a history of success to get support of investors for new technology or be taken more seriously by end-users. Ian of Simmons & Company gave his views on the value of track record in saying that

> *"... we will always look at people's track record and I think if somebody's track record is poor, you know that, that's usually a good sign for us that maybe not a project to spend time on. You know? ... it's back to my point earlier on, don't convince yourselves, you know, don't convince yourself this time will be different. You know the truth is if somebody's failed in business once or twice before, you know he may well fail again. ... there's a caveat ... if somebody has had a business failure, you know, we don't hold that against them because there are lots of reasons why people fail in business ... but you have to just step back and take a view and ask. You know, we form a view on the people. We form our own view on the people. We don't just rely on references, good or bad"*

It is not only investors who are likely to view technology entrepreneurs differently depending on their credibility and social standing. End users of technology are also influenced by past dealings with individuals and/or companies in forming a view about new technology. In recognition of this, technology entrepreneurs like Harry of Caledus work hard to develop a stock of capital with end users. He explained that

> *"As a technology developing company, particularly a new one you need to develop relationships with customers and a reputation of reliability."*

Lack of social standing with critical stakeholders may hamper ability to secure funding for technology development or have access to important decision makers who can decide whether to run a new technology. Earlier the role of experience as an asset that can be leveraged or traded was discussed; experience also increases credibility with end users

6.5.5 Organisational and Social Roles

All the participants in the process of technical innovation construction work within organizations or have to interact with organizations to engage in new technology development activities. Aside from the influence of institutions they work in, it is useful to explore the influence of the roles they occupy and the expectations of those roles on the process of new technology development.

Within the oil companies, research respondents identified budgets and performance targets as impediments to innovation. The budget is set in advance with little room for middle level managers to exercise initiative. In the same way, performance targets are set by senior management and the focus of middle managers is to achieve these targets. There is little room for speculative engagement that may improve performance and the career and social sanctions for failure to meet targets discourages any risk taking.

Kerry, an asset manager described a scenario of how budgetary constraint influences how managers make decision about new technology with potential to reduce oil in water from the Gryphon FPSO in the following words

> *"if we could guarantee that you could move the oil and water from 40 parts rolling down to 30, we know we can put it over this, let the water over the side then, we know what we have 17 tons oil allowance to put over the side in a year. So that means about 15,000 barrels of water, with that 15,000 barrels of water extra available to be produced, that brings with it an extra 4,000 barrels of oil. From that you can then work out what the impact would be, and normally you'd be looking at something in the region of, almost within your sort of budgetary, you wouldn't want to spend anything more than, a few hundred thousand at least to evaluate it. And then you could do a cost benefit."*

The effect of budgetary constraint can be seen in the ways assets put their future development plans together because they realise that projects are ranked on a global basis. The use of new technology may increase uncertainty of delivery which must be reflected in probabilistic cost estimates for projects and put otherwise good projects at a disadvantage. Mark as a subsurface manager acknowledged this dilemma in saying

> *"you're adding cost to your project proposals which you know, as they're stacked up against other things in the world, perhaps don't look as attractive. So you're competing for investment all the time."*

Interestingly within the same organization, Peter, an exploration manager argued that the budgetary process can be flexible provided the manager is willing to make a business case for what is needed. His view demonstrates the role of an internal champion for new technology to use existing structural features of the organization to pursue innovation if required. He argued that

> *"... there is flexibility, it may be peculiar to this office I am not sure, but we have as part of my budget funds I can pay for the development of something that may be of benefit. I think it is very much down to the provider to give a strong business case why we should provide those funds."*

Kerry also identified previous oil price crisis as a factor in the way organization respond to challenges and the way they approach cost management. In his view, some of the senior manager in the industry still remembers the oil price crash of the 1980s which led to the formation of cost reduction in the era (CRINE) initiative. Kerry said

> *"there was also CRINE (cost reduction in the new era) I think it has done more harm than it ever did good, ... cost reduction and new era, and what you've now got is you've got managers in very senior positions in an organisation who are junior or mid-level managers at point, and they still apply that same approach to their business now."*

> *"we live on by the Shareholders, and we live on a quarter-by-quarter, year-by-year basis, and if a long term investment doesn't gain Shareholder credibility, because they're looking at how do you made your volumes this month or next month, and therefore the loss of focus in your daily volumes would impact the company immediately."*

While managers within the oil companies describe different structural features as barriers to technical innovation uptake, technology entrepreneurs see things differently. Technology entrepreneurs see access to decision makers, the ones with the power to sanction whether a new technology gets used, as one of their main challenges. Andy identified the separation of technical, financial and strategic decisions as a problem when he said

> *"one of the big problems inside an oil company again is that people who are making technical decisions are not the same people who are making financial decisions, who are not the same people who are making strategic decisions"*

The point Andy makes is important because people in different roles – technical, financial and strategic – are likely to see things differently which makes decision making about technical innovation difficult. Another technology entrepreneur came up with a similar observation about the importance of having access to engineers within the oil companies and also the speed of decision making.

> *"an individual will say to me, you know you should be speaking to someone very senior in our organisation that has got access to the funding to bring this about because it's got the potential to revolutionise the way that we drill wells and I say to that individual do you know who that is. And within his own company often he doesn't, so how am I expected to know?*
>
> *... I think one of the difficulties is that the pace at which the operator is prepared to or can move in the development of these technologies can often be too slow for the developer to be able to survive the journey before it becomes commercial."*

Alastair of Red Spider Technology identified the role of consultants within the oil companies as part of the barriers to new technology. In his view, consultants who are supposedly hired because of their expertise and experience and expected to bring new ideas into the organization are the greatest stumbling block to innovation. He made this point by painting a hypothetical picture as follows

> *"So I think that's a problem that the industry has got. It's that they are risk-averse and there are reasons why they are risk averse. There is no encouragement for, there is nothing in it for them. All*

they can do is lose their job. If they save the job and save thirty days, they will turn around and say that's why you are paying the guy £600 a day. That's what we are playing for. So there's nothing in for him, he's not going to get a percentage of the money, the $10million he saved. What he can do is sign his own death warrant by taking risk with new technology. Certainly in the UK, that's a big stumbling block."

Managers are judged against tight financial targets but the drive for continuous cost efficiency is driven in part by the external environment. Most of the oil companies are global publicly traded companies who also have to answer to shareholders. The external pressure to meet production targets and deliver credible earnings for investors feed through into how managers at the asset level look at decisions between short and long term, between status quo and a gamble on innovation. Also, if operators do not reward and encourage their employees to take risk with new technology then there is very little incentive for individuals to risk personal financial reward to repeating existing practices and using proven tools to meet day-to-day operational challenges even if results are less than efficient.

6.6 Risks Associated with New Technology

The oil industry by its very nature exists and progresses by dealing with uncertainty, searching for hydrocarbons in difficult and challenging environments without any guarantee of success. Through the decades, the industry have moved from land drilling to offshore, deepwater, high pressure high temperature (HPHT), extreme HPHT, extreme deepwater amongst other frontiers. The progress of the industry could not have been possible without the progress of technology and relentless pursuit of innovation. Yet paradoxically, this is an industry that, even by the admission of people who work in it, is risk averse.

From the data gathered from respondents, risk is a recurring theme. In a purely technical sense, respondents use the word 'risk' loosely and some of the circumstances where they have invoked the concept of risk can probably be better described by uncertainty. Aside from the preciseness of language, what is clear is that use of new technology will always be associated with risks. To be able to understand the process of technical innovation construction, it is important to explore the nature of risks that process participants have to contend with when making decisions about new technology.

As end users, managers and engineers are the ultimate arbiter if a new technology succeeds or fails. Consequently, this section begins the exploration of risks associated with new technology by looking at the views of the end users. The recurring theme from end users' perspective relate to failure of new technology to meet the need of the users. Peter gave an example of how failure impacted on the fortune of a promising technology

> *"I think so much technology is applicable in certain circumstances and an early failure can critically damage the view of that technology. A good example I think is seabed Seismic which not only is extremely expensive but has, I think was oversold early on so that it's now seen as applicable only to very certain problems. It's still very expensive. So that is a major problem. Yes so I think early failure can certainly on large expense projects can critically damage the view of that technology."*

The reason why fear of failure or unmet expectations cast a constant shadow on any decision about new technology is that the consequence of failure is significant in monetary terms. The concerns about new technology not working and potential consequences for meeting targets be it well Authorisation for Expenditure (AFE) or production can be significant, even catastrophic given the amount of money at stake. Mark, talking about use of open hole completion technology, describes how concerns about possible failure share attitude to the technology and influence decision making as follows

> *"You know that would suddenly solve the problem of being stuck and we would be able to just carry on with what we were doing. It's the technology, it's the application of a technique. The risks, the consequential risks of it not working are just, were just too high. And then if you lose the well, yeah, and you lose the production from the field, it's just a consequence that you couldn't live with and you'd forced to come back and do something else. So there's a reluctance to go straight into those kind of decisions and implement that kind of thing without more evaluation. Having said that, you know there are a number of places in the world that have used barefoot completions in the world, it's not that new technology."*

It is clear from these responses that end users are only concerned about new technology risks insofar as to evaluate the chances and consequence of failure. This response underlines how individuals or groups react to potential gains and losses. At the planning stage with maximum expectation of gains, engineers are reluctant to take risks and more comfortable with proven technique, tools and practices. However, after committing significant resources in the pursuit of a goal or project, if existing technologies or practices cannot deliver desired results, then it is easier for engineers to consider innovation to rescue the project and ensure investments already made is not lost.

Engineers and managers commit to new practices and decide on new technology with the constant fear of failure. Risks associated with new technology are presented in different forms by other actors in different roles. Earlier in this chapter, Harry identified the risk that new technology (a) takes longer than planned, (b) cost more than anticipated to develop initially and (c) more complex that earlier thought.

External parties that can provide funds also assess new technology risks based on different interest. While end users are mainly concerned about performance of the technology, fund providers looks at the likely commerciality or materiality of the proposal. As earlier discussed, some of the judgment about risks of new technology from the oil companies is mainly subjective, it is also the case that some of the judgment of the investment community is subjective. Ian identified the type of risks that will be of interest to a company like Simmons & Company saying

> *"We will discuss with the management team and internally we're going to form a view around, the risk of competition, you know, the risk of market adoption. The technical performance risk"*.

He went on to described the process they use as follows

> *"the process we go through is, you know, it's a series of fairly subjective judgements rather than hard objective analytic work. ...it's easy to, I guess, over-analyse something that's at a very early stage of development. ... But, I mean, fundamentally we're looking at ... you know the market size, ... we'll look closely at accessible market. How big could the business be if the product is successful? ... It*

seems to me that customers are much more willing to try a new solution to intervene in an existing well than they might be to try a new solution for a Greenfield completion.

Everyone thinks the oil industry is very conservative and I think, we always say that there's a big queue to be second. You know everybody wants to follow but nobody wants to lead. So I think for us the biggest risk is about forming a judgement on the likelihood of market uptake. … we'll look also at what would be the customer's assessment of this. And where does it fit in the food chain? You know why would a customer be first to use this technology."

The assessment of new technology risks still focuses on the acceptance of the technology but the motivations for supporting or rejecting a new technology are somewhat different from the end users. While the end user may be less concerned about a new technology if he can be reassured that it does not increase the risk of the operation and has a good chance of delivering expected results, the investors need the technology to also meet a commerciality test that will not be possible without significant market uptake.

Andy identified other risks that may also affect new technology development including geological risk, political risk, technical risk, financial or commodity risk stressing the fact that some risks are within the control of technology entrepreneurs while they are at the mercy of other risk. He made the case as follows

"There's risks that were within your control and risks without your control. Risks that are within your control are say something I'm doing in the North Sea UK sector. I can look at the geological risk, I can look at the political risk, I can look at the technical risk, I can look at the financial risk. Let's call that my four key risk factors in a project. I'm comfortable with the technical risk, because that's what I'm supposed to know, or my people are supposed to know. The geological and sub-surface side, again, we have looked at that and, and we should be able to have a feeling or not. The political risk in the situation in the UK is, you know, whilst we have a Chancellor who has doubled tax in the last, sort of, four years, do we think that they're going to nationalise their oil fields, the answer is no. They might tweek the tax and make it unattractive, equally they might actually see that there's been a lack of investment and certainly in areas such as gas, and actually modified the tax to improve the situation. So I don't think there's huge political risk, there's the final thing, of which I have absolutely no control on is commodity risk. You know, if the price of oil or gas drops, then I have to …"

We see from these responses that how individuals look at the different risks depend on which position they operate from in the innovation construction process. The technology entrepreneurs accepts the technical and geological risks but confident that they have the expertise and know-how to handle these risks but concerns about these same risks pushes end users to resist using new technology. Other players like investors are also concerned about technical and performance risks because it is no sufficient for a technology to meet technical needs it must also be successful commercially. To the investors success is to be defined in terms of adoption and more importantly market share. Earlier the position of the bank regarding debt and equity risks make clear that unless the new technology has an order book, then raising bank debt to fund development is not an option. The bank wants to be sure that the technology can generate sufficient revenue to cover the capital lent and interest payments so that they can make their modest returns.

6.6.1 Reasons for Failure of New Technology

Now that we know the risks different process participants identify as part of the innovation construction process. It can be expected that the different players must have worked to eliminate or mitigate these risks as much as possible. Yet we know that innovation is risky and outcome uncertain, therefore, it is of interest in this research to find out from process participants why new technology fails despite the best efforts of those involved in its development and implementation.

Kerry identified a number of factors that may help explain why new technology fails. He identified narrow definition of operating range, inability of technology to adapt to changing conditions, inflexible design, unsuitable or inappropriate design and poor understanding of customer needs. Based on his experience as an operation manager for an FPSO in the North Sea, he said

> *"I think the new technology that comes through tends to always be spawned from a particular idea, one particular idea, and the company, the person that develops it tends to develop it generically, and unfortunately we don't live in a generic world. You're operating at different temperatures and I'm just relaying a discussion I had with this company. I said your system's not working, he says oh, but you*

gave me this spec of how we're operating, I said well that, that was correct at the time I said, but we're now operating here, I says your kit's useless if it can't actually adapt to that. He said oh, but that's not what you said. I said well, you know, get real, this is a real environment we're in... so whatever you, you produce has to make sure it's flexible enough to actually deal with the scenarios.

You've got to really have an envelope that's big enough that the change is actually allowed to happen, whereas what we ended up getting in the recent case, it was a very specific, narrow envelope, and so it's not working, ... the supplier said I know it's not working because you're operating outside the envelope of what it can work in. So [laughter] what's the use of that to me? And that's probably what the issue was, it was looking at too specific [operating window]"

The lack of understanding of requirement described in the quote above probably come from little or no engagement with the end users during the process of development or poor communication or lack of understanding of communicated requirements. The data shows that end users can only take seriously new technology that has the capability to solve their problem as they understand it and suitable for the environment in which it may be deployed. To develop new technology that can satisfy these conditions, it is critical for technology developers to have similar understanding of the problem as the users and deployment environment so that these requirements are fully integrated into the design of the new technology. Kerry finished by stressing the importance of technology entrepreneurs to make an effort to find out from end users what their needs are and under what conditions the technology could be used before committing to a design. Kerry argued that

"you can go and develop this piece of equipment, it's gonna be absolutely no use to us but you can develop it. Whereas this thing here, it would be much better for you to develop, because we know that's the issues that we actually have just now."

Alastair of Red Spider Technology identified designing wrong tools, over committing resources to a technology in the hope of creating a market, misunderstanding of the value proposition especially from the view point of the customer and lack of understanding of oil companies' drivers as possible reasons for new technology failure. He said

"Designing the wrong tool like I said earlier, you can design the sexiest looking paperweight in the world but at the end of the day, it's just going to be paperweight just sitting on the shelf that nobody wants. Over-committing, you are going to sell hundreds of this and you build hundreds and they never move. You've just wiped out your cash, basically destroyed your company because there is no cash flow.

*Understanding what the value proposition is. It's going to the value thing; the whole thing is about value. What is it that the customers are looking for and why? I think that's the biggest mistake people make, is that building the right tool for the wrong reason or vice versa. They think what the client is looking for is a cheap tool. Every time they are looking for discount, they are looking for money off. It's crazy. They may say they are, that's the game they play. … I sat down and listen to a great speech from a senior guy in BP. He said I am fed up of people looking at BP and saying they've screwed us, screwed the profit down, they are trying to play hard ball, looking for discount. He says … "**I'll tell you all right now that we would pay an absolute premium for tools that remove risks from our operations**". Now that's stuck in my head, that is a top guy in BP, Asset manager, we would pay a premium for tools that remove risks from our operations. It's uncertainties and unknown risks that screws the whole thing up. …Taking unknown risks out of the operation, they will pay an absolute premium. That tells all you need to know. You can charge what you want for a tool if it takes risks and uncertainties out of the operation. The TTRD sleeve is a good example. The feedback we got from Statoil, they have junked well on the back of sleeves failing. How much would they be prepared to pay for anything that takes that risk out? … I was speaking to the Statoil guy, you know when they do their risk assessment, damaging downhole jewellery, it's always like run Red Spider's sleeve. That is it rectified. What are we going to do about it? It used to be well we'll get Red Baron, we'll get coiled tubing, we'll get some fishing tools. It's all changed. So if folks are looking at the risk assessment, are we going to do it, are we not? That was a huge thing justifying TTRD and it has taken a huge risk out of the operation."*

The opinion of a BP asset manager, in Alistair's response, is instructive in that it points to the main driver of oil companies when they are looking at new technology. If the oil companies (engineers and managers) are willing to pay a premium price for tools and technology that will remove risks from their operations, how can technology entrepreneurs produce new technology that achieve this goal and persuade the end users to try the technologies? Most of the reasons presented in this section relate to inadequate understanding of the needs of customer, poor appreciation of the operating conditions under which technology will be deployed and poor understanding of the value priorities of the end users. In the next section, there is an exploration of the how technology entrepreneurs access some of the knowledge with the end user organization to be able to avoid some of the issues raised in this section.

6.7 Identifying and Understanding the Needs of the Customer

The accounts of some of the respondents have already shown that it is difficult for technology entrepreneurs to have access to some of the end users, therefore, it may also be difficult to identify their real needs. There are a number of ways through which technology entrepreneurs can access critical information to determine the needs of the end users. From Harry's account presented earlier, this information can be provided to technology entrepreneurs when they are approached directly by the end user with a specific problem to be solved as was the case with Caledus and Chevron. There are also instances when technology entrepreneurs can develop new technology based on their observations and experience.

Alastair, one of the founders of Red Spider Technology, provided an account of one of such instance where a new technology was developed based on observation and experience of the team. Earlier the accounts of respondents point to different sources of ideas for technical innovation with prior experience being one of them. In describing how he used his experience to decide on new technology and ensure that users' needs are incorporated, Alastair said

> *"The first tool we did was a water injection valve. I have been selling them at Halliburton but there have been issues but they [Halliburton, insertion mine] were determined; a valve is a valve and they were not changing it. I says yeah but there are problems but they say, yeah who cares we are selling a bunch of tools. So that was flagged up as a big issue. If we could handle the issues, then there is a big market. So we came up with a design, we played around with the design on paper, fine tuned it. And then we showed it to a couple of people see what their thoughts were, people we trusted, customers. We sought feedbacks from them, is this something you would consider if we were to prove it? We got encouraging feedback, yes it looks great, if it were to work, we'll try it, you know this type of thing."*

In the account from Alastair here, we see the role of experience in identifying a need that existing products and technologies in the market have not been able to meet partly because the provider is unwilling to invest in product improvements or new designs to resolve the inefficiencies. It is instructive to notice that the team started by looking at what is wrong with existing technology and the proceeding to design an alternative. With an alternative design they also consulted likely users to get feedback and inputs into the product design. If these 'trusted' end users will be willing to run such a tool were it to be produced, Red Spider were making sure that minimise the risk of technical and market failure.

To proceed from drawings on paper to building a tool that can be used in the field, Red Spider took a number of proactive steps as Alastair described

> *"When we first brought the injection valve out people said what, you quit Halliburton to do this? It is a commodity. Now you can still sell commodities if it is best bloody commodity on the market and you are prepared to move the bar. We figured Halliburton couldn't move the bar. ... They had a tool that at one time was class leading but they never changed it. They just stayed and treaded water. People's expectations start saying hold on this thing is failing, it's got to be better and keep buying it because there is nobody prepared to move the bar. So we moved the bar, changed it totally and we've now taken the market share in the UK and is now spreading internationally as well.*
>
> *Nobody knows if it's debris friendly. So we had to spend more money and we had a flow loop at QServe and we did a sand slurry test. So we did a full sand slurry test to get data like the pressure drop across the valve, to prove that the valve could handle debris, and then we went to sell it to the first client which was CNR who had tried every valve in the market, everyone of them causing them problems. They had something like twenty failures in one year with injection valves failing. That's twenty unplanned interventions. And we sat down and they reviewed the valve and look at test data and the whole thing. And the question is how do we know this valve is going to work? I say well you don't. All I can show you is who we are, the testing we've done you know, we need a well. One of the engineers said one thing we can guarantee now is that the valves we are running just now, we know none of those work. It can't be any worse. They gave us our first job for injection valve, they ran it in a brand new completion, that was four and half years ago and still in the ground and still working. They have pumped in excess of 50million barrels of water through it, it was tested in January it's still working and they have now standardised now to use our valves in the UK and West Africa. I think they bought something like 40 valves. And they were prepared to take a gamble on new technology."*

Although this product has been a resounding success and demonstrates the importance of end users taking some risk with new technology, Alastair recognized that the break that gave Red Spiders the opportunity was that the Operator had tried everything and they had no alternative. He said

> *"Now the way we got the gamble was evidently everything they tried so far was falling. It would have been an awfully lot harder if they had a valve in the ground that was working. There has to be a reason to change. It's very hard for someone to change for the sake of change because of the cost and hassle factor and a gamble to try something new. But if you can prove that you've done everything you physically can do to test those valves, you can do any more than that."*

Asked about the role of experience in solving technical challenges raised by the end users, Alastair said

> *"Again that comes with experience. It would be very hard to have a graduate engineer straight out of college, very clever guy, he's got done his degree and everything and then an Operator says to him right we've got a problem we want you to come up with a solution. That's hard to come up with something the guy hasn't already thought of himself you know. You are going to tell the guy the obvious, and the guy is going to look and say you think we are stupid we haven't thought of that one. We thought you guys were special."*

While it is not impossible to persuade end users to shift from a technology currently in use to a new one, technology entrepreneurs have to overcome technical and socio-economic obstacles to get end users to abandon the known and proven, even if less efficient for a new, unproven technology no matter how potentially superior it may turn out to be. Significant engagement throughout technology development process may help but more may be needed to convince skeptics within the users' community. In the way Red Spiders have approached the development of some of their products, it is clear that having the wealth of experience inside the company about 'how things work' and 'how things ought to work' has been helpful in designing tools that makes functional tools into excellent tools. The reliance on experience demonstrates that technology entrepreneurs frequently access and select from library of previously successful scripts that can be modified to fit new contexts. Alastair acknowledge this when he said

"… most of our products are stuff we've identified that there's a market or might be an improvement like the injection valve. There's nothing new about the injection valve but if you do it bigger and better, all of a sudden you become number one. Protection Sleeve for TTRD, nothing new in that. There have been sleeves for years but again if you try and listen to the Client to what is important. That's a prime example where Statoil-Hydro really help us … we were probably 80% there but the final 20% took us from a good sleeve to a great sleeve."

The ITF is a body that has been created to be a technology broker for the oil industry. It exists to do help oil companies find the best technology to meet their needs. There is an acknowledgement that engineers and managers within the oil companies do not have the time to scan for new technology but the ITF can do that on their behalf. Eric of the ITF described the process they undertake to understand and communicate need of users to technology developers.

"What we do is we interview or go and talk formally to each of our members on one to one basis about what they perceive as the real challenges they are facing over the coming years in terms of the immediate future and long term future. From that we generate a fairly top level view of what the challenges are. … What we then do is to pull together a number of themes, what we call technology gaps in this area. Once we have identified those themes, we then hold what we call a theme day to which we invite our members and the wider industry who's got a particular interest and experts in that particular area into the room. And we try and engage the industry on a wider subject as well to bring as many experts together as possible. So for example, taking the decommissioning example…

Earlier this year Oil and Gas UK held their own event on decommissioning issues, and on the following day, we held an event, and ITF event which was back to back which drills down into the issues of what is the industry looking for? What are the issues there? What are the challenges they are facing? The output from that day helped us put together the call for proposal that goes out to our network of contacts around the world of developers.

We know there are specific developers, when I talk about developers I mean research institutes and small companies. That goes out and that's on a global scale and also goes to a number of trade associations who have their own membership. So it multiplies out. And we are forever looking for new developers all the time. So that is the process of identifying what the technology needs are and getting to that core"

The process used by the ITF allows the end users and other experts to contribute towards the definition of the problem statement that is then presented to the community of technology developers. By crystallising problem definition and ensuring that different aspects of the problem are made known to technology entrepreneurs and others, the ITF tries to reduce the risk of misunderstanding of customer needs. Throughout this section we have seen that the process of understanding customer needs cannot genuinely happen without social interactions, information exchange and knowledge transfer between technology developers and the end users either directly, indirectly by using members of network to sense check or through an intermediary like the ITF. Talking about how ideas get developed, Harry of Caledus said "***Whether it's an individual within the company or whether it's a group of people is that you've got to do your own diligence by speaking to people***" thereby emphasizing the role of social interactions in refining ideas before committing a lot of resources to development.

People with experience in the industry can be better placed to identify end users needs because they were once end users of technology themselves and can relate to what they would have preferred to use as new technology. This ability to '***think and see as'*** the customer can be a powerful tool at the early stage in defining and setting out a limited number of realistic options that can be refined into potential solutions. Ben of Bank of Scotland identified prior experience as an asset that can help identify new technology when he said

> *"The other side is when somebody comes out with something that genuinely moves the game forward. Generally these are people who have come out of one of the big firms, one of the big service companies or one of the big producers, and has seen the problems they have and have produced something better, more robust, reliable, quiet a lot of cases cheaper and be extremely successful because they've been in there, they know exactly what the end users want again as well and are able to make improvements."*

6.8 Translating Customer Needs to Technical Innovation Solutions

In the previous section we have seen that how the problem that is in need of solution get defined is critical to the innovation construction process. To understand the problem, technology entrepreneurs need experience about how things work and are likely to be more efficient if prior experience allow them to see how things ought to work more quickly. Experience helps technology entrepreneurs to quickly narrow down the range of options likely to lead to a feasible solution. Engineers with more experience are likely to arrive at a feasible solution quicker than less experienced ones in part they have the benefit of the different ways things can fit together within the practices of what is acceptable in the industry. Asked about how they translate customer problems into possible solution Alastair gave the following explanation

> *"What we do is we come back here and often get two or three of the guys together. We'll bounce things around. What you got to remember is that there's only so many things you can do with an oil well you know. It's got round tubing, it's got a packer, it's got safety valve, it's got a landing nipple, it's got a reservoir. It's a bit like the picture in a jigsaw you know. Most of the picture is the same so you just, the pieces might have different shapes but you just put the picture together. Our industry is like that. There's only so many different wells, there's only so many different problems you can get. In over twenty five years we have been involved, it's hard for someone to come up with a problem we haven't been involved with. What we'll do is we'll sit down and consider what we can do and can't do. Try and think of an angle we can come from, try and see how we can add value to the solution."*

Harry describing the process of translating customer needs into a new technology gave the following response

> *"we took that problem and we brainstormed it within our own organisation. We came up with a concept, before we went back to the Chevron engineers that approached us. We asked them to sign a confidentiality agreement. Co-incidental with that we applied for a Patent, we did a Patent Application because … we guestimated that the same issue would exist within other operators in other environments trying to achieve the same thing. So we believe that there was a market for that technology once it was developed. … we sought a modest amount of investment from Chevron to develop the tools and test them, and that's two fold. One so that it wasn't Caledus money, you know, having to go into that development which is money that we could have spent elsewhere. The*

other reason for trying accessing the money directly from the operators that once he's invested he's more like to use because somebody internally would say well why have we invested a sum of money in this if we had no intention of trying or testing it. So that actually helps you to get the first run.

We got at least two, probably three client representatives attending various meetings where we talked about the OD, the ID, the length and we pre-agreed a functional specification. So we suggested that this was a tool design that could be used. We suggested that these specifications could be achieved: OD, ID length, bursting and collapse, tension, all these normal downhole oil field tool things. Once we'd agreed with the operator that functional specification we then went ahead and did the detailed design. We sat down with them again and went through the design and explained how it would work and why we felt this was the most viable way of achieving what they wanted to achieve. And there's a bit of salesmanship in that as well because having gone that far you probably don't want to divert too much away from that and, er, you don't want to add too many bells and whistles that increase complexity and consequently have an impact on the reliability. So sometimes you need to make sure that you do stick to the task in hand and don't end up adding features and benefits that are nicer to haves rather than need to haves. I think once you've got a commercially successful tool on your hands you could potentially add some of these features and benefits, you know to enhance the tool but I think you've got to try and remain focused on the job in hand and consequently agreeing that functional specification's very important and agreeing what the tools are actually going to be is… is very important. We did that.

We then organized the manufacturing of those tools and we built two tools. We then organised a test at the test rig here in Aberdeen where again we involved the operator and we pre-agreed what the test would be, what the objectives of the test would be and what we were going to do on the day to make sure that we didn't leave something undone that we wanted done. We did the test and in this particular instance that test was successful so we published the results of that test and submitted that the operator who then decided that rather than going straight to the field and using it in operational function that we would organise a field trial. So we found an operation where the tool could be used without having to function correctly but it wouldn't have an impact on the operation in hand. So, this particular tool was inserted in the drill string of a well bore cleanup operation that was deemed less critical and consequently the risk of the tool not functioning wasn't essential. But we could prove that it functioned and we would simulate the conditions in a real well. So having achieved that we were then asked to use the tool in its first commercial job because we had pre-agreed with the operator what the rates would be for the tool."

In the account presented by Harry of Caledus we see how social engagement and interactions between technology developers and end users lubricate new technology development process. Harry's account shows how helpful the end user can be to the technology developer when the end user has clarity about the end goals and what the technology should do. Although the end users have an idea of the problem, it was left to Caledus to generate tentative solutions and present preferred option to Chevron for decision and support. At different stages of the development process, a number of activities took place to ensure that what is being developed remained in line with what the end users expected. This joint approach helps to reduce risk of rejection of the final prototype. Because of the nature of the development, the end user provided a test well and even worked with technology developer to reduce the consequences of failure in case of unmet expectations.

By reducing the verbal description of the process Harry and his company used in developing a new product to meet Chevron's needs, it is possible to see the sequence of activities involved in the process and the social dimensions at the different stages of construction (Figure 6-1). For ease of understanding, the work flow overleaf summarises the key elements of the user-developer, joint technical innovation construction process used by Caledus in this particular instance.

The social dimensions of the development process raise a number of issues. Could the technology have been eased through the organisation if it had been developed with the end users more at arm's length? Other than some of the measures the technology developer took in this case, in what other ways could the risk of rejection have been minimized? In the next section an exploration of other options open to technology entrepreneurs to reduce risk associated with new technology development will be explored.

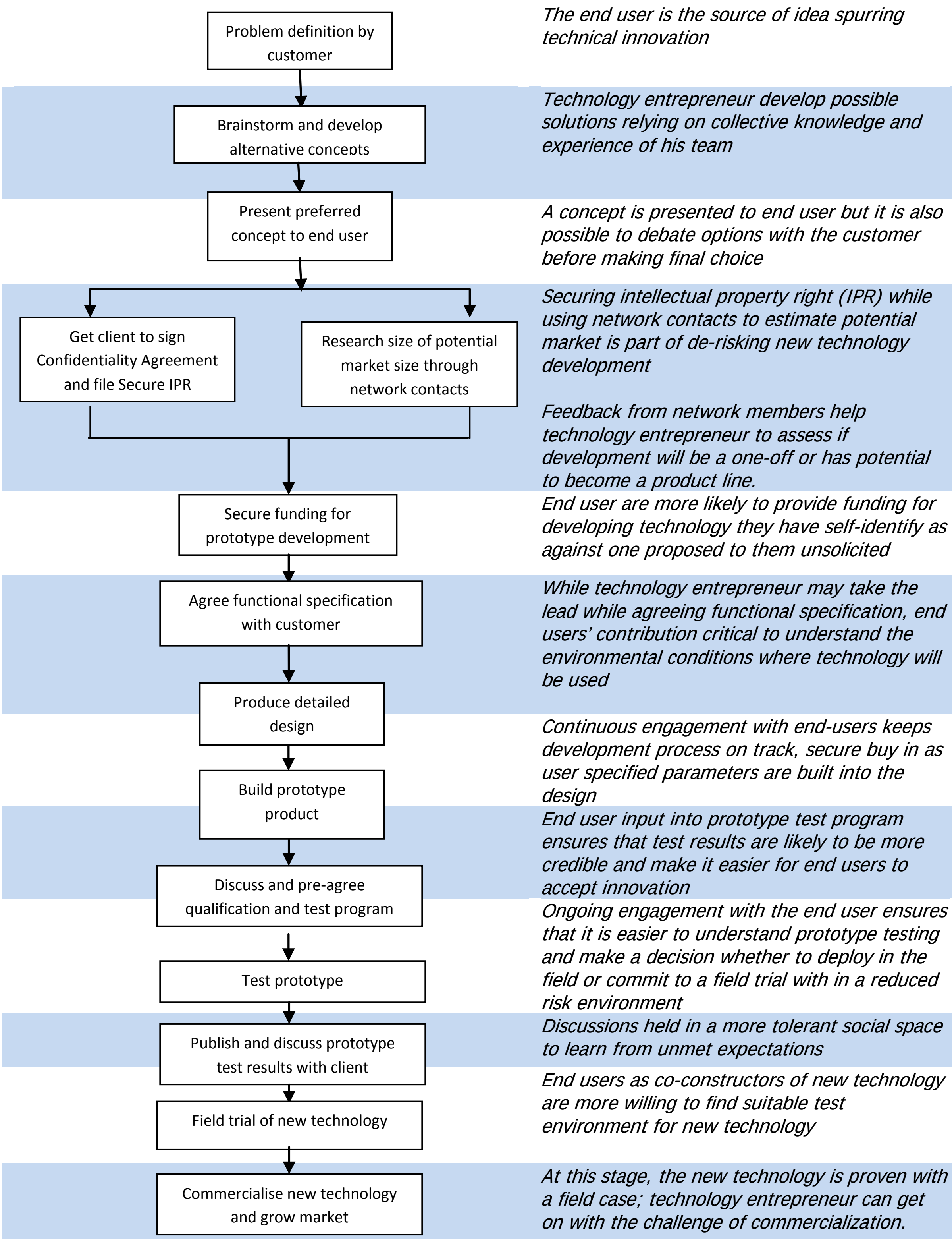

Figure 6-1: Work flow of developer-end user joint construction of new technology

6.9 Approaches to De-risking New Technology Development

In the previous sections, accounts from respondents describing various ways of reducing risks associated with new technology development have been presented. For example, in the case of Red Spider and the development of the water injection valve, prior experience and a good understanding of reasons for past failures provided the foundation for the development of a new tool that is reliable and achieved end users' acceptance.

6.9.1 Learning from Past Failures

Throughout the data, there is ample evidence that end users are cautious about new technology because they cannot be sure they will work, and if they fail, it is difficult to estimate the full cost implication. One of the ways oil companies de-risk future attempts at using new technology is to learn from past efforts that did not succeed. Mark of Maersk describes the company's attitude to failure as follows

> *"We would deal with it in a positive sense. We would, basically we would look at what we did, hopefully we would've fully evaluated it before we would've implemented it. If we implemented it and it didn't work, we would try to understand why... And having understood why, we'd then try to establish if it's something that we could fix, would we want to try again"*

Past failure can cast a shadow on future action long after the event because bad experiences are retained with organizational memories and can be amplified by events. There is so much of the past that is rolled up in the present in the form of practices and list of what not to do. Technology developers need to be careful to work closely with end users to allay their fears or have other means of demonstrating that their fears have been taken care of in the design. Therefore the language that technology entrepreneurs use in engaging with the end users is very important. Alastair of Red Spider made the point as follows

> *"Customers are a bit like a child that was bitten by a dog, they could be fifty year old and they still remember the time they were bitten. Many customers like that, they've had so many bad experiences*

and it's like here we go again. I have heard it all before. There's a few things I've learnt. You need to watch the terminology. This is the best tool in the world. Says who? We've got the best tool. You know when you make statements like that, your credibility goes down. You just see people with question mark, says who?"

6.9.2 Accommodating Environmental Realities

Due to the harshness of the North Sea, technology entrepreneurs have a tougher task to get end users to try new technology on their assets. More often, customers not only want to know if a new technology has got case histories, they are reluctant to consider new technology if it has no run history in the North Sea. Gary described the problem as

"*If you want to succeed in one of the harshest environment which is the North Sea, you have done this in the North Sea. So getting that opportunity is very hard"*

He continued by explaining that

"…companies get round that progressively de-risking. They might try it in something like the drilling school place, DTL. They might try something like that when it's run in a well and you can really have a good look at how it's gone. You can do simulations effectively. Then a lot of company, if they are big enough, would say let's take it to a land site and run it there, that increase their confidence. Their degree of confidence mean, we think this is good to go, let's try it. The metals are good for the alkaline or acid environment where you are going to use it. Depending on that kind of environment, you go through the stages and increase confidence."

The process that Gary describes above is similar to what Caledus did in the development of the swivel tool with Chevron represented in Figure 6-1. In the Caledus case, a test was done at the DTL after which they carried out a field trial in a well where cost of failure is low to provide additional confidence that the tool is ready for field application in the North Sea. The process of testing at the test rig provides technology developers the opportunity to check tool reliability and possible failure modes but it is difficult to completely replicate downhole conditions offshore at the test rig.

Accommodating environmental realities in this case require understanding how end users see how these environmental factors may affect technology performance, their concerns about potential for failures and educating end users about design features to cope with environmental variability. Engagement also helps to understand what standard new technology should be designed to so that end users can be confident that it suitable for the North Sea environment.

6.9.3 Receiving and Interpreting Market Signals

Technology developers who have developed the means of accessing market signals are likely to be more effective at choosing what technology to develop. According to Alastair of Red Spider, this is best achieved through access to and use of personal networks. He said

> *"Before you make a big commitment you need to do some market research, before you go too far. We are lucky that we've got people we know, we trust, we can sit down and have coffee, sort off the record chat. Those guys tend to know what they are looking for. It's also listening to clients, you can often get a huge indicator by listening to what's happening. You have a train wreck, train wreck, train wreck, well you don't need to be a genius that if you can come up with a better version of that they will jump at it. If we could come up with something that's better, they will jump at it. Now we've just done that with a lower reservoir isolation tool, it's an FIV. A prime example when we went in with an e-RED tool showed the client what it could do. After four presentations, four different presentations, I was pulled aside at the end and ask is that a technology that could be adapted to work as a lower reservoir isolation tool? Four times! Now that tells me there is a problem. If there's no problem they wouldn't ask the question."*

Another risk technology entrepreneurs have to contend with is lack of funding. In an earlier account Harry of Caledus explained the 3Rs one of which is revenue, shorthand for describing his company approach to how to survive and develop new technology. SMEs may need to use their internal resources to subsidise or fully fund the development of new technology. Therefore, it is not enough to receive market signals, it is just as important to interpret them correctly so that technology developers can use their scarce resources prudently. The risk of misinterpreting market signal can lead to excessive optimism and over-commitment and demonstrated in the response of Alastair who said

> *"But we also get the one-offs for example, this is when the client say we've got a problem here, we can't do this, we can't do that and that's when you are basically developing for a client and they would normally be one-off tools and they will be priced accordingly. There are times people say you boys can sell hundreds of this. I wish I had a pound every time someone told me that. You know when I was talking about you learn from your mistakes. When I was younger I was even daft enough to believe these guys and we built hundreds of this stuff and put them on the shelf and they are still there. No, when it's a one-off job, it's a one-off job guys. So it's priced as a one-off job, so you pay for the development, you pay for this, you pay for that, so it's priced because we are basically dropping everything to attend to your problem"*

In recognition of the culture within oil companies and accepting the fact that engineers and managers within oil companies are not rewarded for risk seeking behaviour, technology entrepreneurs must seek ways to engage end users and bring them into the technology development process. The engagement process will allow technology entrepreneurs to access tacit knowledge within the user organisation and be able to build better understanding of the needs and the likely environment where technology will be used. Such an intentional engagement process will allow technology developers to be able to think like the end users. Andy, a serial entrepreneur, demonstrate the success such an approach can bring because in his businesses he said

> *"I was thinking more of an end user than as somebody who was just developing technology. I've been lucky in my career, in as much as that in my early work or my early career, in my first twelve years of my career ... I had two years with Schlumberger then I had ten years with Shell and BP, working as an operator, so I knew the problems that were existing in the fields that I was working on, and what were the things that would have made my job easier ... these are pieces of technology I would have used myself. And I know if I could use it myself because I can understand that this is going to make me more successful in developing my business. I can only assume that other people would find the same thing"*

It is important to realise the power of 'seeing and thinking as' the end users because it forces technology developers to challenge their own taken-for-granted assumptions about how technology should be developed, under what conditions it will be used, how it will be deployed and how others might react to its presentation.

6.9.4 The role of Trust in Innovation Construction

The data shows that trust is a factor in the innovation construction process. Earlier in the chapter, Harry of Caledus described his company 3Rs – reputation, relationships and revenue – which are used to gain credibility with the end user and gained some trust. This demonstrates that technology entrepreneurs have to work to earn trust. Alastair, in stressing the importance of trust, said

> *"The trust thing really comes in. You really need to earn it. You don't just turn up with a white shirt and a tie and smile because they've seen these guys come and go. I go back to my Halliburton and PES days, top sales guys as soon as a problem arose, you couldn't see them for dust. People remember that and that sorts the men from the boys. Everybody is a hero when they are selling things and things are good, it's how you react when things go bad. They might say the guy's tools were shot but guess what, the guy was here first thing in the morning, we didn't asked him to be, he didn't have to be but he was here. That's what they want, that the guy to be there when they need him. They had a problem and they were honest. They gave an honest reply to what happened. … In the industry, if you can get yourself into that position where I am expecting honesty back from the client, I am expecting to give it back to them in return. If you can get yourself into that position, great!"*

Building relationships with end users and dealing with them honestly helps create trust and convinces them an individual will be open with them even when there are problems. While trust can help technology entrepreneurs overcome some hurdles in their relationship with end users, it can also stop new technology from being developed because technology entrepreneurs are unwilling to share the intimate information about an innovation for fear of losing competitive edge. In the innovation construction process, trust can facilitate or impede new technology development depending on the attitudes of process participants.

John of DBERR gave an example of how lack of trust can work against honest attempts to help technology entrepreneurs to develop innovation for the industry using the example below

"I tried it in just some kind of industry development work I did in the North East of England where I used to be based. I got a guy from University of Newcastle to come to Aberdeen and research all the technologies we were looking for in general terms. Then he went back and talked to all the companies in the North East of England to find if there was a fit. He came up with a whole list of projects but they didn't go forward because of this issue of IP. The companies were not prepared to share their ideas and if you don't share nobody is going to put money into it. So we only got one technology to come forward from the project. It all fell apart because of the protection of IP."

Some of the technology developers may be uncomfortable about approaching the ITF for funding for their ideas since the big multinational oil companies are also members of the organisation. Eric of the ITF said

"*By having the service companies, we recognise that there might be issues for some of our developers*"

This response suggests that the ITF recognises the problem but as he argued

"By having service companies there, for example probably more so in the well technology area, some people will not want their ideas put to the Halliburtons or whatever because they see them as competition. However, we see that the benefits far outweigh the negatives in that process, at the end of the day the bigger guys can offer a way of bringing that technology to market."

To address this problem, the ITF has put in place a process to minimise the risk of leakage of ideas from technology developers to the big service companies. Eric argues that

"Yes, it does pose an issue for some our members. But we have chosen to engage the service companies. We see the benefit of it. We have the rules of engagement. If somebody can't handle that, then it's tough. It's rule of the game. We don't have many rules and our rules are fairly flexible. Proposals come to us and we send to all our members on an equal way. We can't keep it away from some members and for our assessment, confidentiality is built into that process.

... While the developers can't force our members to sign a contract equally the developers don't have to sign a contract if they don't wish to. There are not many. We have some of our members who come to us and on occasions get hot under the collar about where the information is going but if they don't like that then they shouldn't give us the information or enter into the process. From that point

of view, one of the ways they can do that is to make sure that their IP [intellectual property right] is protected before they come to us."

In emphasising the role an individual can play in breaking through organisational resistance and mobilising colleagues to support innovation, Peter identified charismatic leaders as champions of new technology. While charisma is important, leaders can only lead because they have the trust and confidence of those led. Peter, an exploration and special projects manager with Maersk, summarises his view about the role of a technology champion as follows:

"I think some companies are better at it than others, BP I think is very good at, er, deploying technology, um, things like open bottom ocean seismic repeat sea bed seismic, repeat surveys, time lapse surveys. Um, and I think it comes down largely to some very charismatic individuals, their persuasive powers in that they can drive through a technology and get it adopted and, um, I think it is so often the case that, er, it comes down to individuals and their persuasive powers"

We see in these accounts that role and importance of trust is felt throughout the innovation construction process. It facilitates information exchange and allows parties to enter into social engagements that can be beneficial in the process if they can learn to trust each other. Given the facilitative power of trust to lubricate transactional and transformational activities within the innovation process, technology entrepreneurs and end users ought to invest some efforts into building mutual trust.

6.10 Risk-Value Coupling in Technical Innovation Process

6.10.1 Mismatch between User Needs and New Technology Features

One of the challenges facing engineers and managers in making decisions about technical innovation is about how to relate inherent risk of technical innovation to the value of applying the technology. From some of the respondents, end users make the case that technology entrepreneurs are sometimes oblivious of the conditions under which their technology will be deployed. By not taking the work processes into account through which technology will get deployed, it is possible to fail in matching technical features to the operating conditions and failing to meet customer needs.

Mark of Maersk makes the case that value to the end user is directly related to the need of the business but new technology will be evaluated as one of a series of options.

> *"As I said before, it comes out of the business needs, you know. If a new idea was to be brought forward or developed elsewhere that we want to do then, we would evaluate it as part of how we would execute that project, and the value then would be compared to other scenarios that we would … compare with.*
>
> *I can't think of any offhand in Maersk, there probably are … 2 or 3 a year perhaps come across my desk and if I think they have value then we put them forward. But not everything that … you know, just because it's new technology doesn't necessarily mean that it has an application… You must be convinced of the value of the technology."*

From Mark's remarks, the value of new technology must be seen in part in terms of how it fits into the way the organization carries out specific activities and practices. This raises the question, will a new technology be considered valuable if it changes the way operations are conducted significantly?

Alastair of Red Spider argued that reducing risk associated with new technology development is about

> "*Understanding what the value proposition is. It's going to the value thing; the whole thing is about value. What is it that the customers are looking for and why?".*

While value may be critical to the end user the way the value is delivered and how the end user perceives it is also very important. Taking Mark's view above, it is clear that end users want new technology that compliments existing way of doings things or that do not force them to change existing practices in very significant ways.

From the account of end users, there is no consistent view of how value should be determined; value is a contested concept and it is constructed through social exchange and negotiation. Andy made the case that the history of technology in the oil industry shows that the true value of technology is only realized in hindsight after empirical observations and improvements in efficiencies or production demonstrates the true worth of a technology. He argued that

> *"if you look back and see some of the things that have been done in our industry that have really revolutionised our industry, over the past fifty, sixty years, you know, things like hydraulic fracturing, it's horizontal drilling, it's the development of 3D and 4D seismic, it's all of these things took a brave move and a huge investment to actually determine the added value. And if you look back now it's only … you say well, why wouldn't you do that? It's the logical thing to do … So I think we're re-inventing ourselves and I always believe that you've got to look at history because it gives you a guideline and you know, one of the, sort of, lessons I always say, in this business, is that a hundred years ago our average recoverability of oil and gas in a reservoir was less than two percent. Today it's greater than fifty percent, on average, and it's not because all of a sudden we've … reservoirs which are, you know, twenty five, fifty times better, it's because we've a better understanding and technology to develop them"*

Matching technology development to needs of users requires collaboration and engagement. However, as Andy argues our understanding of value changes as understanding of the environment in which we use technology evolves. It is not possible to develop an effective technology that can deliver real value without a good understanding of how the technology fits into the value process of the end users and a shared understanding of the environment where it will be used.

6.10.2 Risk Sharing

Risk is a recurring theme in the responses of research respondents. Oil companies recognise the need for technical innovation. In forming the ITF, the end users have created a vehicle for sharing risks and ensuring that no single company bears the sole risks of developing technology. Peter, an exploration manager with Maersk Oil argued that

"I think the only way of doing that is by sharing the responsibility but it has got, you know, something like a JIP (Joint Industry Project) … So that would relieve the burden of risk from individual companies and share it around…"

Managers and engineers within the oil companies acknowledge that risk sharing with small companies and technology entrepreneurs is not a credible idea given the limited resources of these companies. Mark said that

"you could not expect little, you know, manpower technical organisations to share in multi-million Pound risks, and certainly any consequential risks"

Gary, formerly of DBERR and now business development manager for Red Spider, argued strongly in favour of risk sharing when he said

"if you have risk, the best way of dealing with risk is to share it out. The whole point of new technology is either to get the recovery, or hydrocarbon that you can't get at or to take something which has got some inherent failure and make it better. So if you take the whole point of new technology is to de-risk, that's part of it. Then it can only be the process of taking on paper to active in the field. So what can you do? You can share that element of it. To me that's back to ITF. That's the industry own body to de-risk technology and I think we should be using it"

Since end users have no faith in the capacity of technology entrepreneurs to bear any risk of failed technology implementation, the only way engineers and managers within oil companies can share risk meaningfully is through the use of the ITF. According to Eric, end users accept that new technology can fail. He said

"There is recognition that at the end of the day we are doing technology development and there are research elements in there. I think there is a fundamental understanding and recognition that research can fail. So just because you are developing the project there's got to be the recognition that you may have backed the wrong horse. Research can fail as well as be a success"

Through the ITF process, there are structures and processes in place to help minimise the risk of such failure. Eric explained *"it goes back to what I have just said. By having these people involved with the steering group, the reason they are called the steering group is because they are putting their expertise into your project as well. It is part of the process, it's part of their responsibility to guide you... The operators are in the steering group can say in the operations we would want to do this or do that, if you do it that way, it's not going be very practical. And so they are putting that benefit of experience in all the time. So by having that you've got more chance of success compared to say you've got some government funding that doesn't need any involvement from anybody and you are doing what you think is right. That may be a problem."*

One of the key challenges of technology developers is how to raise funding for new technology development. The end users are also wary of sponsoring major technology projects on their own because it may fail. Therefore, the ITF provides a vehicle for a number of operators to pool resources together to fund a technology while simultaneously reducing their individual financial exposure. Eric described the process as follows

"Another way of doing risk in a project is that they [the Operators] can decide to split the project up into phases. We might get somebody coming to us to ask for a few millions, say £2M for a project which is built up right from concept right through to completion. Our members might then say okay we know it might cost that much eventually but, we'll like to break this down with a number of gate points. So first of all, let's fund phase 1 and we get a better understanding of what the issues are here and once we get to the end of phase 1, we'll review that. More than likely we'll get to that point and they will move forward because the other thing we do set up is that once a project is formulated, the sponsors will put in their experts in that area, their expert engineer, one of their engineers or whatever onto that project as part of the steering group. That steering group will help guide the development in the right direction or provide them inputs that help the project formulate itself and move forward. So if it's going off track a little bit then the members of the steering group can actually bring it back by offering their assistance and guide the project ... rather than going off and doing research in a particular direction, the steering group might say that is the wrong direction. Those are the ways the projects get de-risk."

The process of technology development that the ITF has established with the help and support of the oil companies demonstrate the importance of continuous engagement between technology developers and end users of technology. Through these interactions, technology developers get access to knowledge information that would have been difficult to access in any other way. As Eric explained, compared to other forms of funding and support, the access to end users that the ITF provides not only reduces the risk end users are taking on but also help minimise the chance that the ultimate development will fail. A staged process with built review and engagement with end users provide the platform for steering the project and making adjustments, based on the experience of the end users, to ensure final product can deliver expected performance.

6.11 Features of Successful Technical Innovation

Through the exploration of the accounts of different respondents, different features and drivers of technical innovation construction have been demonstrated in this chapter. These accounts have shown that actors can and often see the nature of the problem in need of solution different, they are motivated by different drivers, guided by different interpretations and hampered by different issues. Notwithstanding the catalogue of challenges that have been discussed, we have seen great success stories of coordinated social action to develop new technology. Therefore, it is logical to conclude that despite the challenges of technical innovation construction, there are ways of engaging in this process with potential to lead to success and rewarding outcomes.

All the cases of successful examples of technology entrepreneurs interviewed in the course of the field research have elements of deep social interactions, continuous engagement between technology developers and end users, joint development of technical innovation, a shared understanding of problem and tentative solutions, and end users input into the testing and qualification program. The concerns of end users about risk of failure or poor performance are mitigated in these success stories by the nature and quality of social interactions and engagement between parties. In the success cases, technology entrepreneurs found a way to access implicit and explicit knowledge within the client organization in crafting the problem statement. Experience and lessons from the past helps technology entrepreneurs short-circuit development time while also providing critical information that can help developers address concerns of end users familiar with past failures. Technology entrepreneurs also used different channels to access the end user community to sense check their understanding and incorporated feedbacks into the new technology development process. The net effect of these intentional engagements is that technology entrepreneurs progressively de-risked the technology making it more likely that end users will have confidence to use it.

One of the key challenges technology entrepreneurs point to is the lack of access to an environment where they can test their new technology before it is field proven. In the success stories recounted by these respondents, it was easy to find the appropriate well to test new technology, thereby allowing a technology artifact to make the transition from being a prototype to a commercialized product. All of these cases point to joint production of technical innovation as a means to improving quality of innovation and reducing the risk of failure.

There is agreement all round between different actors that some form of social coordination and interaction is important in the technology development process. Peter eloquently made the case (reported on page 354) for having a champion within the user organization to drive new technology. While charismatic individuals might be able to break through social and bureaucratic inertia within organisations, they can only succeed if they have new technology with a reasonable chance of success to sell to their colleagues. Mark argued that the mode of production of technology is the critical factor, saying

> *"There's a difference between developing a product or an innovative idea and executing it hand-in – hand, recognising the risks as you go along, versus going to a company, buying something that's on the shelf, taking it off, off-shore and it not doing what it says it does on the thing"*

The perspectives from these two managers with an oil company underline the social nature of technical innovation construction. In line with Mark's argument, when technology entrepreneurs can engage and interact with end users, it is more likely that they will have a better understanding of the problem, access tacit knowledge that can steer development efforts. In such cases, engineers and managers are likely to be more sympathetic because they are aware of the strengths and weaknesses of technology. Internal understanding of the operating envelope of the technology also makes it easier to identify the most suitable environment for testing or deploying new technology.

Alastair of Red Spider identified a few factors needed for successful innovation technology development. He said

> *"…you need to understand the market you are chasing. The client, what are his goals, what are his drivers? Is it low cost? There's nothing wrong with low cost as long as you know that's his driver. But then it breaks down again, is it taking cost out of the operations? That's what you need to understand. …You need to know your competition. Who are you up against? What's their track record? If there are three tools out there that never had failures in their performances. Superb! Why are you even going in there?*
>
> *Try and find out who your customers are going to be. You need to pick out, pick who are my customers going to be? Because someone has to be the first to run this thing, so what you need to do is to get a sponsoring company if you can. Now that doesn't necessarily mean they are going to fund the development but what you need is somebody who is going to give you some sort of commitment. If this thing does what you say it is going to do, then we would run it. Now that's a huge commitment and that gives you encouragement"*

Understanding the market and the drivers of potential end users cannot be achieved in isolation. To be able to fully understand customer driver, there has to be some form of contact with the end user. An awareness of the competitors' performance may lead to an idea for new technology development but the entrepreneur still need to find out whether his design alternative or suggestions for improvements can win user's approval. Alastair underlined the role of sense checking innovation ideas by stressing the importance of identifying a likely user if and when technology is developed. This requires social contact and engagement.

In the ITF process, we see another demonstration of the role and influence of social interactions and engagements through the innovation construction process. The involvement of the end user in the development process is a major strength as Eric of the ITF described

> *"I think it has got a good chance of success because the projects coming through are actually to meet the end user needs. It's not so much looking at the technology per se, but is that the technology is being developed because there is a perceived need for it. And the end of the day, you are getting involvement with the people that are going to use it. They are not going to support stuff*

they don't want to use. So if it gets to the end of the line, and they can perceive a phase 2 of the project that takes it nearer to its objectives, they would stay involved with it."

Making a similar point, Ben of Bank of Scotland said

> *"From what I have seen in the past I suppose it's buy-in from the end user very early in the process and in quite a number of cases, it is actually engaging the end user in the designing and the shaping of that technology, process or whatever it happens to be to ensure that it meets the needs of the end user. That to an extent de-risk it because you've got a very supportive partner who potentially may provide not only financial support but also allow you test it in a fairly benign environment. In a real life scenario, quiet a lot of technologies we've seen developed have been with the support of a BP or a Shell or a Chevron or Talisman that will put it on one of their lower risk fields, try it there and ensure that it works and then provide a global contract for more of that service in return for getting it cheaper compared to the wider market and in some cases, an exclusive agreement... But that de-risking at outset can be an impediment once it's commercialised to get it out into the wider market if somebody else has or seems to have their hand on it. BP and Shell will quite often use rival technologies simply because they don't want to be seen to be using the same [technology] as each other. I have seen that happen as well. The key ones we have seen as been successful have engaged with a partner or with support of or with the end user in mind."*

Asked to describe his experience with new technology his company developed based on identification of a gap in the market, Alastair said

> *"That's the hardest sell because it's you approaching them and you are trying to establish a need. If someone calls you and says we've got a problem here can you come up with a solution? You are phoning him and you are trying to, right now he doesn't think he needs and you are trying to convince him that he does need it. Now you may be lucky you land up with hey whoa, talk about timing we are looking for something like this. That hardly ever happens you know."*

In this response we see the challenge technology entrepreneurs face when they develop new technology and then in turn try and sell to the user community. The users are most likely unaware of the need that new technology serves or where they see the need, they may not agree with the solution that is being proposed.

These accounts demonstrate the challenge associated with a technology push development in the UK oil and gas industry. These cases do not mean that technology entrepreneurs cannot develop new technology based on their experience and assessment of a gap in the market, these accounts simply demonstrate that there is a steeper hurdle that has to be overcome to succeed. Multinational service companies have access to users' feedbacks through reporting of bugs, product improvement requests and notices providing the information to allow them identify how best to improve existing market offerings.

Alastair and Red Spider Technology succeeded with the water injector valve even though the product came out of their identification of a need without solicitation. However, we see in the development path they took that they employed a number of techniques using their social contacts to develop and de-risk the technology. This section demonstrates the central and critical importance of user involvement in technical innovation. The accounts here demonstrate that an important part of the foundation for technical innovation is a good understanding of users' needs. How technology developers access the information to allow them to understand users' needs will vary through the trajectory of innovation construction.

In the next chapter, the nuances of these variations will be explored.

6.12 Exploration of Similarity and Divergence of Process Participants

In this section, an attempt is made to explore the similarities and differences in the views of different social actors who combine to engage in the act of technical innovation construction. From the descriptive accounts set out earlier in this chapter, there is broad agreement about the role of technical innovation and its importance to the survival and long-term future of the industry. Different actors in different roles have a positive self perception of their roles and contributions to the emergence of new technology. However, a deeper analysis of the data also reveals that these social actors have many different perceptions about different aspects of technical innovation.

Despite the agreement on the role and importance of technical innovation, the different players see the role of each other differently. While engineers and managers see themselves as driving the use of new technology to maximise recovery from North Sea oil and gas field, technology entrepreneurs see them as risk averse, protective of their self interest, reluctant to use new technology from SMEs. On the other hand, managers and engineers think that entrepreneurs design technology without fully understanding their needs, do not pay sufficient attention to how justify the need for new technology, do not understand the challenge engineers and managers have to make a business case for new technology.

Entrepreneurs (Technology Developers)	Oil Companies (Managers and Engineers)	Fund Providers (VCs, Banks and other Investors)	Facilitators (ITF and DBERR)
Create vision of future possibilities and enact ways of translating vision into reality Increase economic returns to individuals and industry at large Extend existing technologies or develop new ones to meet current challenges or anticipated needs Help oil and gas companies to overcome operational challenges Challenge existing convention of how things should be done Develop and commercialise game-changing technology Reshape competitive landscape to get a foothold Seek and deliver value for customers Develop technology to claim place	Maximise returns from oil and gas assets using new technology Drive innovation through use of new technology or extension of existing technologies to new applications Support R&D projects in Universities and the ITF Meet shareholders expectations	Coach and develop entrepreneurs to develop and grow new ventures Question entrepreneur's assumptions about new technology capabilities, intended market and business model Evaluate sustainability and readiness of a new venture for investors Transfer knowledge and experience to entrepreneurs Provide access to investors' networks and potential customer Provide resources to develop appropriate technology Force entrepreneurs to think about and write business plan Support a portfolio of technologies balanced between radical and incremental innovation	Broker between technology developers and end-users of technology Keeper of the public purse (DBERR) Invest in technology of strategic importance to the UK Act as filter for oil companies Bridge communication gap between oil companies and technology developers

Table 6-1: Self perception of role in the technical innovation process

Entrepreneurs (Technology Developers)	Oil Companies (Managers and Engineers)	Fund Providers (VCs, Banks and other Investors)	Facilitators (ITF and DBERR)
Oil companies and their employees are too risk averse Decision making is influenced by self interest and self preservation Fear and consequences of failure dominate decision making Oil companies employees are uncomfortable with ambiguity Business environment in the North Sea is hostile to innovation Technology development is best undertaken when oil price is low There is no clear line of decision and responsibility within oil companies when it comes to new technology Decision making pace of oil companies is too slow for small and owner-managed firms It is difficult to convey value of new technology to oil companies	Innovation is best undertaken by external agents Entrepreneurs often have poor understanding of problems confronting oil companies Entrepreneurs often do not make economic case for technologies they want oil companies to adopt Entrepreneurs risk little or nothing on new technology and oil companies are sole risk bearer Government does not understand the oil industry Technology entrepreneurs are often unprepared to help engineers/managers make a good business case Internal culture is intensely risk averse; there is no incentive to take risk It is more likely that technology already declined by other oil companies will be rejected	There is no shortage of money or resources but a shortage of good people capable to manage new technology development Good technical people have little or no training in how to manage risks associated with new technology development Experience and capable people within oil companies do not want to take risks associated with new ventures Inventors have inflated opinion of the value of a new technology Investors underestimate what is required to transform ideas into profitable business Innovation can sometimes be out-of-sync with time and prevailing industry mood, needs and conditions There is a strong desire amongst oil companies to be second rather than first to try new things	Poor understanding often a result of communication problem Tax and R&D credits to support new technology in the sector undersubscribed; companies have no reason to complain Through PILOT, there is a vehicle for oil companies to bring their concerns directly to government New technology in the North Sea must meet higher standards because of harsh North Sea environment. The UK is a risk averse society; oil companies

Entrepreneurs (Technology Developers)	Oil Companies (Managers and Engineers)	Fund Providers (VCs, Banks and other Investors)	Facilitators (ITF and DBERR)
Oil companies lack faith in SMEs; they see technology developed by SMEs as risky Oil companies are always happy to follow others but not to lead when it concerns new technology Oil companies are often reluctant to change existing practices or way of doing things Oil companies are most likely to try new technology when there is no alternative VCs, with exception of few, are not familiar with how the oil industry work	Use of new technology is best suited to parts of the business that operates batch-type operations like 'Drilling' SMEs have no capacity to share risk; risk is higher when technology is provided by small or owner-managed firms The business is profitable without using risky, new technology. Why take additional risks? Standard for North Sea higher than most hydrocarbon provinces of the world The North Sea is a high cost environment No global mechanism linking new technology risks to value Oil companies are risk averse	Oil companies are reluctant to reward innovation Oil companies likely to try new technology for well intervention rather than well completion	reflect the larger society Good ideas will break though even with existing barriers and obstacles. Idea that new technology from SMEs carries greater risk is based on ignorance

Table 6-2: Selected summary of perspectives of different participants engaged in technical innovation construction

6.13 Conclusions

This chapter presented the findings from the responses of respondents during face to face interviews. The responses provided presented different accounts and perspectives of the different players, reflecting a complexity of the social world of technical innovation construction. Many of the themes developed from the data underline the deep social character of innovation and the ever presence of uncertainty and ambiguity in the process of technology emergence.

The end users have different motivations and expectations of technical innovation compared to technology developers. Providers of funding like VCs, banks and investment companies see risks differently from those who develop technology. The data also shows that understanding and framing the problem of what is at issue and how to solve it is strongly related to experience of individuals. The process of negotiating to use technology cannot be separated from the past because so much of individual and organisational memories is part of the present and cast a shadow on the future.

All of this points to a process that emerges through social interactions and mediated by ability of individuals and groups to make sense of incomplete information, creating a vision of the future within the vortex of change. Some social skills and awareness is required to navigate through the often foggy situation between the problem and a solution bound by contextual conditions. It is easy to see from the data individuals arrive at the innovation space with different assets, understandings, motivations and conceptual appreciation of what is needed. Through social engagement and deployment of skills and resources – material and social – create a shared understanding of what is at issue, an acceptable solution and possible path from problem to solution.

In the next chapter, a model of technical innovation construction will be presented that is rooted in social constructionism and sense-making. The chapter will provide a link between the lived experiences and accounts of respondents and conceptual framework presented in chapter 4 of this thesis.

Chapter 7

Representations of the Technical Innovation Construction Process

Tell me and I will forget
Show me and I may remember
Involve me and I will understand
CONFUCIUS (450 BC)

7.0 Introduction

This chapter opens with a discussion of the context of innovation construction in the UK oil and gas industry and its social construction. The relational process of actors shaping the context and being shaped by it is explored through an interpretation of the accounts of respondents presented in the preceding chapter. In this chapter, a model of innovation construction that is grounded in the practices and lived experiences of process participants has been developed using the conceptual framework presented in chapter 4. There analysis presented moves away from interpreting the experiences of social actors through the prism of duality of agency and structure into a view of social reality predicated on and sustained by relationality and communally constituted by actors and their relations to non-human entities. This approach provides a deeper insight into how actors engage with each other and the world in the creation of new combinations. In the early part of this thesis, how innovation and process of its emergence has been treated in the academic literature has been discussed, including the strengths and weaknesses of different models of innovation. This chapter presents the findings of this research revealing the subtle processes that drive actors and their relationship with the material world to imagine and create innovation. The challenges and resistance of social and material world is explored in the context of an engagement process that is shaped by echoes of the past and in the shadow of the future.

Happenings at the innovation site is examined through the prism of social constructionism drawing on accounts of respondents to build a picture of how actors makes sense of fuzzy information and create shared meaning from multiple understandings. Human agency ought to provide engineers and managers with the freedom to act as they see fit in dealing with problems and issues at hand. However, as already demonstrated in the previous chapter, social actors, time and again, come up again social forces constraining their reach but compliant and open to rearrangement with skills and know-how.

Rather than limit our understanding and explanation of technical innovation construction process to *market-pull* or *technology-push*, this chapter presents an alternative model of technical innovation construction exploring the social mechanisms for problem framing and negotiating in forming the social foundation of new technology development. This chapter provide an alternative explanation of how human actors proceed from different interpretations, understanding and driven by different expectations to creating and sustaining a shared picture of technological solution in response to a problem. Through an analysis of different elements of sense-making which makes it possible for multiple actors to act in concert and pursue joint action, a new understanding of the decision makings that drive acceptance or rejection of innovation is explored. While joint production of technology between producer and users of technology is shown to be more likely to succeed, an explanation is provided on how *technology-push* technology can be successful.

7.1 Context of Technical Innovation Construction

Entrepreneurship allows social actors to extract and create value from the environment through an engagement with the context and others (Anderson 2000). The context refers to the surroundings associated with a phenomenon. Technical innovation construction takes place between social actors who operate through different social institutions. These institutions embody political and economic rules which create or restrict opportunities for entrepreneurship. Institutions like the ITF and DBERR, different exploration and production companies, banks and other financial institutions shape innovation emergence while informal institutions including rules, norms and attitudes structuring what resources can be accessed and how opportunities can and should be exploited.

Technology entrepreneurs engage in technical innovation by shaping the context while simultaneously being shaped it. Through social engagements and discourse, technology entrepreneurs shape the context by shifting perspectives of users and thereby creating new understanding. Through the use of agency, elements of the context are transformed from inhibiting to empowering innovation. On the other hand, technology entrepreneurs cannot act except with the agreement of the social others, therefore what is possible is limited by social rules and what others can mentally apprehend. Technology developers have to adapt to elements of the context that is not within their power to manipulate or transform.

The process of technical innovation construction brings together many actors with different interests, constrained by role requirements but with a shared interest to find solution to a common problem through the use of technology. To follow in the footsteps of Whetten (1989), who, where, when and why questions need to be addressed to fully grasp the influence of context on the process of technical innovation. In this respect, the abiding presence of others shape how process participants, especially end users of technology, relate to and act in concert with others in response to the context.

The operational and environmental challenges UK oil and gas companies face are very similar to their counterparts in the Norwegian sector. However, the regulatory environment operating in the UK is different from that in Norway which in turn has a significant influence on the choices that engineers and managers relate to innovation. In the Norway, the government requires oil and gas companies seeking to secure and operate licenses for oil field that they must demonstrate a minimum commitment to use of new technology to maximise recovery. On the other hand, Operators in the UK sector have no such requirement placed on them; it is left to the Operator to decide if, when and where technical innovation may be helpful. While it is true that Operators will act in their own economic self interest to deploy technology, there will be circumstances where the interests of individual actors within these companies may impede the acceptance of technical innovation.

Without question, the North Sea is a high risk and high cost environment, consequently engineers and managers within the oil companies try to use tested and proven technologies and ways of doing things. The cost of failure is easily magnified when oil and gas production is lost if and when technical innovation fails to meet expectations. Engineers and managers are judged by pre-agreed performance metrics, and the incentive structure rewards meeting agreed objectives. Budgets are agreed in advance and managers are expected to deliver agreed performance within budget leaving little room for individual agency. Managers provide inputs into the budgetary process, therefore the final product is partly an outcome of their beliefs and aspirations for the future. However, expectation and reward structure make it very difficult for these managers to stray outside the boundaries of pre-agreed parameters and little space to react to emerging, situations that could not have been foreseen at the time budget was agreed. The budgetary process and the budget, though of human creation within oil companies, assume structural properties with power to enable or restrain social action, constraining choices, disempowering managers and engineers to act and respond to emerging situations.

Technology entrepreneurs aggregate resources to develop new technology in an environment where likely end users are reluctant to use innovation because of the social cost of failures. Simultaneously, they interact with and depend on for funding people and institutions with strict criteria about materiality and commerciality, conditions that are difficult to satisfy in the early stages of technical innovation development. Consequently, most technology entrepreneurs have to rely on internal resources for developing new technology up to a point that it is credible enough to attract external funding.

Agency should be about autonomy, purposeful independence and deliberate action. Technology entrepreneurs exercise agency by taking on the challenge of developing new technology. As we have seen in the previous chapter, the response of co-participants – managers, engineers and fund providers - in the process of technical innovation show the interplay between structure and agency is complicated and not free of the influence and control of others. Risk aversion by end users is conditioned by concerns about the challenges of the operating environment where technology will be deployed.

The behaviours and choices of economic actors can be better understood when the context and the setting of action is taken into account (Low and Macmillan 1988). The behaviour of human actors within an organisation and the meaning they attach to their actions constitute the culture of an organisation. The value and behaviours moderate how people act and make decisions. The culture therefore forms part of the context and the background against which people act, decision and judge others (Auernhammer and Hall 2013). New technology development is a product of interactions between people. Social actors identify problems to be solved, allocate resources, make choices between alternatives, therefore, the decisions and the product of those decisions cannot be separated from the context (Mueller 2012). The context is that all encompassing medium through which social interaction take place and action instantiated (Kayworth and Leidner 2003). It cannot be separated from the process under investigation. The behaviours and choices made by actors are influenced by perspectives of individuals, their motivations, their expectations from and motivations for using new technology, and influence of social roles and norms within the context of action.

7.1.1 Perspectives and Expectations

There is broad agreement between all stakeholders in the innovation construction process about the importance of technology and the role of risk. Generally, technology producers and end users agree that the industry is conservative but different actors advance different reasons for this behaviour. They also identified different drivers for innovation including who and how technical innovation is constructed, how to understand users' needs, evaluate and mitigate risks, link understandings of risk to value creation, and different expectations of technology-in-use.

End-users of new technologies are constrained by official demands and expectations about performance leaving little room for trial-and-error, experimentation or testing of new technology with uncertain outcomes. Oil companies prefer to share risk of new technology with developers but small or owner-managed firms do not have the resources to share the risk or test new technology to the satisfaction of the large companies. Oil companies do not want to bear the cost consequence of failure alone. Entrepreneurs on the other hand seek ways of risk reduction to minimise their exposure. Generally, techno-entrepreneurs have limited resources and cannot share risks with oil companies to demonstrate commitment to end users. Technology entrepreneurs expect oil companies to bear the risk of new technology implementation because, if successful, the benefits that accrue from reduction in cost or improvement in production is expropriated by the oil companies. However, it new technology fails, oil companies stand to lose substantially with no opportunity to share losses with SME responsible for new technology development. End users of technology are unwilling, unable or reluctant to take risk with new technology until they have built internal consensus around the value of technology and whether the risk is worth taking.

There is a strong drive by technology entrepreneurs for wanting to be original. Technology entrepreneurs used language such as not wanting to develop 'me too' technology, removing 'road blocks', and 'challenge business models' to describe their motivations. These technology entrepreneurs see themselves as agents of change. The evocative language these technology entrepreneurs used in their describing their encounters with barriers suggests an understanding of structural hindrances and how to work around or with them in pursuit of a goal. While end users acknowledge the important role technology providers play, they question if these developers fully understand the problems for which they seek to develop new technological solutions.

At some level, technology financiers and techno-entrepreneurs share similar views about the pervasiveness of a risk-averse culture hampering technical innovation efforts of technology developers. However, technology financiers are also reluctant collaborators who demand proof of commerciality before supporting new technology development effort. Fund providers question the quality of some of the ideas techno-entrepreneurs seek to develop, how well they understand real user needs and lack of management skills to manage the process of transforming ideas into technology artefacts. Technology financiers believe that there are occasions where techno-entrepreneurs seek to develop innovation without adequate understanding of user needs or the market product is meant to serve. In the oil industry, fund providers (like VCs) believe that with good ideas and competent people to manage the transformation into technology, there are sufficient financial resources available to develop technical innovation.

7.1.2 Motivation and Social Roles

Entrepreneurs who are engaged in the process of new technology development in the industry are driven by a set of objectives that may or may not be aligned with that of end-users of technology and financiers of technical innovation. Entrepreneurs want to develop and introduce new and radical innovations to help oil companies while oil companies are interested in using proven technology with low level of risk that reduces uncertainty and assure performance. Although all the actors – entrepreneurs, end users of technology and financiers of technical innovation – aspire to increased technical efficiency and increased production from oil field as objectives, managerial mindset within oil companies creates attitudes that conflict with entrepreneurial intentions of trying something new to improve performance. Rather than take risk with new technology, managers and engineers within oil companies would rather extend known technology to new application.

Prior experience and previous disappointments in and disenchantment with big service companies motivate some entrepreneurs to create new venture and engage in new technology development. Alistair of Red Spiders is a good example. Alistair once worked for Halliburton and sold a lot of water injection valves. Even though these valves had a number of design flaws with reliability issues, Halliburton were not interested in modifying the design of the injection valves or creating a superior product. When Alistair co-founded Red Spider Technology, the first product they developed was an alternative water injection valve, building on their knowledge of the limitations of the old valve, designing out known problem and providing new features that will improve sand tolerance, reliability and deliver improved performance. His experience with his previous employer and their reluctance to improve a technology product with obvious technical failings because of lack of competition is a good example how motivation to improve existing technology can spur innovation. In his case, through daily experiences and market signals about an inefficient product beset with operational failures, we see how individual understanding can serve as motivations for technical innovation construction.

VCs or technology financiers play strategic, operational and personal roles in the life of companies they invest in (Sapienza, Amason and Manigart 1994; Sapienza and Clercq 2000) in that they act as sounding boards for entrepreneurs and help shape their strategic thrust, provide key contacts for market opportunities, share experience from other markets and investments, and most importantly challenge the robustness of the business model and its assumptions. Technology financiers can also acts as friends, mentors, coaches and confidant for entrepreneurs.

As VCs play these multiple roles, they are cautious about investing in new technology firms. Their primary objective is to protect the interest of their investors and, in the discharge of this responsibility, VCs try to diversify their risks and avoid making investment in risky technologies with uncertain futures. VCs mitigate risks by carefully choosing at what stage of new venture they get involved, investing in technology with proven record of generating sales and demonstrable market acceptance, demand high return rate on investment (Mason and Harrison 2002). They insist on an exit route through which they can liquidate their investment. The attitude to risks is not just a product of individual preference for risks but also reflects the different demands and expectations of their stakeholders and the objective they are expected to meet.

7.1.3 Influence of Social Roles and Norms

Entrepreneurs who develop new technologies, end users who make decisions about when and where to use them, and VCs who provide resources for development of new technologies do not simply act as individuals but also as occupants who fulfil social roles in the process of technology construction. A social role is a set of inter-relating behaviours, rights and obligations as perceived by individual actors and their social co-actors that imposes social expectations on individual in these roles to conform to a set of socially legitimated norms and expectations. How individuals acts is different roles is influenced by prevailing norms, where norms provide indications of how actors behave socially but norms are in themselves powerless unless given power by consent of actors, socially recognised and legitimated. When individual subscribe to the norms of a social group and identify with the group's identity, their behaviour will most likely be influenced by the group norms. Smith (2007) asserts that group norms strongly influence behaviour and are activated by reminders or cues from the social environment. Over time, through individual internalisation of norms, sharing norms with others and regular activation, people maintain adherence to social norms.

Stark (2007) contends that occupants of social roles are expected to follow socially constructed and legitimated scripts. Engineers and managers as end users occupy 'achieved roles' (Banton 1965) therefore, these actors have an interest in ensuring that they act in a way that preserves their continued occupation of and being socially accepted in their roles (Bandura 1982). End users of technical innovation (engineers and managers) are expected to meet a set of expectations – performance targets, budgetary targets and objectives set by senior management – to continue to occupy and function in these roles. Cultural influences and experiences shape individual and group's values and social expectations of them. Situational and structural factors outside the control of actors also helps create and shape roles, expectation of roles or how role occupants discharge their duties. These situational factors can be enabling or constraining depending on prevailing norms, meanings and understandings in a social setting.

In the technical innovation construction process, there are interlocking social roles creating the process through which technical innovation emerges. The data from the research indicate that individuals in different roles in the process operate with and are expected to conform to different norms although they all understand the importance and supportive of new technology introduction to the UK oil industry but their degree of freedom for action is constrained by role's requirements and expectations. Technology entrepreneurs can act but within the constraint of resources they can access, end users recognise the importance of new technology but can only act within the constraint of budgetary and other organisational constraints while fund provides can only support technology if certain investment criteria can be me met.

7.2 Barriers to technical innovation

The data indicate that barriers to technical innovation are structural and social. As I hope has been demonstrated in chapter six, the social issues in the technical innovation construction are central to relationships and meaning constructions that are deployed in support of technical innovation construction and emergence. In this section we present what research respondents identified as some of the barriers in the way of new technology development and subsequent likelihood of success or failure.

7.2.1 Lack of resources

The success or failure of technical innovation construction not only depends on receptiveness of end-users but also the availability of resources to develop, test and qualify new technology. While oil companies employees are preoccupied with the challenges of maximising hydrocarbon recovery from their North Sea assets, most entrepreneurs are confronted with battle for resource accumulation to develop technologies to a point where it can be deployed on a 'trial basis' to ascertain performance. Because resources required to develop new technology are intensive, entrepreneurs from small or owner-managed require financial resources from external parties including VCs and end users. However, VCs' criteria for supporting new technology are very restrictive. VCs have as their motivation maximisation of return on investment, strong preference for supporting technologies that have already demonstrated strong growth and profitability track record. Most VCs will not support new technology that is at conceptual stage of development, consequently, technology developers have to look for alternative sources of resource accumulation including high personal financial risk to transform an idea into a technology prototype that is ready for trial, testing and qualification.

Resource acquisition needed for technology development is difficult to achieve. Often techno-entrepreneurs have to find alternative revenue streams – personal wealth, family and friends, revenue from existing business - to subsidise the cost of developing new technology. Entrepreneurs cannot rely on VCs to provide resources to develop new technology because most VCs will only support technologies with book and ready for commercialisation. VCs also demand high equity stake in the firm to justify the risk they bear for investing in developing new technology with uncertain outcome. The share of the company that VCs demand and their requirement for clear exit route to liquidate their investments serve as additional obstacles that technology entrepreneurs must surmount.

The quality of management and the confidence they inspire in the investment community to deliver is critical to raising money to developing new technology. In many small and owner-managed firms, although technology developers are technically competent, these entrepreneurs often lack the skills in such areas as production, marketing, channel management and financial risk management to guide product development to the point of where it can command economic rent. If entrepreneurs can assemble competent and credible teams to manage technical innovation construction process, they will enhance their chances to engage, persuade and secure support for viable technical innovation projects. Therefore, SME engaged in new technology development need material and human resources of the right type to gain support of critical process participants and stakeholders.

7.2.2 Slow Decision Making Process

Although oil companies can sometimes provide funding to develop new technology, the decision-making process is very slow. The need for entrepreneurs to divert scarce resources to develop new technology creates an opportunity cost decision on how best to use scarce resources, discourages innovation and in some circumstances can threaten the survival of SMEs. Oil companies treat new technology with caution and decision about testing or deploying new technology are preferably taken after extensive peer reviews, risk analyses and assessments, cost benefit analysis and value of information exercises. These processes allow engineers to develop a common frame of understanding of technology capabilities and limitations, identify scope for additional information requirement, where and how to get needed information. Through these processes, group decisions tend to lend greater weight to performance records, testing data and experience. Importantly, the cost of technology development increases as total development time increases.

7.2.3 Lack of Trust in Technologies Produced by SMEs

Trust confers a degree of predictability on human actions and interactions based on history, prior actions and previous encounters (Anderson and Jack 2002; Casson and Guista 2007). The ease with which people communicate is facilitated by common language and system of meanings aided by an effective channel of information flow. In the innovation construction process, social actors can develop common ways of interpreting available information through dialogue and in the process reduce the risk of misunderstanding and misinterpretation. In order to achieve an efficient and effective communication, entrepreneurs must immerse themselves and become embedded in the social context to have access to interpersonal system of meaning operating within a group or become a participant in developing shared understanding of system of framing and meaning-making.

End users have misgivings about technical innovation from technology entrepreneurs because of suspicions relating to exaggerated claims about technology capability and limited understanding of users' needs. Some end users even see entrepreneurs as selfish who only see the good in their technology offerings without giving serious thoughts to how it fits the needs of and situated practices of end-users during implementation. Although end users' hesitation may be due in part to inadequate trust, technology entrepreneurs believe that being small can be a liability because end users prefer the comfort and relative security of the bigger organisations.

In supporting technical innovation, users expose themselves to a degree of uncertainty since success cannot be guaranteed in advance (Zahra, Sapienza and Davidsson 2006). The basis of trust is firmly rooted in shared history and previous social interactions. Entrepreneurs who have had a history of successful technology development or recommended by respected sources are likely to gain higher level of trust than newcomers. To be successful, end users of technology and techno-entrepreneurs need to develop mutual trust and recognise their obligations to each other. When there is trust, techno-entrepreneurs expect end users to support and share critical information important to problem framing early in the planning process and end users in turn expect techno-entrepreneurs to develop innovation based on mutual understanding and achieve expected level of performance.

7.2.4 Lack of Access to Test Environment

Applying innovation is risky, unpredictable and surrounded by uncertainty where outcomes cannot be guaranteed. It is not possible to know in advance, and under what particular set of circumstances, a new technology might work as intended at the design stage. Therefore, there is always a risk of failure the first time new technology. To reduce failure risk, technology entrepreneurs prefer to test new technology in an environment that is representative of where it would ultimately be deployed. The economic consequence of failure – increase in cost and loss of revenue – combined with social cost of failure make end users reluctant to take risk with a new technology. While big multinational service companies have access to facilities to test technology through the development stages, small or owner-managed firm cannot do the same. Consequently, it is difficult to produce test data to dispel performance concerns of end users or demonstrate how new technology avoid previous failures. Because of the difficulties of explaining unmet expectations to peers and superiors, end users are reluctant to take risk with new technology.

Before technology can transition from prototype to a commercial product, it must be tested in an environment similar to where it will ultimately be deployed. Such tests require an understanding of the operating environment where technology will be deployed, the life cycle changes technology will be expected to cope with, failure modes of new technology, consequence for operating performance of producing asset and other requirements users may have.

To overcome the additional challenge and extra demand of harsh North Sea environment, technology entrepreneurs have to overcome significant operational and social challenges to get end users to consider using their technologies. The design and specifications of new technology in the North Sea must be suitable for a range of operational conditions that could be encountered thereby increasing design complexity, uncertainty and likelihood of failure. To reduce concerns about risk of performance failure, end users frequently ask for case histories to persuade them technology is suitable for North Sea conditions. However, most technical innovations are unlikely to have previously successful case histories to demonstrate operational suitability if they are genuinely new. Access to a representative test environment is one thing technology developers need to assess readiness of new technology but it is one thing that is difficult to secure except for technologies developed in cooperation with the end users.

7.2.5 Lack of Clarity about Linkage between Risk and Value

Oil companies as end users of technology want risk and value of new technology to be linked and communicated in a useful and transparent way. The data suggests that there is no universally acceptable rigorous process to qualitatively or quantitatively assess risks relating to new technology. Different companies and even groups within companies assess risks differently. What is often presented as risk in discourse of these practitioners is uncertainty and ambiguity inherent in different technical and operational challenges they face.

Extensive review processes of evaluation are designed to find measures or ways to quantify technology risks and establish some relationships to economic value. Techno-entrepreneurs have a high threshold to overcome to persuade oil companies to try new technology. To earn support for technical innovation they have to be able to demonstrate innovation can provide value, reduce operational risks below existing technologies and/or enhance operational performance. The uncertainty surrounding innovation implies that outcomes cannot be predicted in advance although extensive testing can reduce uncertainties associated with technical innovation implementation. Responses from respondents suggest that it is possible for techno-entrepreneurs to overcome these obstacles if they develop new ways of interacting with and communicating with end users to persuade them about the value of new technology. New ways of communication will place emphasis not only technical capability but also on the system of meanings and understandings upon which end users define what is valuable and worthy of pursuit.

7.2.6 Communication of Failures

Within the oil companies there are different power and decision making centres; different people make strategic, financial and operational decisions. These different groups have different views of risk and roles' expectations. Those who make strategic decisions may profess to using technology to achieve long-term business goals but those who make day-to-day operational and financial decisions may have or are likely to have different interests. With little reward for success and significant social cost for failure, it is not in the interest of those who make financial and operational decisions to take risk with new technology. The price for failure is higher still if technical innovation is from small or owner-managed firm that does not have credibility, track record or enjoy support at higher level within the organisation.

As was demonstrated in section 6.5.2.2, 6.5.4, 6.6.1, 6.7 and 6.8, there are many reasons for technical innovation failure but some of the most critical ones are listed below:

a. Poor understanding of customer problem
b. Poor definition of expected operating window
c. Poorly specified technology – functional and technical
d. Inability of technology to adapt to changing environment post installation
e. Poor communication between end-users and developers of technology
f. Technology developers lack understanding of life cycle needs

Managers within oil companies argue that entrepreneurs are poor at communicating the value of their technology to the end-users. In the context of technical innovation construction, value is contested because entrepreneurs largely see the strength of their technologies without considerations for how engineers and managers have to communicate inherent value to their superiors for approval or support. Insufficient recognition of the challenges engineers and managers have to justify their decisions to use new technology to superiors by entrepreneurs slows down decision making. Entrepreneurs can help make the case for trying their products by helping end users they interact with to build a business case for using new technology. This will require new attitude, use of active language to create the future and manner of communication to be able to cut through the structural constraints against new technology.

The barriers to technical innovation discussed here suggest that technology entrepreneurs and end users of new technology have different understandings and expectations leading making it impossible to establish an overlap of meanings between all stakeholders. To develop new technology, all process participants led by technology entrepreneurs have to create a common basis for coordinated social action. That common basis has to start with a shared understanding of the problem to be solved and access to the different understandings critical stakeholders hold of the issues. In the next section, an exploration of how social actors frame a problem to be solved and work together to create shared understanding and meaning will be presented. This section will also start to illuminate our understanding of why some innovation success where others fail.

7.3 Framing the Innovation Challenge

A problem is a gap, a difference or disparity between the way things are in the present and a future state of what ought or expected to be (Laughlin 2011; Weick 1995). Once the difference between current and future states are recognised, human actors are motivated to bridge. To qualify as a problem and be deemed worthy of investment in time and resources, the effort required to fill the gap will not be trivial and there will be reasonable expectation that the performance gap can be filled. Actors envision means of bridging performance gaps using different devices including conceptual constructs to paint a picture that can be socially recognised and act as a basis for common understanding. Therefore, this thesis argues as Weick (1995) did that problems are conceptual constructs reflecting current understanding of realities and prevailing preferences of individuals involved in the construction.

If we accept that a problem is a conceptual construct, whether invented or constructed, then we can argue that a problem is only meaningful to the collective if it fits into a context and conform to a system of shared meaning. The context in turn constrains and defines how the problem can be solved. Problem framing during which individuals or groups create socially recognised and acceptable conceptual constructs and representations of a problem is central to and is a subset of sense-making. Since technical innovations are designed to solve communicated, perceived or anticipated problems, this thesis submits that the framing to which an innovation is directed is conceptual and a social construct.

A problem can either be well understood and structured or fuzzy, ill-defined and unstructured. When a problem is well structured, participants dealing with the problem and seeking a solution are familiar with the necessary steps needed to proceed from current state to a future desired state (Schrader, Riggs and Smith 1993). On the other hand, when confronted with a fuzzy, ill-defined and unstructured problem, the dimensional variables required for full description, the intermediate steps required from current understanding to preferred solution through an optimum solution path are unknown and are usually defined through a trial-and-error process. Every participant in the technical innovation construction process arrives at the innovation site with some prior experience, expertise and interests. Consequently, there may be as many interpretations of a problem as there are participants. It is through social interactions and social exchanges that opportunities are created to develop shared understanding and shared meaning evolves.

For unstructured problems, although there is dissatisfaction with the current state, there is no socially agreed articulation of how to move from current state to a desired future state. However unstructured a problem might appear to be, there are those within an organisation or stakeholders with some degree of experience, expertise and partial understanding to define the problem and hypothesize on possible routes to a satisfying solution. Too often, the knowledge required to articulate a general description of an unstructured problem and chart possible routes to a solution is tacit. To help solve complex and unfamiliar problems, social actors have to proceed from the '*known and familiar*' to the '*unknown and uncharted'*, using analogies and seeing elements of the problem-at-hand as something familiar from the past.

Thinking through analogies or *seeing elements of a problem as something else that is familiar* help social actors take specific pattern of actions and effective scripts and apply to a different but similar situation in a different context. While seeing-as, human beings can explore communalities and similarities between situations even in the presence of apparent differences. Seeing-as is useful when we lack full understanding of situations but different actors may see the same problems differently. This mapping between what we know and new and partially defined situations is critical to problem solving. Technology entrepreneurs take what they know as the starting point for problem solving and use the knowledge and know-how as the launch pad to explore different problem-context pairings.

In a broader sense, seeing-as is a useful tool for sense-making when human actors are confronted with unfamiliar challenges. As powerful and resourceful as seeing-as may be, it must be remembered that analogies are tentative constructions predicated on our understanding of how the world hang together and conjectures of how things should work. When seeing-as, social actors use their experience to identify what is similar between two situations and map what is known to potential solution paths. Problem framing is used to negotiate understanding and agree trade-offs between different and even conflicting tentative constructions of understandings. The example of how Caledus engineers transformed users' needs into a technology outlined in section 6.8 of this thesis is an example of how technology producers and end users negotiate the trade-off in the technology development process.

Problems are framed by seeing elements of a problem as something already in the repertoire or collection of previously successful scripts from the past. This approach allows technology entrepreneurs and those involved in the problem framing stage to see an unfamiliar situation as both similar to what is known and proven and different from exemplars. The process of seeing-as and doing-as is not necessarily articulated but reflected in the range of options actors perceive and evaluate. Technology entrepreneurs along with other stakeholders should use 'seeing-as' during the problem framing stage as a conceptual ladder for reaching new heights of understanding, individually and collectively. Seeing-as provide stakeholders engaged in problem with a means of constructing tentative work-in-progress solutions to kick-start problem solving and also make sense of unexpected interpretations that emerges from social interactions. In section 6.8, Alastair of Red Spider Technology argued that there are limited things you can do in an oil well when he said "most of the picture is the same, just the pieces are different". The picture metaphor used by Alastair encapsulates how technology developers use *seeing-as* in problem solving and new technology construction.

In a cooperative and interactional technical innovation construction process, when new technology fails to achieve intended results or lead to undesirable consequences, group re-examination present new opportunities for learning. A failure becomes a critical incident for learning, re-examine assumptions, create and test new tentative solutions based on new interpretation and understanding. Based on this understanding, the innovation process should be seen as a series of reflexive conversations and information exchange between human and non-human entities through the different stages of innovation emergence.

The process of transforming material objects to meet new needs could happen sequentially or concurrently among process participants. At the beginning of the problem framing stage, some or all of the following social conditions exist within a group, in varying degrees:

- Individuals apply their own frameworks to available information to create meaning they can relate to as demonstrated in section 6.2 and 6.5.5 showing that the cues that innovation vary depending on individual experience and roles.

- At the beginning of problem framing, there are multiple and possibly conflicting interpretations and meanings within the group. In section 6.3 of the thesis we see how prior experiences shape understanding. Therefore, since no two individuals have the same contents of experience, there are bound to be multiple interpretations and meanings at the outset of the innovation construction process.
- Participants are willing to consciously accept new interpretations and alternative meaning through social exchange and communication. Respondents accounts in section 6.7, 6.8 and 6.9 we see different ways technology entrepreneurs use in engaging with potential end users to be demonstrate they understand their problems and have the appropriate solution.
- Relationships between available information and possible outcomes are not well understood. As demonstrated in section 6.10, there is no direct relationship between risk and value. Therefore, the value of new technology is socially constructed because meaning is created through the interactions of developers and users.

Through the use of the spoken word and other props like maps, charts, calculations among other things, human actors engage in social interactions and exchange creating new meanings and rearrangements of material entities. In face-to-face communication, technology entrepreneurs demonstrate their competence through the use of language, their understanding of the issues and use their social capital to influence and shape outcomes. During the problem framing stage, social actors listen to, act on and respond to others thereby enriching the context of exchange and creating new reality.

Participants can take advantage of information exchange between stakeholders to create new combinations or even take advantage of unintended consequences. The language of design adopted addresses specifics of the problem without losing sight of what can be gained from ability to deploy new technology under different operation conditions. Through verbal and non-verbal tools, participants can rework, reframe and re-interpret elements of a problem until shared meaning and acceptable combinations are formed. The request from a customer to Red Spider Technology to investigate if the e-RED tool can be used as a formation isolation valve is a good example. Prompted by the customer asking if a technology designed for a purpose can be used for a different purpose, Red Spiders was able to develop a different product line using existing technology platform for a purpose it was not originally intended.

Problem framing should provide the basis for coordinated social action with a plan from transiting from the problem to tentative solution in the future. At the end of the problem framing stage, the following elements should be in place to provide a platform for new technology development.

- A well defined problem statement encompassing elements of the problems as understood by all stakeholders. The boundaries of expectations are defined.
- An agreement of the minimum features of an acceptable solution
- Influence of context has been captured in the problem definition and tentative solutions.
- Potential sources of uncertainties identified with broad agreement around how to manage some of the uncertainties
- Alternative solutions have been mentally and rhetorically evaluated without incurring significant costs
- A limited set of alternative solutions has been considered and stakeholders can agree on preferred solution that will form the basis of coordinated action to develop new technology.
- A set of tentative technology-relevant tasks has been developed
- Agreed solution captures the nuances and tacit knowledge of different actors while proposed solution meets the critical requirements of most if not all stakeholders
- There is some understanding about how tentative solution will fit into the existing work flow and practices that end users are familiar with
- A template for presenting and communicating possible solutions to the larger community of end users has been agreed

A number of elements come together to make up the problem framing process that precedes the more mechanical and structured part of technical innovation process. In Figure 7-1, elements of problem framing are presented as floating units in lava of context.

The arrangement in Figure 7-1 is one possible configuration among many depending on the problem at hand, the experiences of individuals engaged in problem definition and their interpretation they impose on the issue at hand. The influence of these elements will vary depending on the problem to be solved and the mental models participants adopt. Although the entire process of problem framing is immersed in context, the boundaries of each of the elements are permeable to contextual influences, accentuating or diminishing their contributions to problem framing depending on particular situations.

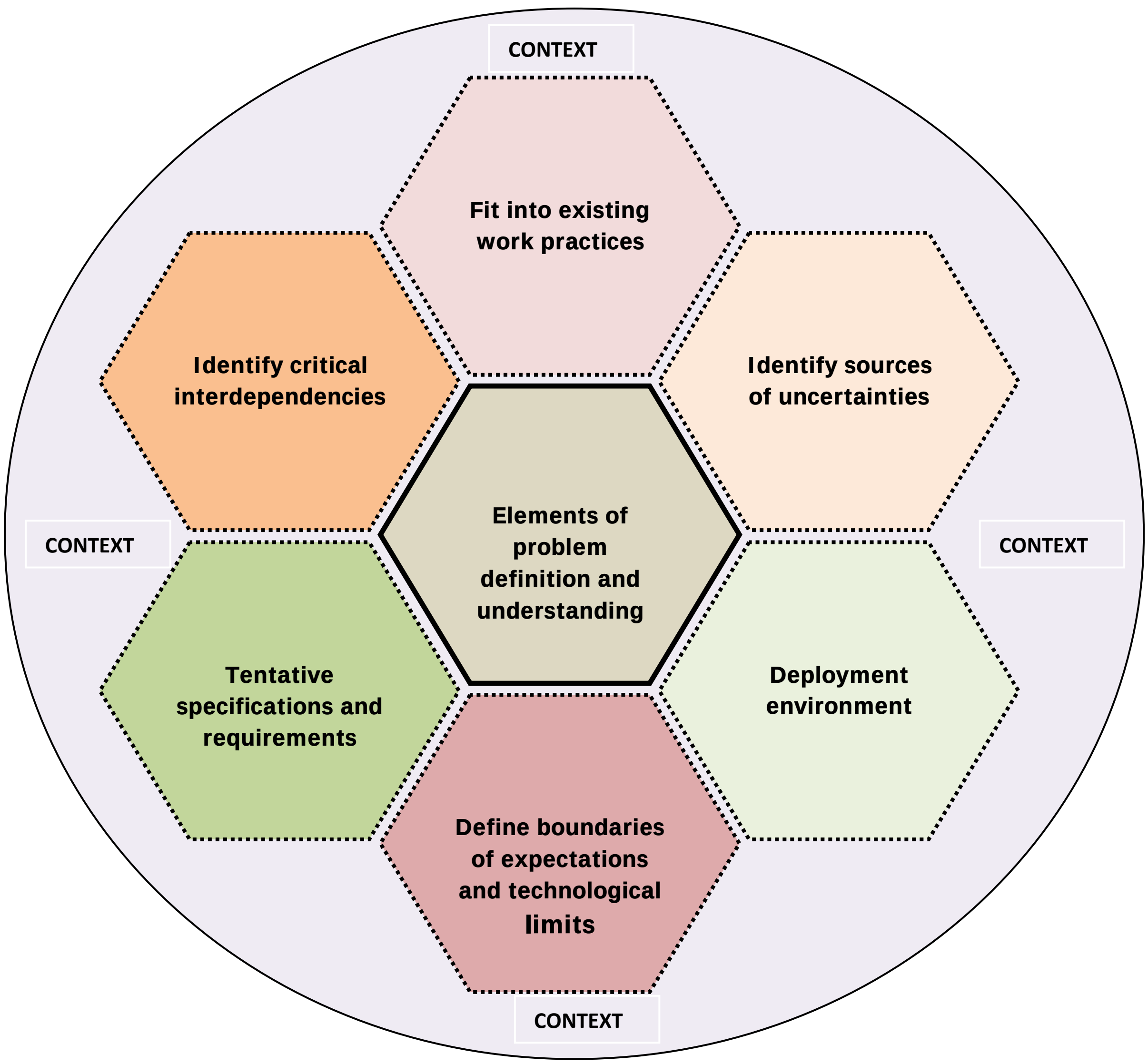

Figure 7-1: Elements of technical innovation problem solving

Based on Figure 7-1, for a problem that can be solved using familiar and proven method, uncertainties will not be a major factor nor will it be difficult to identify critical interdependencies. On the other hand, if the problem is ambiguous and uncertain with different meanings for participants, the influence and relationships these factors will be different. The arrangement and influence of problem elements in Figure 7-1 will be configured based on the understandings and experience of stakeholders and what they interpret to be important and meaningful.

Elements of problem framing in Figure 7-1 depicts how technology entrepreneurs and end users collaboratively assemble information, access tacit knowledge, draw upon individual and group experiences, and use exemplar to improve understanding of messy, poorly defined and unfamiliar situations. Individuals and groups make sense of puzzling problems or situations by mapping the familiar unto the unfamiliar. During the problem framing stage, actors use existing knowledge and plausibility structures to interpret and order chaotic information that would otherwise have been meaningless into something meaningful. As understanding evolves, human actors can begin the manipulation of the natural world and non-human entities into some form of arrangement capable of meeting new needs and challenges. The evolving understanding of a problem through social interactions and exchange allows human actors to make decisions and arrange resources in the pursuit of desirable ends.

In this section an account has been presented of how problem framing allows social actors to think through the intersection between what is desirable and what is actionable or actually feasible. Through problem framing, individuals can overcome cognitive limitations and tap into alternative interpretations created in concert with others in order to apprehend the range of possibilities. By simultaneously framing problems and constructing tentative solutions, individual and group understanding of the interdependencies deepens all of which helps to create new meanings.

7.3.1 Creating Shared Meaning and Space for Technical Innovation

Problem framing allows social actors to make sense of unstructured data, incomplete and ambiguous information. As a dynamic and social process through which experiential, tacit and explicit knowledge is captured, individuals cannot make sense of messy and fuzzy situations by themselves without the support of and coordination with others. As argued in the previous section, technology entrepreneurs and other stakeholders and process participants generate problem definition that captures multiple and alternative understandings of stakeholders.

It is likely that different participants arrive at the innovation site during problem framing with different requirements based on prior experience and varied understandings. Through social interactions and in the course of social exchanges, actors gravitate towards a set of constructions capturing the essence of the problem as individual and group understanding increases. The process of meaning construction is facilitated by use active language seeking to chart a path from the present to a desired future state. While recognising the structural and environmental constraints, led by technology entrepreneurs, the group identify what is possible and set out what can be accomplished. Through language, actors explore different material order configurations that can be constructed to achieve desired ends, testing and re-examining their assumptions in line with evolving understanding. Gradually, social actors within the group develop understanding of the problem evolving from the exchanges between individuals. Through these exchanges actors move from individual preferences or a list of wishes to focus on what is technically feasible and achievable. Over time, through dialogue and willingness to trade one need or requirement for another, actors agree on mutual interests and goals that new technology has to meet if it is to serve the goal agreed upon during problem framing.

The establishment of mutual interest creates room to develop collaborative capacity between actors. At this stage, although actors in different roles might have started the innovation journey with different expectations, shared understanding and mutual goals have created joint purpose. While they may not agree on every details of the design or proposed technology, they can perceive elements of a proposed solution that meets their needs and is in accordance with their expectations. As shown in Figure 7-2, these overlaps of interest and understanding around proposed technology solution create the space for technical innovation construction.

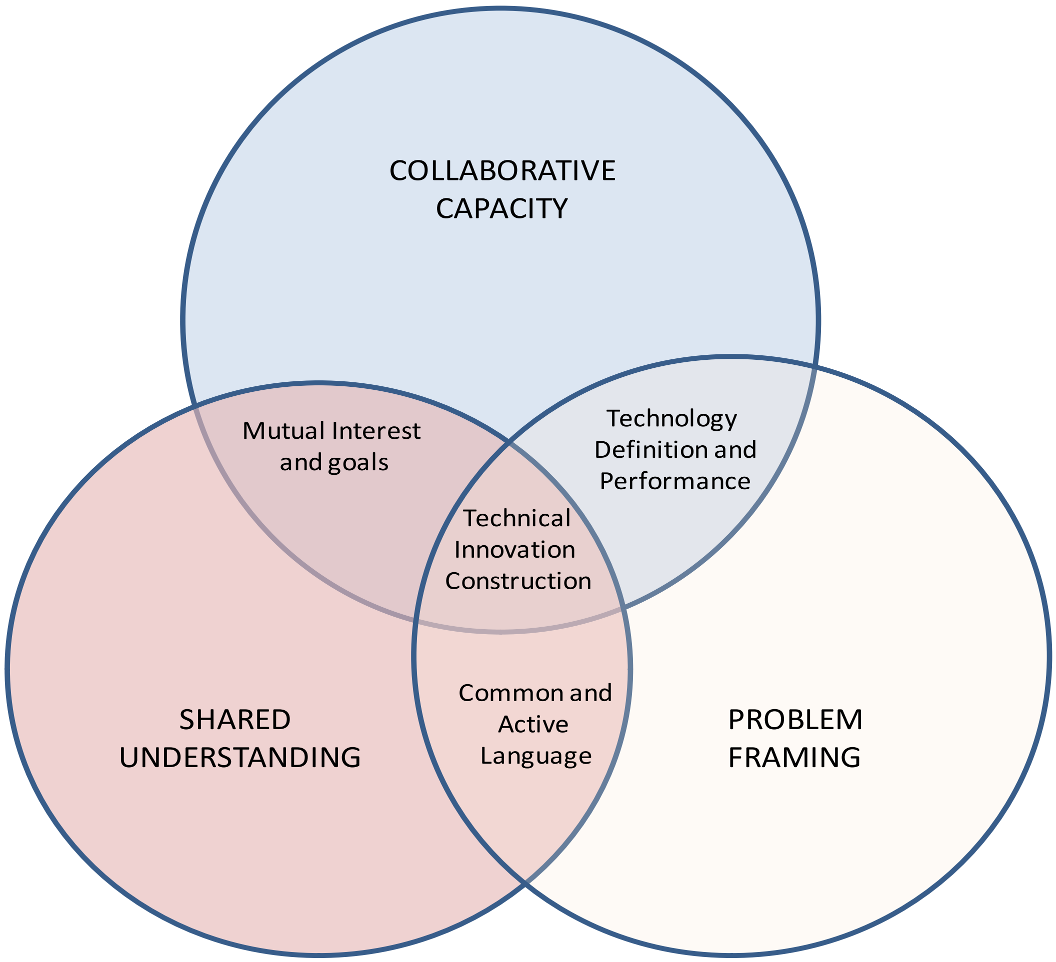

Figure 7-2: Creating space for technical innovation construction

The process of negotiating what is an acceptable solution and how it should be constructed can be contested at the beginning because of different understandings, interpretations, trajectories of experience and motivations. At its core, the problem of politics of innovation should be seen as a struggle between different interpretations attempting to influence what problem to address, how it should be addressed and the most suitable solution to be pursued. Technical problem framing requires process participants to resolve the tensions between what is desirable and what is feasible, creating a synthesis of meaning to guide joint production of new technology.

End users of technology argue that sometimes technology entrepreneurs do not fully understand the problem they are trying to develop new technology for. Lack of access to critical stakeholders may blind technology entrepreneurs to requirements critical to end users. A technology development plan developed in isolation from end users may appear to be robust based on presumed understanding of needs but could turn out to be driven by illusion of understanding.

Perception of risk is linked to understandings and expectations of different actors but also influenced by fear of failure, unmet expectations and performance uncertainty. By actively engaging with different stakeholders and ensuring that elements of their cognitive understanding are represented in a proposed technological solution, it is possible to co-opt end users to support a new technology. The fear of failure is tied to prior experience in an industry where the ghost of the past and the shadow of the future intersect to handicap decisions taken in the present.

End users demand for case history is a search for comfort and a protection against possible peer rebuke in the event of failure. When end users ask 'has anybody used this technology before?', they are pleading for information and an opportunity for technology entrepreneurs to demonstrate good understanding of the problem. How a technology entrepreneur answers questions relating to experiences of the past can either alleviate some of the concerns of end users, through a mastery of the subject and an articulation of how proposed technology resolve issues of concern to end users, or accentuate end users' reluctance about innovation. Rather for technology entrepreneur to equate enquiry for case histories to a reluctance to try something new and a demonstration of risk aversion, they should seize these opportunities to create shared meaning. Successful technology entrepreneurs use these opportunities to create a bridge to an envisioned future by linking existing stock of knowledge and practices to possible solutions that expands, and not negate the horizon of cognitive understandings of the end users.

In the innovation space, actors generate new meanings and understandings through coordinated experimentation. For any technological innovation, the performance of new technology cannot be guaranteed in advance, however, the overlapping elements in Figure 7-2 are held together by trust between parties. Trust helps to hold these elements together and lubricate the process of creating shared innovation space from where coordinated social action can proceed.

During the problem framing and early stage of technical innovation construction stage, actors may recognise aspects of a problem as familiar while treating each of the tentative options generated as unique. Through feedback and connecting relevant experience and existing stock of knowledge, technology entrepreneurs can broaden shared understanding, avoid narrowness of specification, poor understanding of operating conditions and ensure that end users' intentions are reflected in the final design. Through the series of social exchanges, the technology entrepreneur uses these opportunities of engagements to identify peculiar features of the situation while holding essential features of new technology in his sight. How technology entrepreneurs and other social actors make sense of the situation is the subject of the next section.

7.4 Enabling Technical Innovation Sense-making

Technical innovation is bound up with uncertainty and ambiguity. Uncertainty associated with technical innovation could be in the form of technological performance, timing, market, social or political acceptance. In all cases of uncertainty, there is insufficient information in the present to know how the future might unfold and fully define the value of tentative constructs (Galbraith 1973). Ambiguity on the other hand arises out multiple interpretations leading to confusion and possibly, paralysis of choice (Weick 1995; Saint-Charles and Mongeau 2009). In line with Weick, this thesis argues that the process of technical innovation construction cannot proceed without sense-making because it cannot be separated from uncertain and ambiguous conditions. The process of sense-making allows individuals to jointly develop shared meaning and create the social space for coordinated social action.

Why is sense-making integral to technical innovation construction process? Sense-making provides insight into how individuals transform ambiguous and unfamiliar situations into forms that can be understood and as resources for further social action. Sense-making in action is demonstrated by examining the accounts of how individual stakeholders in the technical innovation process interpret and use cues from the environment. Multiple individuals, faced with a common problem and purpose, jointly develop a framework for bringing coherence to ambiguous and fuzzy situations through social interaction and exchange. Social actors persuade each other through the use of active language (Pettigrew 1997) and other props to create meaning that transcends individual differences, stitching together generative meaning that can form the basis of coordinated social action (Matlis 2005). Technology entrepreneurs cannot simply impose their interpretation on a situation but rather they use their know-how and communication skills to seek out tacit knowledge and recognise alternative interpretations of same set of cues.

Sense-making is about how people construct meanings while sense-giving is about how people intentionally try to influence what meanings others ascribe to things and situations (Smerek 2011). The intent of technology entrepreneurs is to frame the problem and/or provide an interpretation of a confusing situation to shape the meanings that should form the basis for collective action. While technology entrepreneur may lead this process, he is by no means the only actor trying to shape meaning construction. All participants are learning from each other and influencing each other and the outcome simultaneously as innovation development process unfolds.

The process of sense-making can be seen as one of seeing-as in which different cues are rearranged, transforming what would otherwise appear to be fuzzy or puzzling into a partially coherent assemblage of words, symbol, numbers, drawings and calculations to create technology artefact. Sense-making allows social actors to create, disassemble and recreate meanings through different arrangement of the natural world and available materials. In the technical innovation process, sense-making allows participants to address the following questions:

- Why do we need to develop this new technology?
- What do we need to do and what information do we need to understand the problem?
- What are the features of an acceptable solution?
- What is the most effective solution to the problem at hand and how will the solution be implemented?
- What is the best path from moving from the problem to the desired end state and how will the solution be communicated?

For any given problem, some information required for understanding is available to critical stakeholders however some of the knowledge required for adequate problem framing has to be extracted from individuals' experiences, their interpretations and conceptual understanding of current realities, which is often difficult to access. Within social groups, when confronted with an unstructured problem, uncertainty and ambiguity hampers groups' ability to develop a coherent problem-solving framework without which it is difficult to create a commonly shared framework for problem solving. Different interpretations of realities, insufficient information and different trajectories of experience all contribute towards the development and sustenance of multiple interpretations. Developing a commonly shared problem-solving framework allows a group of individuals to impose a shared order on available information, agree on needed information to reduce uncertainty while allowing group consensus to emerge over time around the critical elements of the problem that must be understood and resolved to move from current to the desired future state. The achievement of consensus requires the group to work from same frame of meaning.

Sense-making occurs when individuals or groups transform circumstances into meaningful situations that can be comprehended and shared with others in words or other forms of communication thereby providing a foundation for social action (Weick, Sutcliffe and Obsttfeld 2005). Interaction with customers, efficient use of network members and communication and intentional engagement help group make sense of unstructured problem, reduce uncertainty and ambiguity, and proceed in a coordinated manner towards agreeing a solution.

Episodes of sense-making can be prolonged when actors are searching for a new invention or social constructions in need of additional information to be articulated. With insufficient information and attendant ambiguity, it is quite possible for entrepreneurs to mistake a problem (performance gap) that calls for additional information to establish common understanding and problem framing as a situation that can be resolved by a technical innovation. In this type of situations, innovation could easily be deemed unsuitable by end-users because they have yet to fully process cues and agree on the best way of dealing with emerging and ill-defined problem. In an extreme case, entrepreneurs may develop new technology for a problem users either do not recognise or considered the performance gap sufficiently worthy of a search for a new solution. To successfully develop new technology and make good use of available information, process participants and critical stakeholders must work from the same understanding of a problem and agree on proposed solution. Sense-making provides a way to understand the social forces that help create this shared understanding and how actors jointly develop shared meaning.

7.4.1 Elements of technical innovation sense-making

As previously argued in chapter 2 of this thesis, recent models of innovation are more suited to large corporations with significant resource base and do not help us adequately understand important behaviours of entrepreneurs at a micro level of society where SMEs operate. The data from this research indicates that technical innovation is more likely to succeed when jointly developed with end users. However innovation and technology development within the oil industry cannot rely solely on customers approaching entrepreneurs with a request to develop technology. We also know that there are cases of successful technical innovation in the industry that do not originate as an idea from end users.

A critique of both technology-push and market-pull models of innovation has been presented. If the development process of market-pull or technology-push is not solely responsible for technical innovation success, how does this research contribute to our understanding of this process and why people accept or reject technical innovation? A number of social forces supporting technical innovation sense-making and underpinning successful technical innovation construction, be it through *market pull* or *technology push* development route, are presented in this section. This model of sense-making recognises the influence of social structure, power relations, agency network and social capital within the confined social space of technical innovation construction.

7.4.1.1 Internal support for innovation

The decision to use new technology is both a technical and a political process (Dyer and Page 1988; Smith 2007). Managers and engineers within oil companies make decisions about new technology that can be supported by their superiors and peers so that all can accept consequences of unmet expectations should technology trial fail. The data shows that internal political and social interactions skew decision on new technology in favour of big service companies with known brands because senior managers and peers are likely to be more understanding of failure if new technology is from one of the bigger, more established companies. The pressure to deliver to pre-agreed performance targets discourages innovation or experimentation that may jeopardise attainment of set targets.

A champion for technology who has authority, respect and credibility among peers and superiors can help sell innovation internally and help develop narratives internal to the organisation in support of innovation. Some within the oil companies advocate the recognition of, even the appointment of, technology 'champions' to help push through innovative ideas and technologies (Smith 2007). Some research respondents identified credible internal support as critical even though from their descriptions it would appear that the responsibility for such support is shared across multiple roles rather than concentrated in one person. Rogers (2003) contends that those who act in the role of champions are typically middle managers and not necessarily very senior managers or executives. End users interviewed during this study have no dedicated person in the role of 'technology champion', but there may be a role for such an individual that can help bridge the gap between technology entrepreneurs and end users, bringing users into the technical innovation construction process early before framing the problem that needs to be solved.

But if most companies do not have people occupying these roles formally, how do techno-entrepreneurs know who these technology champions are? Since all cases of technical innovation sense-making require people who are familiar with the problem and have the experience to chart a course towards a solution, there are always individuals within the user community that can be co-opted to facilitate the sense-making process. Entrepreneurs that are sufficiently socially embedded are likely to know who to engage and discuss with regarding needs and possible solutions. There are examples in the data how technology entrepreneurs use network resources to refine ideas, access information about user's needs and acquire information about environment where technology might be deployed. Although individuals may not be labelled 'technology champions', they can act as a 'clearing house' for gathering local information and compiling requirements that end-users expect a new technology artefact to meet (von Hippel 2006). Engagement with lead users while framing the problem and through the development stage may secure some degree of emotional and intellectual commitment that may prove useful in selling new technology into the organisation. In supporting a technical innovation, an internal support lends his credibility and social capital to new technology which increases the level of trust other users have in the innovation.

7.4.1.2 Group preference and influence

Evidence that social actors within the oil companies prefer to share decision-making responsibility about new technology trials in conjunction with others can constrain or facilitate efforts by technology entrepreneurs to develop technical innovation. Joint reviews and decision about new technology provide end users with advantage of establishing common understanding of the problem and securing broad support within the organisation for chosen solution. However, the need to achieve consensus is advantageous to big, multinational service companies who can provide information that reduced uncertainty while users are likely to view technologies from small and owner-managed firms negatively or suspiciously because of insufficient information.

Oil companies use the peer review process to allow other experts and peers to voice their opinion about the risks and adequacy of a new technology, learn from the experience of other colleagues who might have implemented similar technology solutions in the past, access tacit knowledge within the organisation, and even gain from the experience of other oil companies with relevant experience. During these reviews, the view of an innovation can be heavily skewed based on previous bad experience(s) titling attendees to gravitate towards conservative thinking. The case for new technology by SMEs is not helped by the need for consensus and desire to select a safe and comfortable option. As already discussed, individual decision making carries within it traces of past encounters, experiences and interpretation of others. The habitus of the individuals involved in these reviews influence what they see as possible and how they relate to inherent uncertainty.

To break through the fog of information and uncertainty, technology entrepreneurs need to create a narrative that addresses the concerns of decision makers, acknowledge the impact of past failures and provide plausible explanation on how new technology resolves failures of the past. Most importantly, technology entrepreneurs need to communicate the possibilities that new technology offers and how its use can reduce uncertainty and help end users achieve relative cost certainty.

7.4.1.3 Roles, Risk perception, communication and management

The social position of different actors engaged in the technical innovation process places different demands, and in some cases conflicting expectations, on occupants of these roles. The actors come to the innovation space with different expectations. Consequently, the way different individuals perceive and seek to manage risk becomes a critical element of how technical innovation is constructed and how new technology emerges. Managers and engineers within oil companies are primarily expected by their employers and superiors to meet business targets of production and cost reduction. Because of uncertainty associated with innovation, meeting these objectives is often incompatible with taking risk or experimenting with new technology to achieve the twin objectives of increase in production and cost reduction. Therefore, it is no surprise that end users of technical innovation prefer to use technology with a known operating envelope and proven performance history.

How the different stakeholders deal with these risks is moderated by their objectives. The different perceptions of risks and how different actors seek to manage these risks help to define the social space in which new technology is developed. Users within oil companies seek to use technology that carries minimum inherent risk of failure, fund providers only seek to commit resources to technology that has a high chance of market acceptance while technology entrepreneurs want to develop new technology that is better cutter market offerings. It is the responsibility of entrepreneurs to create a narrative that ties current needs to a vision of the future in which prospective technical innovation can deliver desired results.

In areas where operations are batch-like with some degree of repetition like drilling of wells, there is increased likelihood of trying new technology. This is due in part because limited repeatability reduces ambiguity, practices are well tested and proven, and maximum cost exposure can be capped. In such instances, entrepreneurs get quick feedback, the lag time between planning and execution is short, and the budgetary process is not as constraining. Also, undesirable consequences of applying technical innovation can be reversed by simply reverting to known and proven technology with minimum loss of time and money. Capacity for understanding is greater and users are more likely to view technical innovation positively. This suggests that rather than blame reluctance of users within oil companies to use new technology on a dominant risk-averse culture, it is the desire to reduce and manage risk that drives decisions to accept or reject new technology.

This understanding imposes a burden on technology entrepreneurs to moderate the way they communicate risks of technology to end users and target possible areas of application. Through intentional engagement, technology entrepreneurs can work together with end user to understand their concerns and ensure that new technology addresses important issues. Collaboration is likely to alter end users' perception of technology based on better understanding of the design, its limits and potential.

7.4.1.4 Mutual interest and understanding

In developing new technology, it must be in the interest of end-users to use new technology. Where there is alignment of interests between developers and consumers of technical innovation, and there is a clear need for technical innovation, the process of technology construction operates more efficiently and to the benefit of the parties. This is the case when oil companies as consumers of technology approach entrepreneurs to develop application-specific technology to solve known and clearly articulated problem. It is also the case that *technology push* innovation can find acceptance if it is clear to end users that in the product's technical and functional specifications, innovation fits into a common, internally shared understanding of what is needed to bridge a performance gap.

If there is misalignment of interests between developers and consumers of technology, it is difficult to persuade users that the innovation is needed and likely to solve problems as understood within the organisation. Here, small and owner managed firms have an advantage because end-users see them as having greater focus on technology development and eager to see new technology developed, tested and implemented speedily. However to ensure that technology is developed for the appropriate need and conditions, technology developers need some means of relating to end users, understanding the subtleties of the problem and a means of ensuring that new technology specification remain true to problem as originally framed.

7.4.1.5 The Role of Prior Experience

Different companies use different techniques to objectify the use of prior experience in ranking new technology including past experiences with similar technology or by relying on information from peers. However, recall of past experience is often unreliable and entrepreneurs have no way of dealing with these subjective influences except where these concerns are articulated by the end-users. It is also true that one bad experience can dominate the thinking of a social group, community or social networks critically damaging a technology or the reputation of its developer(s). How engineers and managers within oil companies use their past experiences of successes and failures to make sense of the present especially with new technology is largely driven by what value individuals and the organisational collectively put on past experiences and memory recall of unmet expectations.

Entrepreneurs can only begin to understand these values and how individual and group understandings within the organisation, developed through the years, affect decision making about technical innovation. Entrepreneurs who develop better understanding of the organisational and individual values, especially those with decision making powers, have a better chance of being able to codify unspoken assumptions of what end-users expect of technical innovation solutions. Through social interactions, techno-entrepreneurs may be able to get access to negative information that help shape problem framing stage and sense-making process as a whole. If technical innovation design addresses specific concerns based on past events or unmet expectations, it may be possible to secure attention and demonstrate that technology developers understand the nature of the problem and lend credibility to solution proposed.

The problem framing stage offers the best chance to discuss prior bad experiences and accessing group understanding of reasons for failure. From the explicit and tacit knowledge that is gained, the group can create new understanding based on interaction and develop constructs for dealing with residual concerns. Encouraging the sharing of individual understandings of past experience and active solicitation for tacit knowledge within the organisation sharpens understanding of the past in light of present knowledge and create the social space to build constructs for reaching desired end states.

7.4.1.6 Severity of customer needs

Different players in different roles all recognise the vital role of innovation and new technology, yet most end users of technology are reluctant to pioneer use of new technology or blaze new trails to introduce radically new practices. As already demonstrated by respondents' accounts in section 6.7, it is easier for end users to accept new, even unproven technology when there is acute need or when every other known way has failed to achieve desired result. Individually, oil companies have no clear way of communicating their technology needs to the industry except through conferences and joint industry forum like Industry Technology Facilitator (ITF). However, where there is a clear and urgent need for a technical solution to solve an operational problem, oil companies are very proactive in seeking individuals or organisations that can develop appropriate technical solution based on prior experience or information from network members.

Market pull technologies that are designed to solve specific problems gain quick acceptance within the user community, stand better chance of field deployment and adoption. Attitude to jointly developed technology can be explained by the need for immediate solution. In the case of joint production of new technology, active, on-going but unsatisfactory performance is the main driver for seeking a technological fix. Consequently, problem framing is relatively easy and significant effort is not required to create shared meaning and collaborative capacity because these are framed by day-to-day inadequacy of existing technology. As demonstrated in chapter 6, the focus during joint production is on how to specify technical requirement that adequately mirrors current understanding and how to test a prototype to be sure it will be up to the demand of the situation.

But it is also possible for technologies that emerge out of a *technology push* approach to gain acceptance if during the problem framing stage, technology developers identify the key problem(s) that must be solved so that when new technology emerges it is capable of meeting needs that are deemed critical by the end users. Technology developers can only develop technologies that can solve immediate needs of customers if they have a way of communicating with the end users in the early stages preceding concept development so that the concerns and needs of the end users are incorporated into the design.

In cases where end users have no sever need for technology, it is a bigger and tougher task to persuade users to try new technology. To be successful, technology entrepreneurs have to be able to communicate the value of new technology in a way that demonstrates that it solves a problem end users are unaware of or do not deem sufficiently important to resolve. Unless and until end users can be persuaded that new technology provide a better advantage that what they are currently doing, there is little incentive to risk the known for the untested and unproven.

7.4.1.7 Mutual trust

Entrepreneurs from small and owner-managed firms need to earn legitimacy with and respect from technology user community within the industry to be effective at developing new technology. To do this they need to be trusted based on proven results from the past. Trust is earned over time of acceptable performance and sustained period of demonstrating ability to solve end users' problems. When there is trust between entrepreneurs and end-users of technology, actors can engage in open communication and convey the essence of technology requirements to entrepreneurs in a way that can be helpful in the knowledge acquisition through problem framing stages until concept development is completed.

Essentially, most technology entrepreneurs who are engaged in the technical innovation process are individuals who have worked in the oil industry before becoming entrepreneurs. Prior work experience confers on these entrepreneurs a cloak of respect, credibility and helps them earn legitimacy with their intended audience. End users of technology within oil and gas companies are not likely to listen to or take seriously new technology developed by someone they perceive as lacking in understanding as to how the oil industry operates. However, legitimacy derived from experience and/or know-how is insufficient to attract attention to new technology. The developer of new technology and the individuals who are the end-users must have mutual trust between each other. Entrepreneurs with higher stock of social capital can use this asset to meet critical decision makers and present alternative ways of doing things that may command attention. Socially embedded techno-entrepreneurs with high social capital can create narratives of future possibilities, making a plausible case that can serve as the basis for engagement through which trust can develop. Red Spider Technology Ltd. is an example of a company that traded on the collective experience of its founders as a way of gaining legitimacy and securing attention of potential customers.

Trust allows users to open up and share tacit knowledge with entrepreneurs engaged in dialogue in which intended problems get refined and frame for problem solving and understanding established. The stair case of access that social capital provides to an entrepreneur can be very instrumental in reaching individuals with power and influence that can change attitude towards a particular technology within an oil company. Where senior managers can be reached and convinced about the value of a new technology if they trust the source of new technology, they can use their influence and power to shape opinions and influence attitudes towards innovation

7.4.1.8 Technology capability

Inherent capability of the technology is very important but data from this research suggest that while it is a prerequisite for success, it may not be the most important. While there is no way to guarantee technology from a trusted source will not fail ahead of its installation, entrepreneurs that are not trusted by end-users have no way of demonstrating the capability of their technology until installed and in operation. Since small and owner-managed firms rely on oil companies to provide test environment for them to be able to demonstrated ability of new technology, small and owner-managed firms are caught in a trap in which the true technical capability of new technology cannot be demonstrated until it has been tested in an environment that is representative of the native environment where it will be deployed once adopted. In effect, technical innovation is caught in paradox of trust. On the other hand, big multinational companies benefit from having their own test facilities and have resources to rigorously test new technology so that it can be refined and made ready for field application. Through rigorous testing, they can reduce uncertainty and increasing trust in their technologies.

Technologies that are constructed through *market pull* find it easier to get test well environment offered by oil companies to test and prove adequacy of technology because it is in the interest of oil companies to see technology proven so they can be deployed to resolve on-going problem. Capabilities of technologies that are jointly developed are not in question because both parties pre-agree technical and functional specifications ahead of emergence of new technology artefact. Oil companies are aware of the risk of innovation and do not expect new technology to work as intended the first time always. However, the tolerance and understanding with which unmet expectations is treated is what differentiates technologies that ultimately succeed from those that fail. For technology push innovations, there is greater scrutiny of technology capability and lower tolerance for unmet expectations. As previously demonstrated in sections 6.8, 6.9 and 6.11, technologies that are genuinely jointly conceived and developed between entrepreneurs and oil companies are likely to be treated with greater understanding during the development and testing phase thereby providing the social space to refine and improve performance of technology artefact.

The relative strength of these factors as they influence customer decision to accept or reject new technology artefact will have depending on context. This thesis argues that the factors discussed above operate in a constellation surrounding the process of technical innovation construction as shown in Figure 7-3. These factors increase our understanding of how actors make sense of data over the entire process of technical innovation construction.

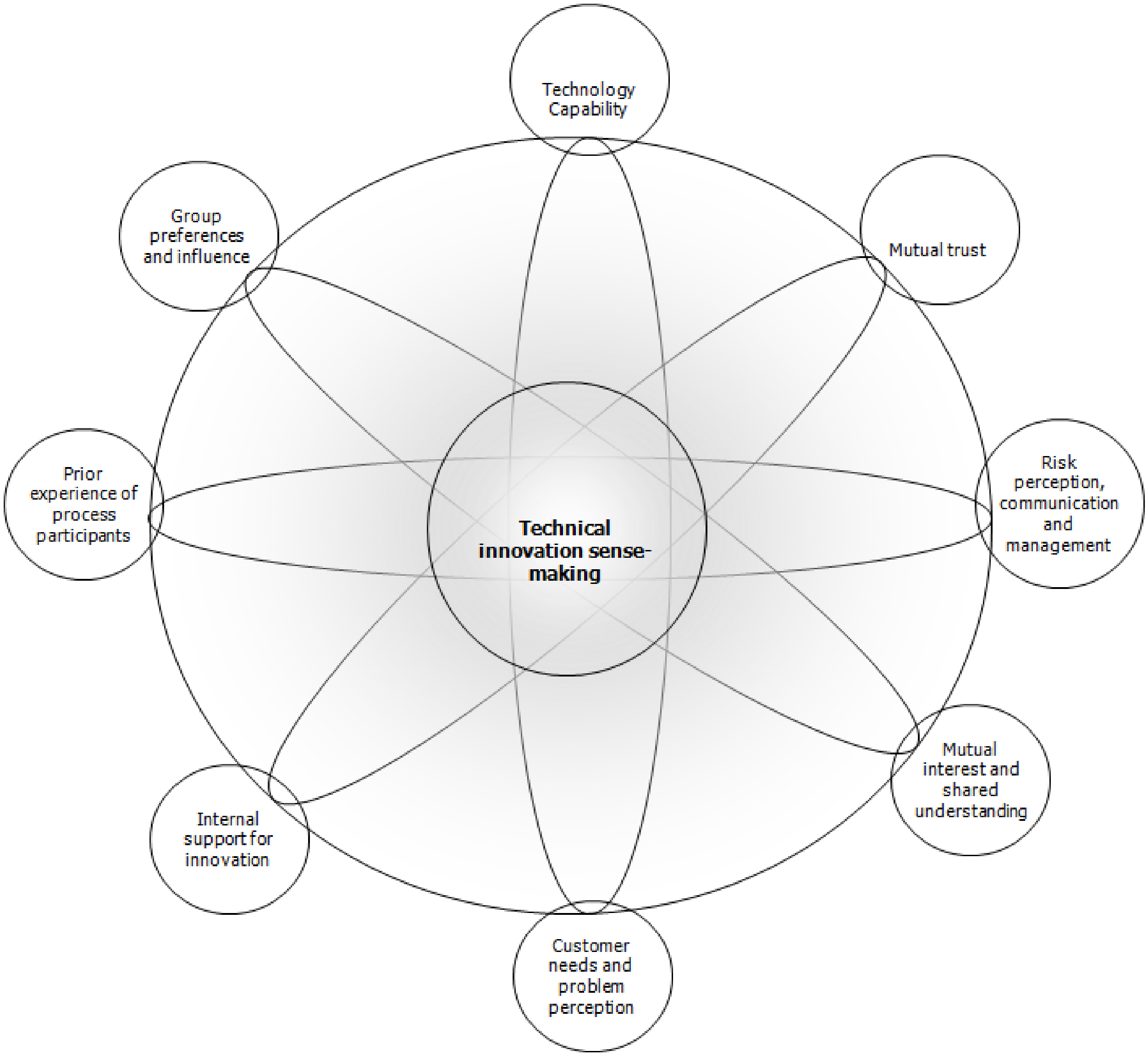

Figure 7-3: Supporting system for technical innovation construction

Technology is endowed with potential for multiple interpretations, influenced and shaped by specific social and organisational context of action. The variation of and multiplicity in meanings associated with technology-in-use is also true for framing the needs for and ultimately deciding whether or not technology artefact is worthy of consideration and trial. Sense-making is retrospective where human actors seek plausibility rather than accuracy (Weick 1995). Technical innovation construction like sense-making is pregnant with ambiguity and uncertainty, holds multiple meanings and interpretations for different actors as demonstrated through research data. Therefore, sense-making provides a peep into the underlying processes of decision-making and social information exchange that would otherwise have been opaque to critical analysis needed to understand the drivers of this social process. Before end users can accept technical innovation, they must have accepted the need for change. However, before users' commitment to change can be secured, individuals and groups must develop a shared meaning, understanding and expectation of what the innovation entails based on a common frame of reference. In making choices, the desire to reduce discomfort associated with multiple interpretations and ambiguity forces people to choose familiar solutions they are comfortable with while accentuating the negative potentials of unfamiliar alternatives.

As an alternative explanation, sense-making allows us to understand how we create the basis for meaningful action and act in concert with social others, calibrate our responses to the environments and cognitively integrate our understanding into an existing schema. Innovation embodies change, promising progress but inherently uncertainty. When users reject any technical innovation, it may not be necessarily be due a culture of risk aversion but it could be due to perceiving change and its consequences viewed through different lenses. The next section discusses how social actors use sense-making along with other resources in the social construction of technical innovation.

7.5 Social Construction of Technical Innovation Construction

The innovation process as presented in the academic literature range from simple, linear forms to more complicated variations with feedback loops. As already argued, market-pull and technology push models are overly simplistic representations of innovation process and later generation models of innovation are not reflective of what happens at the micro level of small and medium enterprises. The technical Innovation process, which is the subject of this study, is a multi-layered with interconnecting tracks. As will be demonstrated later, the convergence of the social, technical and entrepreneurial tracks in relation to the context has significant influence on the likelihood of success or failure. The construction of mental and physical representations of new technology is multi-faceted, multi-dimensional and relational involving physical materials, cultural symbols and institutional forces. Technical innovation construction is shaped not only customer requirements but also by composition of social groups, roles and understandings. A process that exhibits such relationality between people, material objects, language in use, institution, memories and prior experience is most suited to be studied by applying a social constructionist lens.

The schematic representation of the process in Figure 7-4 encapsulates the patterning of socio-technical activities and interactions during the process of technology construction, presenting an alternative account of doing and actions in developing new technology. The process representation is neither a market pull nor technology push model of construction but predicated on the understanding that technical innovation is a relational and socially constituted process. The process captures the representation of concepts, symbols, material entities, social and relational processes of how and why people enact technical innovation in the way they do.

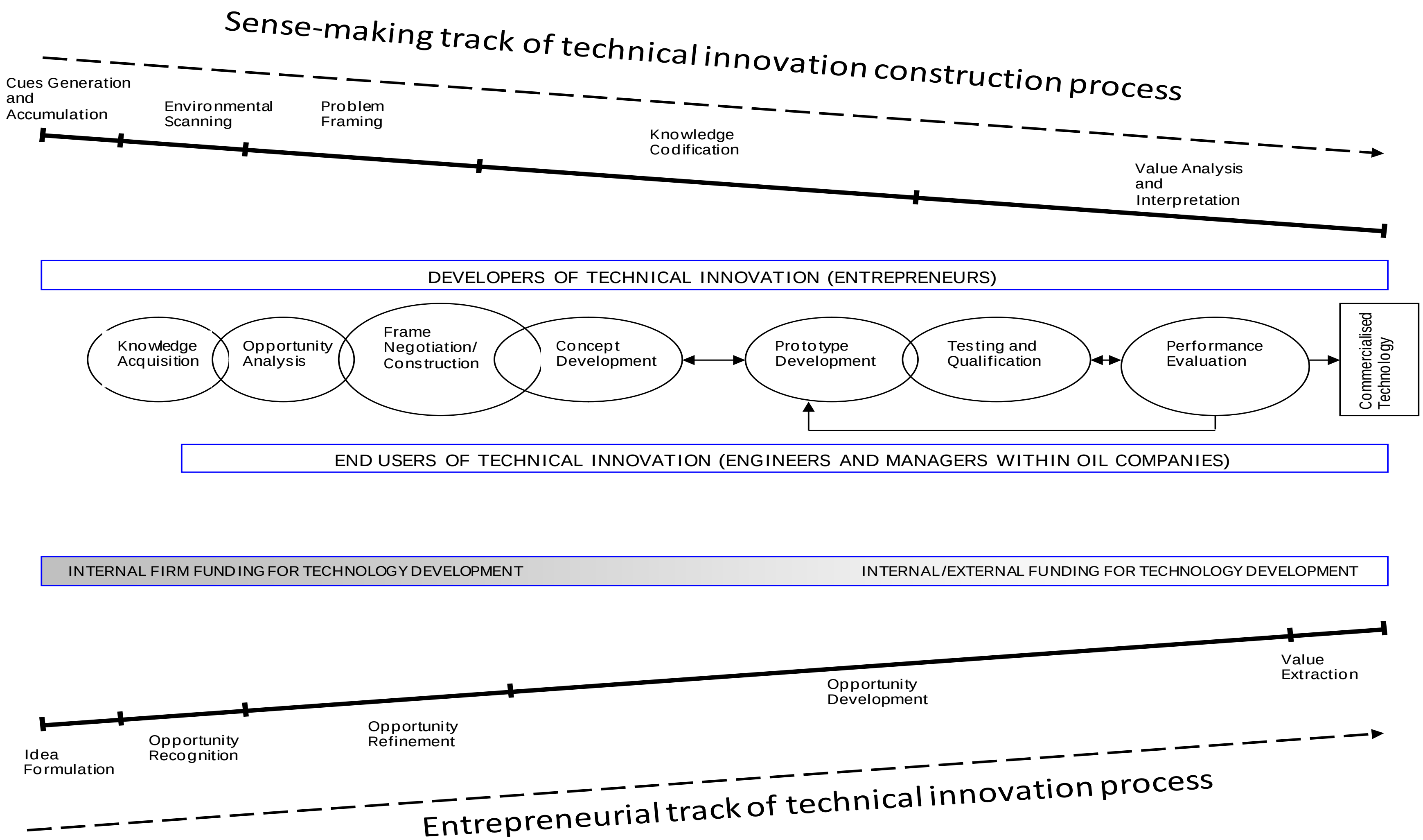

Figure 7-4: A social constructionist model of technical innovation construction

The model of technical innovation constriction represented in Figure 7-4 will be analysed along three tracks: sense-making, temporal-linear technical process and entrepreneurial track and how the three relate to the socio-economic context. In the technical innovation process, actors work these three tracks simultaneously as they relate to others and the material world sometime consciously but more often without reflection and awareness.

Innovation starts with an idea but the emergence of the idea reflects a particular form of understanding and history. As previously argued, human actors – technology entrepreneurs and other participants in the innovation construction process – engage with the world in available or ready-at-hand mode, where entities have meaningful, causal relationship with the world. Now and again, existing tools including technology fail to meet the needs of day-to-day existence and human actors recognise a performance gap or problem. When available equipment or technology can no longer meet the needs of the day, social actors are forced to reflect on their doings and move into occurrent or present-at-hand mode. In this mode, human actors see the world differently, think about new possibilities and become open to new possibilities. In the occurrent mode, material objects are liberated from the referential relations shaping our views on how they can be used and it is possible to envision and create new combinations, which is the essence of innovation and entrepreneurship.

Ideas for new technology may come from end users or from technology entrepreneurs. In cases where end users identify a problem and approach the entrepreneur for help to develop technical innovation, it is useful though not critical to engage in some analysis of market potential for technical innovation. When innovation idea come from technology developer, ideas about new technology come from cues in their environments, from past experiences, conversations with other social agents or like one of respondents put it ‘from daily journey through life’. When an entrepreneur encounters the same or similar cues from multiple social encounters, he starts to recognise the emergence of an entrepreneurial opportunity. At this stage, entrepreneurial opportunity is not well defined but there is sufficient information to generate entrepreneurial interest. With this limited knowledge, the entrepreneur proceeds to scanning the environment for information to refine and crystallise opportunity through dialogue and other forms of social action while simultaneously trying to estimate the size of potential market for innovation. Irrespective of the source of the idea, the provenance of innovation idea cannot be credited to a single individual but trace back a multitude of social encounters, dialogues, linking the past to the present with tentatively formed visions of the future.

The stages of ‘knowledge acquisition’ and ‘opportunity analysis’ are not necessarily sequential but recursive and mutually reinforcing. They help technology entrepreneurs to assess materiality and potential for commerciality. There is recognition of an opportunity without sufficient information to assess if it can be transformed into a new technology because different dimensions of the problem are either unknown or insufficiently defined to apply engineering judgement or decide the best way to resolve the problem. The entrepreneur knows there is a potential business opportunity but not armed with enough information to judge if there is the basis for innovation that can be exploited. As shown in Figure 7-4, multiple processes are unfolding simultaneously as the entrepreneurs work with others to understand and define problem, tap into the knowledge and understanding of others while sizing up the price to determine if it is worthy of the chase.

Frame construction is critical and at the heart of technical innovation construction. During frame construction, technology entrepreneur in concert with others begin the process of framing the problem and identifying its different dimensions. The cues, information and knowledge gathered from earlier stages of the process are used as input to define the nature of the problem and construct a framework of how the problem might be solved. At this stage, entrepreneurs aim to achieve inter-subjective and interpersonal understanding with end users. The negotiation between parties during problem framing is critical to the emergence of innovation. During this process, technology developers with the right mix of social capital and access to members of the user community can tap into tacit knowledge distributed throughout the community to develop a deeper understanding of the issues. Different elements of the problem will be distributed unevenly between different process participants and stakeholders. At the problem framing stage, social actors proceed from multiple understandings to creating shared understanding of requirements, create meaning oriented towards a solution and negotiate trade-offs between requirements. The essence of the problem, mental constructs of users on how problems might be solved, operating variables that will affect product when fully developed, anticipated changes in operating conditions and what users expect of technology over time all come into the open.

The habitus defines how individuals comport himself or herself to the world, informs how individuals think, their beliefs and the way they engage with the world. Consequently, how engineers and managers see a problem and what solutions they deem most appropriate may be in conflict with how technology entrepreneur sees the same set of information. However, since habitus can be made compliant, it is within the realm of possibility for properly skilled technology entrepreneur, through socially engaging process, to alter perception and understanding of a problem.

Practices are the medium through which human actors generate meanings in the day-to-day engagement with others and the material world. Our understanding and articulated intelligibility of life are embodied within practices forming the organising structure of social life in which we are immersed. Since practices are interwoven into any set of activities, and in any given social domain, technical innovation construction is no exception. Therefore, evaluations of tentative constructions during problem framing must take cognisance of how innovation under construction fits into existing practices. Given the investment in existing ways of doing things, innovation that upends proven and acceptable practices or place significant burden of change on end users may encounter resistance of end users.

Prior experience of participants is a critical enabler during the problem framing stage. The use of analogy or 'seeing-as' allows participants to decompose available information and elements of a problems into units of knowledge to improves understanding. The boundary for problem solving is delineated with the agreement of all stakeholders. The choice of developing a solution in preference to alternatives is grounded in experience and has the support of all. However, since experience is critical to the understanding that can be developed and what possibilities are envisioned, experience therefore limits what can be done and nature of technical innovation that emerges.

At the frame construction stage, the preferred path for future decision making is established creating a basis for joint social action and new technology production. For a market pull technology, entrepreneurs have easier access to data, knowledge (explicit and tacit) and other information for frame construction. The users and developer jointly negotiate and frame the problem boundaries including possible paths towards acceptable solution. Entrepreneurs engaged in technology-push path may have greater difficulties in accessing all information and interpretations necessary to frame the problem sufficiently and design framework for solving the problem. While the nature of the interactions between producer and users of technology for market pull technology during problem framing, those engaged in technology push can access required information for problem framing by activating relevant network contacts, asking the right questions and having the know-how to envision what is needed in response to a performance gap.

Innovation of any sort has different meanings for different individuals because individuals occupy different roles in the innovation process and these roles impose or demand different expectations of the individuals. Consequently, individuals in different roles have different motivations and interests. In the technical innovation process, individuals make different assumptions about the need, application and suitability of any technical innovation. Because ideas for innovation come from extracted cues, and the understanding of these cues by individuals, the cues we recognise are not unfiltered but deceptively presented to us as environmental inputs for decision making based on what we know, familiar and comfortable with. While accepted cues are integrated into our schema, rejected cues, for all practical purposes, do not exist. To avoid cognitive we accept cues that fit into our assumptions and frame of meanings. In making decisions about technology, social actors seek many cues but often rely on habitual, routine and familiar cues for information ordering, reducing complexity, information analysis and decision making. Therefore, to engage and persuade others to accept and support a technical innovation, entrepreneurs must seek ways to enter into the social worlds of end users and decision makers and seek to influence the set of cues around which a problem is framed and upon which decision making is predicated.

The idea of ‘creative destruction’ and how new products or technology displaces existing ones implies that there is the right time, conditions and supporting environment for new technology to emerge.

To understand the contextual environment and how timing might affect entrepreneurial opportunities, we need to understand the dynamic forces at play in the process. Timing is important because it helps entrepreneurs understand when to transition from exploration to exploitation. While this thesis is not contending that timing is not an important factor in the technical innovation process, it argues that recognising when there is sufficient information around which common frame of meaning and sense-making can be built is the foundation of technical innovation construction. The problem framing stage not only allows the different mental models about a problem to be coalesced into a coherent frame of meaning around which everyone can support as a basis for action. Since framing allows simultaneous exploration of dimensions of the problem and tentative solutions, it offers technology entrepreneurs the opportunity to refine not only technical concepts for problem solving but also the business idea and how it can be transformed into a successful product.

Once the problem has been defined, technical innovation construction can proceed towards concept development where the entrepreneur, in coordination with others, defines the functional and technical specifications. The functional specifications (what the technology should be able to do) and technical specifications (where and under what conditions technical innovation can be used) establish the design boundaries for technical innovation. Technical specification allows stakeholders to develop from stated and vague needs of customers and agree on the minimum requirements. In negotiating the technical specification, technology entrepreneur has to strive to transform incomplete requirement and ill-formed wishes of stakeholders into a coherent set of design specification. However mapping what users want to a technical specification sheet is a selective, non-linear, imperfect but often negotiated process.

At this stage of the process, knowledge and collective understanding of the problem along with how it should be solved becomes codified. Technology developers translates and codify the understandings embedded in the problem framing, functional and technical specifications into engineering drawings and ensure design conforms to known industry standards. There is potential for iteration here as technology entrepreneur work with the right people to refine functional and technical specification until it reflects what users deem important. These iterations do not necessarily sacrifice augmented features of innovation that may broaden its application and extend its operating envelope. For a market-pull innovation, the degree of freedom to extend operating envelope and features is limited because users have fairly defined view of what innovation should do, how and where they intend to deploy it. On the other hand for technology-push innovation, provided technology entrepreneurs have access to required information to define the problem and specify suitable solution, there is greater freedom to augment product features and extend its operating envelope in anticipation of future needs or different applications. However, where innovation is based on inadequate understanding of a technical problem or the framework for solving the problem does not sufficiently address user needs and expectations, it is likely that innovation that emerges will be poorly specified and unattractive to end users.

Armed with a well defined problem and adequately specified technology, technology entrepreneurs can proceed to prototype development stage and manufacture a technology artefact in line with the design produced at the end of the concept development. For all technologies, a prototype has to be tested to ascertain if it meets the design specification. Technology starts to become useful if and when it can be demonstrated to have met the design, functional and technical requirements. Therefore, technical innovation construction move through ‘prototype development’ to ‘testing and qualification’ and ‘performance evaluation’ sub-processes before a judgment can be made whether innovation is ready for customer use or return to prototype development stage. For a market-pull innovation, technology developer and users jointly agree on the testing programme including the acceptance and rejection criteria based on shared understanding embedded in the problem framing and agreed specification for technology. Since the end user has been co-opted into and remains an active participant throughout the development process, end users often prove a testing environment that is ‘safe’ and there is greater social space for unmet expectations. If prototype testing fails to meet expectation, joint effort is made to examine the assumptions underpinning the design and appropriate adjustments made. If prototype testing is successful, end users are quick to deploy technology to resolve the problem that gave rise to its development.

For a technology-push innovation, moving through the stages of ‘prototype development’ to ‘testing and qualification’ and ‘performance evaluation’ sub-processes is fraught with difficulties. Prototype development, testing and qualification and performance evaluation are resource intensive sub-processes of technical innovation construction. Accumulating the resources to undertake these sub-processes is one of the barriers in the path of technology-push innovation. Even where technology entrepreneurs can assemble the skills and resources to develop prototype equipment, testing and qualifying the technology does not rely on availability of resources alone. Prototype technology has to be tested and qualified to a level that users find satisfactory. For a successfully tested and qualified technology, it is also important that users are convinced that it is reliable and meets their needs. This is where technical innovation based on a frame of meaning and understanding different from that end users can encounter difficulties.

Technology-push innovation based on limited or incomplete understanding of user needs or that does not conform to their expectations in terms how a perceived problem should be solved may find it difficult to attract interest from the user community. However, if technology developers can engage and access the knowledge within the user community to frame problems and specify technology that meets the needs and expectations of users, it may be easier to overcome user resistance. The production of appropriate and suitable solution to a problem must be coupled with a convincing narrative demonstrating good understanding of problem and a showing technical innovation can reduce risks and/or improve operational performance compared to existing technologies.

Testing new technology in a well environment replicating real operating conditions is the last critical step to successfully create technical innovation. The transition from prototype to commercial technology product is similar to what Moore (2002) calls the chasm or ‘valley of death’. This is a chasm that a lot of new technologies fail to cross and subsequently fall into oblivion. It is more likely that a technology developed at the behest of an oil company will cross the threshold than one developed independent of and marketed to potential end-users. It would appear from this research that oil companies are more proactive to test technology developed jointly with entrepreneurs because the need for technology is widely understood internally, managers do not have to embark on extensive justification of technology to superiors and peers, and the monetary investment they have made serves as an added incentive because they need to show expenditure on the technology they have developed is worthwhile. The success stories of Caledus and Red Spiders along with ITF testify to the advantages of joint production of new technology between entrepreneurs and end users.

A common theme from the research was the fogginess surrounding how risks associated with new technology is evaluated. Managers and engineers within oil companies do not trust technical innovations from techno-entrepreneurs because they believe that entrepreneurs are likely to exaggerate the capability and value of any technical innovation. This is a problem for technology-push innovation. In the case of jointly constructed technology, anxiety about risks exist but does not dominate decision making process because of users' involvement with the process of technology construction, internal understanding of the environment where it will be deployed and strong desire to solve an existing operational or business need. Therefore for *market pull* innovation, entrepreneurs need less effort in comparison to *technology push* to create common understanding of the problem and establish common frame of reference for problem solving. The successful production and installation of a jointly developed technology helps entrepreneurs improve their reputation, increase mutual trust and elevate entrepreneur's stock of social capital which are all useful factors for future engagements.

We have shown that what separates *market-pull* from *technology-push* technology is not only the source of idea for a new technology but also the nature of social interactions during the process of problem framing, sense-making preceding and during the process of agreeing functional and technical specifications, and how technology specifications relate to the needs and performance expectations of end users. Social interactions between technology developers and users, relationality between social actors, practices and context of action, improve chance of understanding how technology can and should relate to the environment in which it is employed. These interactions not only help improve user acceptance but also help improve technology performance.

7.6 Conclusions

The deployment of technology is context-specific depending on social and economic forces forcing human actors respond to and accommodate their environments. Technology is a means to an end in accommodating resistance of the natural world to human and managerial intentions. The character and utility of any technology evolve depending on how and why it is used by human actors within organisation and in relation to a context. Therefore, for any technology to be successful, it must be structurally embedded, socially constituted, relationally embracing of the context and predicated on shared meaning created by social actors.

This chapter presents technical innovation as socially constituted that can be better understood if studied through social constructionist lens. The account presented allows us to depart from dualist ontology and epistemology and focus on relationship between human actors and non-human entities and in the way they constitute innovation at the innovation site. By taking social interaction and human relationship with the social context, this chapter presents an account of technical innovation describing the generation of meaning from what goes in the process of technical innovation construction.

The innovation model presented in this chapter provides an alternative insight and deepen our understanding of how social reality and new technology as a by product shaped by multiple conversations, social encounters fragments of experiences and happenings. It provides an understanding of how the past is brought into the present and help shape the future. Through accounts of human actors, this chapter summarises the different dimensions of technical innovation process presented in the previous chapters into a coherent framework for understanding how actors transform thoughts, ideas and ill-formed concepts into technology artefacts in the process of becoming.

Chapter 8

Conclusions and Research Contributions

8.0 Introduction

This is a study that began because of the curiosity of the researcher watching the paradox of an industry filled with people who see the need for innovation but notorious for not taking up innovation or pioneering technology. This chapter begins with a brief recount of the background to this study and the key issues of interest. Through an exploration of the literature, a high level overview of the social theories and theoretical tools used in constructing the conceptual framework for this study is outlined.

A brief overview of the justification for the methodological approach for this study is presented before an exploration of the happenings and doings in the process of technical innovation construction as shown in *Chapter Six*. Important conclusions from the analysis of the lived experiences of process participants, and interpretation by the researcher, provide the basis for an alternative account in *Chapter Seven* of a model of innovation, explaining how owner-managers and SMEs and others engage in and construct technical innovation in the oil and gas industry. This chapter demonstrates how data analysis and research findings address the research questions posed at the outset of the study. This chapter also discusses practical and theoretical contributions of the study using the conceptual framework that underpinned research data analysis. Implications of research findings for action in relations to policy and practice along with areas for further investigations are discussed.

8.1 Summary of the Thesis

This section describes the summary of the chapters in this thesis. In *Chapter One* the reader was introduced to the background to the study, the motivation of the researcher to undertake the study and why it is important to investigate the process of technical innovation construction in the oil and gas industry. Innovation is inherently risky and novelty or newness alone does not guarantee success. The oil and gas industry would appear to be an environment very well suited for innovation and creative destruction but paradoxically, uptake of new technology is slow and difficult. The central issue of interest in the research was if the oil industry has acute need for technology, why is the oil and gas industry slow in taking up new technology? The objective of this research was to improve understanding of how innovation occurs and the transformation of ideas into technology artefact.

Different dimensions and the character of innovation and its nexus with entrepreneurship were discussed in *Chapter Two*. The chapter how our understanding of innovation evolved through time as presented in the academic literature. In this chapter, it was argued that although our understanding of innovation has evolved, earlier models of innovation – technology push and market pull – are linear, too simplistic and do not allow the observer to see the complexity of relationships underpinning innovation emergence. More recent and sophisticated models of innovation are unsuitable for describing the process of innovation that technology entrepreneurs engaged in because they focus on how big corporations deploy resources and managed innovation. Based on the literature, the chapter demonstrated the importance of contextual factors to the emergence and nurturing of innovation. The chapter concluded that innovation cannot be understood by simple categorisation but must be seen as a social phenomenon, shaped and moderated by context.

The different social theories relevant to the research are explored in *Chapter Three*, explaining how social agents engage with each other and the world meaningfully. Meaning is presented as dynamic and contingent, constructed on an ongoing basis in socialisation with others to fit the context of action. This study argues that, technical innovation construction emerges from social engagement with the world and depending on our modes of being. It was argued in this chapter that our understanding arises out of our practical engagement with the world. Through agency human actors use their understanding of prevailing rules, norms, practices and arrangement resources to create new combinations in the appropriate mode of being. The chapter is concluded by presenting sense-making as conceptual tool for bring together the different elements of the innovation construction process.

The conceptual framework for the research was presented in *Chapter Four* grounded in social constructionism. The chapter discussed theoretical limitations of structuration theory and habitus on their own in explaining the social forces that drives the process of technical innovation construction. Innovation emerging from new understandings when human actors are in 'occurrent' mode is presented as transpiring at an innovation site where material objects are free from their referential relations and can be rearranged into new combinations within the limits of what can be socially legitimated. This chapter argued that innovation occurs when human actors are compelled to engage differently with the world because taken-for-granted assumptions about existing technology meeting everyday needs have broken down. The conceptual framework used the concept of site ontology (Schatzki 2002) to create a bridge between the human-to-context engagement of Heidegger and Bourdieu's description of how social action and practices are replicated through habitus.

Chapter Five presents a discussion of methods and methodology of research. For a study about innovation and entrepreneurship, two social phenomenon that are context bound with multiple meanings for different individuals, a qualitative methodology was the most appropriate technique for investigating the phenomena. The study adopted an interpretive stance predicated on the assumption that reality that technology entrepreneurs and other social actors deal with is socially constructed. The chapter justified the methodological approach adopted in the research including the use of purposeful sampling strategy, conduct of field research and method of analysis.

The descriptive account of research respondents is presented in *Chapter Six*, describing the process of technology development in the words of and using the lived experiences of process participants. Through the voice of respondents, this chapter give a detailed account of and attempts to answer the ‘who’, ‘what’, ‘where’, ‘why’, ‘when’ and ‘how’ questions to increase understanding of happenings during the process of technology development. Drawing on the accounts of research respondents, a picture of how actors move from ideas to technology prototype in presented in *Chapter Seven* through the lens of social constructionism. Compared to the linear, simplistic models of market-pull or technology-push, this chapter presented a multi-layered and socially grounded process of technical innovation construction describing the happenings at the innovation site.

8.2 Conclusions

The model of technical innovation construction developed through this research emerges from a social constructionist interpretation of what transpires in the course of new technology development in the oil industry. Innovation as a social phenomenon is triggered by occasional moments of human awakening when social actors are woken up from their unreflexive engagement with the material world and when available equipment cannot meet day-to-day needs. This social process, which centres on value creation through problem solving, is contingent on the interpretations of cues, creation of a unifying frame of reference and development of shared meaning.

Although at the micro level, individual’s understandings and meanings are shaped by habitus, happenings and social exchanges at the innovation site creating the social space for collective action and shared meaning. An essential feature of the innovation space is that it is socially constructed and have no structural properties other than those conferred on it by social actors. Being a social product, technical innovation development is a product of social interactions and cannot be fully explained by simplistic models such as technology-push or market-pull models of innovation that pay little heed to the actors involved and their social engagements.

At a meso (relational) level, technology entrepreneurs as agents and subjects of change in collaboration with others, envision a future that is not totally knowable, but one that must be mentally represented in the present. The future that is crafted stitches together fragments of understanding and multiple interpretations based on recall of the past and expectations of what is yet to come, to crystallise meaning in the present. The creation of the future and emergence of innovation is predicated on the social interactions, understanding and meaning that is created at the problem framing stage of the innovation process. These creations and possible configurations of the future can be hazy and blurry based on the understandings of the actors because actors can only envision a future that their habitus and cognitive capacity will allow them to imagine in the present. Therefore, defining the problem in need of technical innovation response and the creation of artefact is contingent, socially constructed and subject to change as understanding increases.

In the social construction of technical innovation, human actors actively construct the reality they contend with through the use language and reproduction of practices. Language is not a neutral or objective medium but deployed as a negotiated medium of communication for transmission of meanings and interpretations.

Innovation as an outcome of entrepreneurial engagement with others and non-human entities is directed, socially embedded and enabled by the properties of available materials. Although structural impediments to technical innovation remains, adopting Schatzki's site ontology perspective allow the researcher to reach beyond the limitations of Giddens' structuration theory and Bourdieu's habitus to conclude the success or failure of innovation results from the combination of practices and resources pressed into action in a particular context. How and what social actors combine into new forms to press into action is determined by their understanding of the world and how things should or ought to hand together.

This study was driven in part by curiosity and presumed lack of empirical evidence that 'creative destruction' as posited by Schumpeter (1934) is not happening in the industry UK oil and gas industry. The study showed that the climate supportive of technical innovation by SMEs is created by changes in commodity price. In a high oil price environment, the high cost of operations and production can be accommodated by end users without significant concerns about impact on profitability. In a low oil price environment, engineers and managers are driven to find alternative and cheaper ways of accessing and producing oil and gas resources. Under such a climate, a different kind of performance gap is created by the macro-economic environment and creative destruction occurs as application specific technologies are sought by end users to meet the demand of the day. The problem-to-be-solved is defined by the need to lower cost of production as a necessary part of a mix of strategy for survival. The overlapping relationships between context, process and interests become the driver for innovation.

A model of technical innovation construction that is based on social interaction, negation and collaboration has been presented as alternative representation of what transpires during the process of innovation. Technology developers either work directly with end users (*market-pull* model) or indirectly by proxy (*technology-push* model) by accessing critical information and framing problem by tapping into their networks. The translation of customer needs and requirements into technical innovation is a negotiated social process irrespective of the mode of emergence. Barrier to technical innovation construction and other structural impediments are co-opted, re-arranged and diminished through social interactions and intentional engagement in the pursuit of common goal.

Although this model has been developed using the oil and gas industry as the context of action, there theoretical and practical advantages in adopting the conceptual lens used in the study, seeing innovation as products of exigencies and failure of human actors to achieve desired ends with available means. Since being is exemplified by active human engagement and involvement with the world, the seed of innovation is being planted when our mode of being calls upon us to acknowledge the limitations of the present.

8.3 Research Contributions

The research methodology employed in this study allowed the researcher to peep into the world of social actors engaged in technical innovation construction and to see the means and mechanisms through which meaning is generated. Through the lived experiences and accounts of the respondents we see how Heidegger's portrayal of meaningful engagement with the world is instantiated and how social practices are sustained. These understandings would have been inaccessible without the research approach that seeks to delve into and immerse the researcher in the sub-processes of meaning-making.

This thesis argued that innovation is a product of social creation arising from the temporary liberation of social actors from the bondage of their unreflexive engagement and interaction with the world. When available tools and equipment, including technology, can no longer meet day-today needs, social actors are awaken to new possibilities as they shift from ‘ready-to-hand’ into ‘present-at-hand’ mode. The breakdown of available tools and/or equipment triggers an awakening that forces human actors to re-examine their taken-for-granted assumptions, re-examine what they are doing, why and how they are doing it and the goal they seek to achieve. This study shows that the sources of ideas for technical innovation by technology entrepreneurs and end users is close to the Heideggerian perspective of modes of being and how we engage with the world. Innovation is presented as the outcome of social interactions, borne out of necessity for change but limited by present understanding of what is possible.

This understanding of innovation, using the conceptual lens presented in chapter 4 of this thesis, is predicated on a process model of innovation that is based on multiple, interconnected and concurrent tracks in constructing technical innovation. The model presented demonstrates how the sense-making, technical development and entrepreneurial track work together in support of innovation. This model shows that if these phases are out of sync with each other, technical innovation construction becomes more challenging but when the patterning of socio-technical and entrepreneurial tracks are aligned, a more supportive social foundation for innovation is created. This model of innovation attempts to capture the doings, happenings and actions at the micro (individual) and meso (relational) level of technical innovation construction whilst acknowledging the influence of the macro environment. The conceptualisation allows us to see innovation construction site as a conceptual space of expanded possibilities where technology developers and end users of technology inter-relate to create a tapestry of reality woven from human creativity, prior experiences, socio-economic and cultural context, and non-human entities.

The study increased our understanding of what transpires at the innovation site by revealing the mechanisms through which mental representations and understandings of multiple actors collide and mesh to create shared meaning to underpin collective social action. Instead of taking the agency or structural perspective in the study of phenomenon of interest, this study used a meta-theoretical conceptual framework in investigating the subtle social forces driving the innovation process. Social capital, embededdness and connectedness in a network of relations are used by technology entrepreneurs to refine ideas, access users' needs, increase understanding and ultimately create innovation. The study shows how organisational rituals like target setting and budgetary limits, which are products of human creation, are transformed and endowed with structural properties with capacity to impede innovation but can also be manipulated and deployed in support of innovation.

Different social actors in different roles with different motivations and expectations arrive at the innovation site with varied understanding and perception of uncertainties, risk and value. These differences generate different social constructions that must be aligned to create a coherent problem frame. The mode of technology innovation emergence is neither through unadulterated market-pull nor technology-push but mediated through a socially constructed process of interactions, negotiations and trade-offs. This thesis submits that technical problems to which innovation is an appropriate response are examples of failure of ready-to-hand equipment and only recognisable when actors are in the 'occurrent mode of being'.

Problem framing is the bedrock of technical innovation construction when social actors with different understandings work together to create and imposed shared order and understanding on chaotic and fragmented information. Through the use of existing plausibility structures and 'seeing as', actors use language to construct an understanding of the present and chart a path to the future. Within the limit of what is socially legitimate, social actors have the freedom to endow material entities with new capabilities, altering practices and creating previously unrealisable value. Problem framing allows a group of individuals to overcome individual cognitive limitations, develop shared cognition of a problem, create and use shared meaning as a launch pad to rise above spatial-temporal limitations, co-opt and fuse the past with the present while envisioning a jointly constructed path to a desired future. While problem framing for market-pull technology is jointly constructed between technology producer and end users, problem framing for technology-push can be more problematic.

While prior experience is an asset that increases credibility and can be traded for access to decision makers, it is a double edge sword that can also impede innovation. Past failures or previous poor performance of new technology are also archived in individual and organisational memory. In the problem framing stage, habitus of process participants shape understandings based on experience of the past, and more importantly, what future social actors can envision. Experience, if not handled correctly, can create inertia and make social actors prisoners of the past. Although technology entrepreneurs and other agents retain the power agency within the process, their power of comprehension, manipulation and enactment is circumscribed by their habitus. This study shows that critical decisions about new technology is always taken in the presence of social others, haunted or invigorated by the past as actors try to create a future that is shrouded in a fog created by the shadow of the future.

To be successful, developers of technology-push innovation must find a way to access critical user needs and develop problem frame that encapsulates the essential futures of a solution that end users can recognise and accept. Technology push is more difficult to sell to end users than market pull technologies. However, technology-push innovation may be successful if technology developer can demonstrate that his understanding of the problem mirrors or overlap with that of end users and have features that address the concerns of the users including failure(s) from the past.

The North Sea is a high risk and high cost environment, consequently end users of technology are sensitive to risks and performance uncertainty of new technology. Context shapes attitudes and forms significant part of the innovation emergence process. This study shows that risk aversion alone does not explain slow uptake of new technology; reluctance to try new technology in the oil industry can be explained in part by end users having different social constructions of a problem that is different from that of technology producers. Therefore, if new technology does not have features and/or capabilities end users expect to see, there is reluctance to try new technology because of concerns about failure and poor performance.

Irrespective of the inherent value and performance of new technology, technology entrepreneurs need to address the concerns of end users, demonstrating how to reduce uncertainty, achieve relative cost certainty and show how to avoid a repeat of failures of the past to improve chance of acceptance. Social construction of technical innovation gives voice to different interpretations of process participants in the creation of shared understanding and meaning. Through social interaction and negotiation, barriers can be managed by working with end users on a one-to-one or one-to-many basis or through an institution like the ITF. Collaboration can and does provide the foundation for altering users' perception of innovation performance and create shared understanding of design limitations and potential of new technology.

It is argued in this study that technical innovation construction is forged in the vortex of change but reflects particular understanding and expectation of the future. The recall of the past and understanding in the present are meshed to form the basis of a socially constructed future that is context bound. Therefore, this thesis submits that problem framing is foundational to technical innovation development and has a bearing on the likely future acceptance or rejection. The understanding and creation of the future are nothing but social constructs and interpretations, which are susceptible to selective bias if carried out by an individual. However, within a group a collection of interpretations of future states can be aggregated to create shared meaning and basis for technology development. This thesis increase our understanding of how social actors interact, how overlap of universe of understandings is achieved and what practical actions are taken to enact innovation based on shared meaning.

8.4 Implications of Research

A number of issues have arisen from the study which may have implication for further research, for practitioners within the oil industry and policy makers.

8.4.1 Research and Theoretical Implications

A useful conceptual lens has been developed and used in this study, informed by a deep commitment to social constructionism, as the most suitable means of studying phenomena like entrepreneurship and innovation. The conceptual framework presented in Chapter Four allows the researcher to dig deep into the accounts of practitioners and the meanings that drive social action in their world.

There are different models of innovations, but as previously argued, recent models of innovation are unsuitable for studying innovation development at the micro level of SME and individual technology developers. Conversely, *technology-push* and *market-pull* models of innovation are too simplistic and ignore the subtle social relations and interconnectedness that drive social change at this level of economic relations and exchange. The relational model of innovation development presented in this study, through the probing for meanings of the actors involved in the process, present an alternative way of looking way of looking at innovation and may be relevant outside the context of the oil and gas industry.

The approach taken in this research indicates that the level of analysis has significant implications for results and our understanding of social processes. Studying the process of technical innovation development through an examination of the accounts and lived experiences of participants with prior experience of the process produced rich and vivid descriptions of the nuances, texture and subtleties of relations and relationships that mediate technical innovation emergence. Given that entrepreneurship and innovation are social phenomena, the methodology approach used in this research contributes to our continuing understanding of these social processes.

The model of innovation construction that is presented identifies problem framing as the defining phase of technical innovation process. Although this study has been conducted by closely relating emerging explanation to field data, this understanding and role of problem framing has wider theoretical relevance in studying innovation beyond the context of oil and gas industry. Since consumers of any kind need to be convinced a product can meet their needs, how producers of innovation captures essential issues of concerns to end users and then proceed to develop appropriate solution is at the heart of any innovation effort. Understanding of the forces that shape problem framing from this study may possibly improve understanding of research in a wider entrepreneurial context.

8.4.2 Implications for Policy Makers

The state continues to be interested in promoting innovation in the UK oil and gas industry as demonstrated by various schemes designed to help technology entrepreneurs and SMEs to develop new technology. From the research data, two critical stages have been identified where the power and influence of government can have a positive effect on technical innovation development.

Firstly, aggregating resources for new technology development is a challenge for technology developers. Lack and challenge of pooling resources can discourage nascent entrepreneurs taking early tentative steps towards developing new technology. Since innovation is inherently risky with no certainty about possible future performance, bricolage and bootstrapping for resources by technology entrepreneurs may be problematic. Paradoxically, there are enough schemes that technology entrepreneurs can access to help them develop their ideas up to 'proof of concept' stage after which other avenues of funding open up. The fact that funds provided by the government to support new technology development are undersubscribed even as technology entrepreneurs complain about challenges of aggregating resources suggest a communication problem. Better communication to ensure that new technology developers know what help is available and how to access it will help technology developers in the early stages of transforming an idea into technology artefact, at least past the 'proof of concept' stage.

Secondly, when SMEs and owner-managed firms who are already established produce new technology that is not developed in close cooperation with the oil companies, it is very difficult to find a test environment where technology can be tested to demonstrate it is suitable and ready for deployment in a challenging environment like the North Sea. While technologies developed jointly with oil companies on a one-to-one basis or through the ITF do not have to overcome this challenge, technologies developed by technology entrepreneurs on their own find it difficult to get end users to test them under suitable or representative conditions. The issue is that oil companies are concerned about failure and possible loss of production if a technology they don't fully understand its design is trialled and fails to deliver expected performance. The government may be able to induce a change in attitude towards testing unproven technology by creating fiscal incentive to reward those willing to take risk with new technology.

This study establishes a link between the severity of needs and willingness to try innovation. Until now, the UK government has adopted an approach of allowing oil companies to determine the level of resources to allocate to new technology to extract hydrocarbon from North Sea fields. However, as already demonstrated in this study, what problem people see and choose to address is socially constructed; influenced not only by business drivers but also personal or self interests. To ensure that individual or self interests, or as one of the research respondents calls it 'personal economics', do not trump national interest, government could choose to set recovery targets for the UK section of the North Sea without changing existing fiscal regime. Operators could also be made to regularly appraise the authorities on how they plan to use new technology to improve recovery factors of North Sea oil fields. This should have the effect of nudging oil companies to seek new ways of maximising hydrocarbon extraction and improve attitude towards new technology.

8.4.3 Implications for Practitioners in the UK Oil and Gas Industry

The oil industry is often portrayed by technology entrepreneurs and some end users of technology as being risk averse. This research shows that what is often lumped together and explained away as risk aversion could in part be explained by different social constructions of a problem and how it should be solved. Technology entrepreneurs need to see and manage the innovation construction process as a social process, paying sufficient attention to how technological problems are framed in the early stages of development.

This study affirms that the experience and knowledge that social actors bring to the innovation space matter. In the innovation process, experience and knowledge are assets that increase individual social capital and, under the right conditions, can be traded for access to decision makers and information. One could argue that in the oil and gas industry, it is a taken for granted assumption that experience is central to understanding customer needs and creating effective new technology. In the view of a lot of the practitioners, sense-making is enhanced by experience and knowledge by 'seeing as' and 'doing as' based on past successes. While this study acknowledges the role and importance of experience and understandings structured by existing practices, the innovation process model presented in this study encourages a widening of individual and collective horizons to encompass new thinking and previously untried ways of looking at innovation challenges.

The study suggests that to achieve the broadening of horizons, a new attitude and approach to problem framing is required. In line with the conclusion of this study that problem framing is foundational to the innovation process, technology developers and end-users of technology should seek to encourage new voices in the problem framing stage of new technology development. Presently, the ITF tries to achieve this through the use of industry experts to develop themes summarising the challenges facing the industry. This process can be enhanced by inviting voices from further afield away from the boundaries of the oil and gas industry to access new insights, understandings, interpretations and possible solutions to the challenges of the present.

By seeking to marry experience and knowledge within the industry with new understandings and interpretations that outsiders can bring with them to the problem framing arena, the industry can open up potentially new opportunities and develop new technology platforms to address present and future challenges. Presently, the Operators are confronted with challenges such as finding environmentally safe and cost effective technologies for well and field abandonment, drilling and completing extreme HPHT wells, maximising recovery from brown field, and decommissioning of North Sea's installations among others. Since it is not possible to recognise what we cannot make sense of, and what we can make sense of at the problem framing stage depends on the understandings and interpretations of participants, then the key to creating a basis for new technology is to widen the experience and the background of actors who participates in the problem framing stage.

Technology entrepreneurs need to develop new technologies that recognise and take account of prevailing technological frames whilst simultaneously respecting and accommodating prevailing practices. In an attempt to create change, technology entrepreneurs should seek to create new technology that addresses end users' needs without forcing complete change of practices on the user community. The type of accommodation needed could be in different forms ranging from working with end users to understand how technology will be deployed to, in some circumstances, collaborating with companies that could otherwise be considered competitors, provided technology entrepreneurs have secured intellectual property rights. The insistent of the oil companies to have the big, multinational service companies in the ITF is a demonstration of this reality. Oil companies want the big service companies in the ITF because these companies have the know-how and resources to take technology from prototype stage and commercialisation. Technology entrepreneurs and SMEs need to realign themselves and accept that in some cases the only way to get their technology to transit from prototype to a commercial product will be through one of the big service companies that would otherwise be seen as a potential competitor or an acquirer in the future.

Finally, a recurring challenge for technology developers is how to test new technology to demonstrate it is suitable for North Sea applications. This cannot be done without the cooperation of Operators. As already demonstrated in this study, the challenge of finding a test well for new technology developed without active involvement of end users is acute. Since all new technologies cannot be developed alongside end users, therefore there needs to be a place and role for new technology developed by socially embedded technology developers. To overcome the challenge of testing and qualifying new technology not developed in coordination with end users, technology developers need to resist equating reluctance to resistance, seek to enter into the world of end users and convince them that new technology can solve the problem by demonstrating a good understanding of the problem. The challenge is to identify the needs end users have and be able to demonstrate how new technology meets these needs, creating an overlap of understanding between what the end users seek and what the new technology offers. The alignment of interests will likely improve the attitude of end users even for largely technology-push innovation. The ITF can be strengthened to become a more efficient clearing house for the expressed and implied needs of Operators. A more open ITF that technology entrepreneurs can approach, not just to apply for grants to develop specific technologies but one that also acts as a provider of information about challenges facing Operators and the priorities they attach to these needs. This type of access will help technology entrepreneurs have a better understanding of users' needs as they frame technical problem and develop new technologies even when they are not funded by the end users. This will allow technology entrepreneurs to develop largely technology-push innovation without losing the ability to frame the problem in a way that incorporates end users needs and other market intelligence information.

8.5 Recommendations for Further Research

This research has offered new explanations and insights about the process of technical innovation construction in the UK oil and gas industry. Along with the answers to old questions offered in this study, research findings have also produced new questions to further our search for understanding. This section discusses new areas of research that can be explored in the future.

The findings presented in this thesis are based on the interpretations of the researcher and cannot be claimed to be a definitive or an exhaustive account of all that influence or shape innovation construction. It will be useful in a future research if the findings of this thesis can be tested using a case study. Case study analysis will allow future research to dig deeper into the network of relations in the innovation process and how these relationships unfold over time and across spatial boundaries.

In this study, a rich description of the process of new technology development in the oil industry has been explored, with strong emphasis on the influences of different social constructions on the problem framing. Another area of further research could involve a deeper examination of happenings and doings in a case where new technology is developed without active and direct contributions of end users. A methodology similar to the one adopted in this study with a focus on a technology-push innovation will provide additional insights about the process of technical innovation in the oil industry that can be compared to and contrasted with the findings of this study.

The perception of risk varies among process participants depending on roles and consequences of outcome. Key concepts like risk and value are contested because different meanings they hold for process participants. Although this thesis argues that value of technology is socially constructed, this study did not explore the social construction of value in sufficient detail. It would therefore be useful to improve our understanding of innovation if the relationship between perceptions of risk by different process participants and value of innovation can be investigated.

Finally, the model of technical innovation construction developed in this study suggests that the sense-making, technology development and entrepreneurial tracks unfold concurrently and moving in the direction of convergence to improve chance of successful innovation. This does not mean a certain amount of lag between these tracks cannot be tolerated without affecting outcome. However, this thesis does not attempt to speculate on the degree of lag or mismatch between these tracks that can be tolerated before chance of innovation emergence is doomed. This intriguing question could be addressed in a further study.

8.6 Concluding Remarks

This thesis began out of curiosity borne out of observations and experience of watching the struggles of owner-managers and SMEs who develop technology but cannot get end users to deploy them. As an engineer working in the oil industry himself, the researcher was curious about how engineers and managers make these decisions and why they make the choices they make. This long journey of discovery that began with a modest aim has taken the researcher on an enriching travel through the world of great scholars and contemporary actors engaged in the process of innovation construction.

In the course of this journey, I have dialogically engaged with many texts trying to understand what the author has to teach us, what meaning their ideas have in the present and contrasting the high theory of the text with the lives and actions of present day process participants. I have taken many detours, walked along many paths that lead nowhere and proved ultimately unsuccessful, but through these intellectual excursions my understanding of social life has been enriched. I have been lucky to have mentors who warned of the futility of some of my choices but one learns best when one can claim to have experience. My pickings from these intellectual excursions while not reflected in the text of this thesis have undoubtedly shaped my world view, hidden yet present in my analysis and understandings of the subject of study.

The research respondents taught me a lot in the course of this journey, exploding my theoretical grasp of social concepts and creating conundrums that I needed to solve to excavate a deeper structure of meaning at the social site of innovation. The lived experiences, actions and meanings of research respondents reported in this study provide the substance of this work. Whatever understanding and insights about phenomena of entrepreneurship and innovation that may be gained from this work I owe to their achievements and cooperation. I hope my search will prove useful to those who travel their own paths after me, searching for understanding and what it means to innovate and be enterprising.

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